SEMICONDUCTOR DIODES AND TRANSISTORS

PROGRAMED INSTRUCTION

MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

VOLUME 3
TRANSISTORS

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SEMICONDUCTOR DIODES AND TRANSISTORS

VOLUME 3

TRANSISTORS

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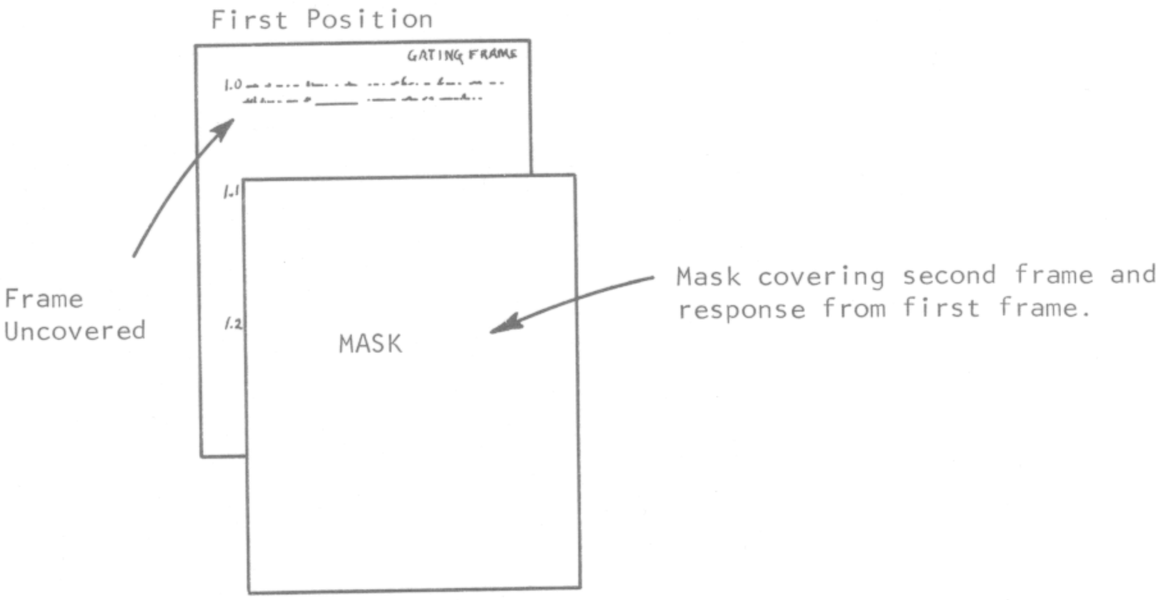
This mask will help you as you go through this program.
Here is how to use it:

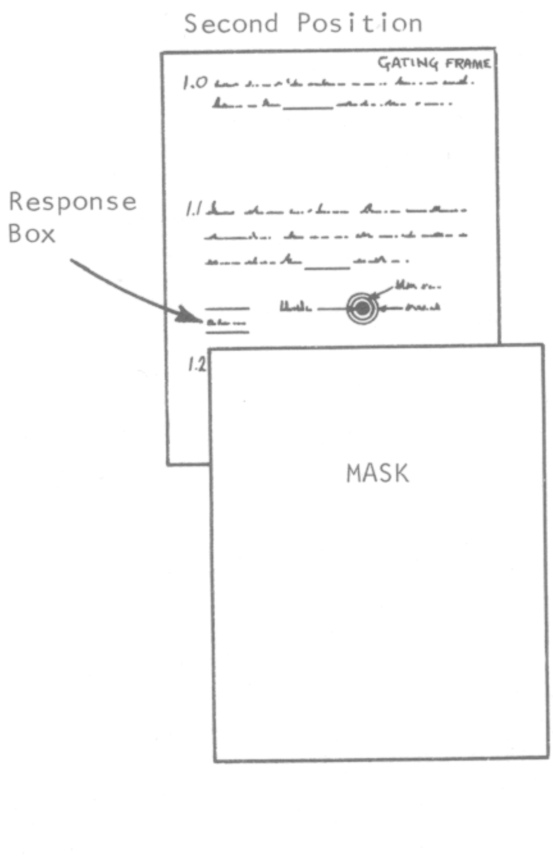


First Position:

Read the frame.
Write in your response.

Second Position:

Move the mask down. Check your response with the one printed in the box in the lower left hand corner of newly exposed frame. Read the newly exposed frame and write in your response. Slide the mask down again, and repeat this step.



VOLUME 3 - TRANSISTORS

This volume is about the theory of operation of transistors, their characteristics, parameters and limiting factors. It discusses the operation of the transistor as an amplifier and as a switch. It further discusses methods of measuring the transistors characteristics and parameters and the effects of external energy and environment on the transistor.

PREREQUISITES:

This volume assumes the reader's successful completion of Semiconductor Diodes and Transistors - Volume 1 - Basic Semiconductors and Diodes, and Volume 2 - Diode Devices or their equivalent.

BROAD OBJECTIVES:

On successful completion of this volume, the reader will have gained knowledge of the theory and operation of junction transistors as amplifiers and switches and their characteristics, while preparing himself by meeting some of the prerequisites for volume 4 of this programed instruction series (Circuit Analysis 1 - Amplifiers).

SPECIFIC OBJECTIVES:

When the reader has successfully completed this volume, he will be able to do the following:

1. Recall that a forward biased PN junction has majority carriers crossing the junction and becoming minority carriers. Some carriers move well beyond the junction before recombining. The average time the carriers exist as minority carriers is termed "minority carrier lifetime".

2. Recall that a different degree of doping in the two sides of a PN junction results in some carriers diffusing through the opposite side without recombining.

3. Recall that doping one side of a PN junction lightly and making it very narrow results in much of the current being transported by diffusion.

4. Recall that the N or the P side of the junction can be doped lighter and made narrow to enhance current by diffusion.

5. Recall that two junctions can be formed in a single piece of semiconductor and the same action will take place at both junctions as when the basic diode is formed.

6. Recall that junction transistors are constructed by doping two junctions in a single piece of semiconductor, and that the center is doped much lighter than the ends to enhance diffusion current in the center.

7. Recall that the center portion of the transistor is made very narrow to enhance diffusion current in the center.

8. Name the three parts of the transistor and the paths of current carriers through the parts.

9. Recall that forward bias is applied to the emitter-base junction which results in the emitter injecting carriers into the base.

10. Recall that the collector junction is normally reversed biased and depends on minority carriers in the base for current.

11. Recall the current distribution in the transistor when conducting.

12. Recognize the symbol for common base d-c current gain. Recall the definition of common base d-c current gain and be able to apply it to the solution of a problem dealing with transistor d-c currents.

13. Recognize the symbol for common emitter d-c current gain. Recall the definition of common emitter d-c current gain and be able to apply it to the solution of a problem dealing with transistor d-c currents.

14. Recall the proper polarities for biasing both junctions of the transistor. Recall the effects of a varying emitter or base current on the collector current and for a given change, while will result in the larger change in collector current.

15. Recall that without injected carriers from the emitter there will be some collector current carried by thermally generated carriers. Recognize its

symbol as I_{CBO} and recall that its magnitude will vary with temperature changes.

16. Define I_{CEO} and recall its relative magnitude with respect to I_{CBO}.

17. Recognize the symbols for both an NPN and a PNP transistor, and be able to label the parts.

18. Recognize the common emitter configuration and recall its current gain capabilities with respect to unity.

19. Recall that both voltage gain and current gain are possible with a transistor in a common emitter configuration which makes possible a high power gain.

20. Recall the definition of the symbol h_{fe}, and recall that it does not take into account the circuit effects.

21. Recall the definition of the symbol h_{fb}, and recall that it does not take into account circuit effects.

22. Recall that voltage gain is possible with a transistor in a common base configuration and a corresponding power gain.

23. Recognize the common collector configuration and recall the magnitude of possible current and voltage gains with respect to unity.

24. Recall that the common collector configuration is also termed an "emitter follower".

25. Recall the definition of the symbol h_{fc} and its relative magnitude with respect to h_{fe}.

26. Recall the typical magnitude of input and output resistance of the common collector configuration.

27. Recall that the emitter follower finds use in situations requiring high output currents to drive capacitance.

28. Recognize the collector family of curves for a transistor, and recall how it is plotted. Recall that it allows a cross reference of the transistors voltage and currents.

29. Recall that h_{fe} may be calculated from data gained from the collector family of curves or plotted directly on the 575 Transistor-Curve Tracer, and be able to apply this in making a measurement of h_{fe} when given the curves and the point of measurement.

30. Construct a load line on the collector family of curves by recalling what determines the slope of the load line and how to construct it when given appropriate values.

31. Construct a load line on a collector family of curves and determine the quiescent operating point when given a circuit with component values and a collector family of curves.

32. Recall the definition of transistor saturation, V_{CE}(sat), h_{FE}(sat), and the bias condition at the collector junction at saturation.

33. Recall the bias conditions of the two junctions at saturation and that entering saturation increases the stored charge in the base of the transistor.

34. Given a circuit and collector family of curves, construct a load line, determine the static operating point base current, collector current, collector voltage and, given an applied signal current, determine <u>circuit</u> current gain.

35. Recognize avalanche breakdown on a collector family of curves, and recall that it relates to avalanche breakdown in the basic diode.

36. Recall the definitions and circuitry involved for B_{VCEO}, B_{VCBO}, and B_{VCER}, and that they are all temperature sensitive. Recall the curves on which each is measured when using a collector family of curves.

37. Recall the factors limiting the maximum power handling capability of a transistor and the terminology involved.

38. Recognize the symbols used and recall their meaning when using a thermal to electrical analogy to gain parameters for dealing with thermal problems in transistors.

39. Recognize the change in the thermal to electrical analogy that takes place when a heat sink and silicone lubricant are used to increase the power

dissipation capabilities of a transistor.

40. Solve a problem determining maximum steady state power dissipation when given Θ_{SA}, Θ_{JC}, Θ_{CS}, T_A and $T_J$max.

41. Construct a maximum power curve on the collector family of curves of a transistor and recall the position of a load line for maximum output current swing.

42. Position a load line on the collector family of curves of a transistor for maximum output voltage swing.

43. Recall that very little power is dissipated by the transistor at cut-off or saturation, but that substantial power is dissipated in the area between these two limits which is termed the "active" or "transient" region.

44. Recall that when the transistor is acting as a switch, with its resting states at cut-off and saturation, it is possible for its load line to cross the maximum power hyperbola which allows greater power dissipation during switching than when a resting state occurs in the active region.

45. Recall that operating a transistor in the cut-off to saturated switching mode has the advantage of low resting state power dissipation, but the disadvantage of a larger stored charge which limits maximum repetition rate.

46. Recognize the symbols for the transistor switching parameters, and be able to define them. Recall what limits t_{on} and t_{off} of the transistor in the switching mode and a method of measuring the switching parameters.

47. Recall that the Tektronix Type 290 Transistor Switching Time Tester, or the Type 292 Semiconductor Tester in conjunction with a sampling system, may be used to check a transistor's switching times.

48. Recall the action of a speed-up capacitor when used to speed up a transistor switch, and be able to calculate the optimum value of speed-up capacitor given the voltage across the speed-up capacitor and the stored charge of the transistor.

49. Recall the meaning of current mode switching and that this mode reduces storage time which increases maximum possible repetition rate while sacri-

ficing maximum power dissipation with respect to the off to saturated mode.

50. Recall that current mode switching offers high speed, low noise, less critical transistor requirements, but more complicated design problems when compared to the off to saturated mode.

51. Recall that an avalanche switching transistor operates between cut-off and a point in the avalanche breakdown region and that the switching time can be on the order of fractional nanoseconds.

52. Recall that the main high frequency limiting factors of a transistor are junction capacitance transit time and the spreading out of carriers in the base.

53. Recognize the symbol for the cut-off frequency of a transistor in a common base configuration, and recall that it indicates the frequency at which low frequency h_{fb} has decreased to 0.707 of its low frequency value.

54. Recognize the symbol for cut-off frequency of the transistor in a common emitter configuration, and recall that it indicates the frequency at which h_{fe} has decreased to 0.707 of its low frequency value.

55. Recognize the symbols for output capacitance of the transistor in a common emitter and a common base configuration, and recall that they are related by the formula $C_{ob} = C_{oe} (1 + h_{fb})$.

56. Recall that high frequency construction calls for a thin, uniform width base and that the narrower the base, the less the transit time and spreading out of the carriers.

57. Define f_t as the frequency at which low frequency h_{fe} has decreased to unity, and recall that f_t gives information on the transistor beyond f_{hfe}.

58. Recognize the construction of the rate-grown and alloy type transistors, and recall their high frequency limitations.

59. Recognize the construction of the micro alloy and micro alloy diffused transistors and recall their frequency limitations. Recall that the micro alloy diffused is sometimes termed a drift field transistor.

60. Recognize the construction of the mesa and the epitaxial mesa, and recall the advantages gained from the epitaxial layer.

61. Recognize the construction of the planar transistor, and recall the definitions of the terms "surface passivated" and "double diffused".

The reader will know when he has met these objectives by correctly answering 90% of the questions in the self-test at the back of this program.

INSTRUCTIONS

The material in this program is presented in a series of numbered statements. Each numbered statement is termed a "frame" and each group of frames bearing the same number (3, 3.1, 3.2, etc.) is termed a "set". The answer to each frame is in a small box in the lower left hand corner of the following frame.

The material is presented in three types of frames within a set; the "gating frame", the "teaching frame", and the "criterion frame".

The first frame in each set is the gating frame. Cover the following frame which contains the answers with the mask provided. Read the frame carefully, studying any diagrams that are provided and fill in the blanks. Do not look at the answer until you fill in the blanks.

You must know something about the material to fill in the blanks in the gating frames as there is no clue given to the answer. If you can answer the gating frame and you are sure of the material, skip to the next gating frame and continue. The gating frames are designed to give the student that is familiar with the subject an indication of the information contained in the set and allow him to skip the set if he feels he knows the information covered.

If you cannot answer the gating frame, continue with the teaching frames in that set, covering the answers and filling in the blanks. You will find clues to the answers in the teaching frames or their diagrams.

The last frame in each set will have 2 (**) asterisks following the number. This is the criterion frame and once again, no clue is given to the answers. The preceeding teaching frames should have provided the information needed to work the criterion frame. If your answer is wrong, go back and review the material in the teaching frames.

You may progress through the program at any speed you select. Don't miss an opportunity to review the material in a set if you can answer the gating frame but are a little hazy on the subject.

This is not a test. You are not being graded and you are not expected to be able to answer the gating frames unless you have the knowledge to let you skip a set. If you answer the teaching frames or the criterion frames incorrectly, don't be concerned, but go back and review the previous frame or frames as needed. Answer from the information presented and, if your answer does not match, review the material before going on.

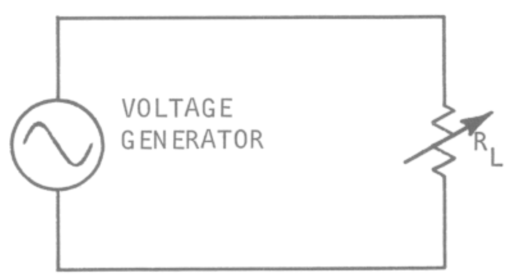
If you would like to measure your progress, go to the back of the volume and do the self test without grading it before proceeding with the programed material. After completing the programed material, do the self test again and grade both attempts. This will give you an indication of the gains that you have made with this volume.

Do each set of the programed material in sequence, starting with Set 1.

If you are ready to proceed with the programed material, turn to the first gating frame - - - -

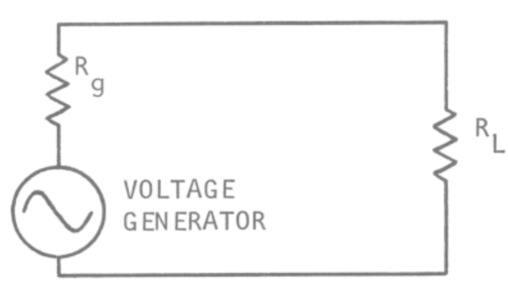
1 A generator with a very high internal resistance with respect to the external circuit can be considered to be a constant __________ generator, and a generator with a very low internal resistance with respect to the external circuit can be considered to be a constant __________ generator.

1.1 The generator shown has zero internal resistance. Changes in the size of R_L have no effect on the voltage across R_L.



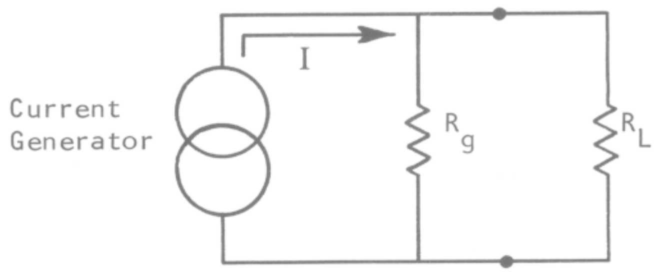
current
voltage

1.2 The generator shown has a finite internal resistance represented by R_g. The generator voltage will be distributed between __________ and __________.



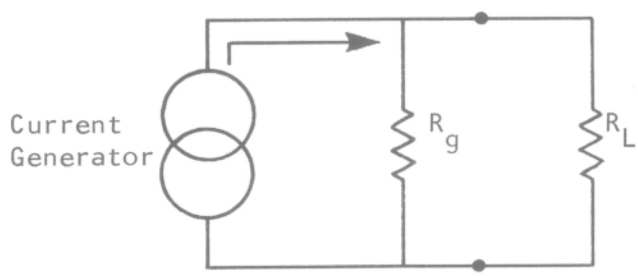
no answer needed

1.3 A generator can also be shown as a current generator shunted by a resistance. The current supplied by the generator shown divides between _______ and _________.



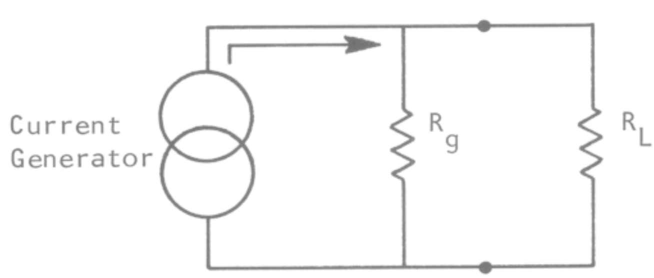
R_L
R_g

1.4 If R_g in the diagram has a value approaching infinity, most of the generator current is in __________.



R_L
R_g

1.5 If R_g in the diagram is not approaching infinity, but is very large with respect to R_L, most of the supplied current will flow in R_L.



R_L

1.6 A generator with an internal resistance very large with respect to the external circuit can be considered a constant current generator (referring to magnitude).

no answer needed

1.7 A generator with an internal resistance or impedance very large with respect to the circuit it is supplying can be considered a constant ________ generator, since the ____________ will change very little with changes in the load resistance or impedance.

no answer needed

1.8 A constant current generator has a very _______ internal impedance with respect to the circuit it is supplying.

current
current

1.9 A generator with a very low internal impedance with respect to the circuit it is supplying will have very little change in the output voltage with changes in the load.

high, large, etc.

1.10 A generator with a very low internal impedance with respect to the circuit it is supplying will supply a near constant* ___________ with changes in the load. (* referring to magnitude)

no answer needed

1.11 A low impedance generator can be considered a ________* voltage generator if it is driving a circuit with a much higher impedance. (* referring to magnitude)

voltage

1.12** A low impedance generator will supply a near constant _______________ magnitude if driving a high impedance circuit and a high impedance generator will supply a near constant _______________ magnitude if driving a low impedance circuit.

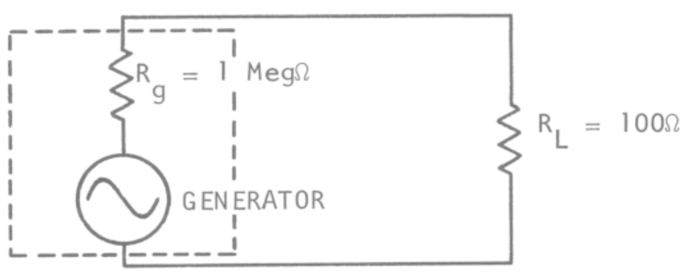
constant

1.13 END OF SET

voltage
current

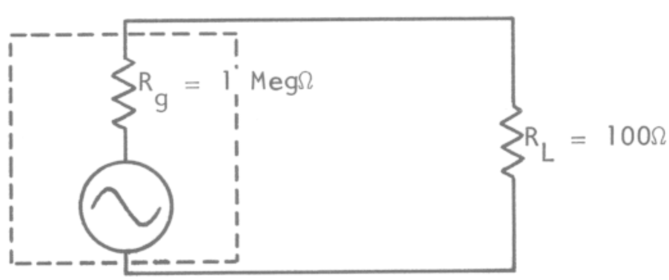
2 A circuit or device can be said to be essentially current or voltage driven or biased depending on the ________________ of the driving generator with respect to the ________________ of the circuit being driven.

2.1 In the circuit shown, the resistance of R_L must increase greatly to cause a significant change in the current in the circuit.



impedance
impedance

2.2 The generator shown can be considered to be a constant amplitude ____________ generator.



no answer needed

2.3 Varying R_g will change the current in R_L. R_L is essentially current driven. (The current is changed which results in a voltage change.)

current

2.4 If the circuit or device to be driven changes its impedance when driven with voltage, it may be desirable to use a ______________ impedance generator and essentially drive with current.

no answer needed

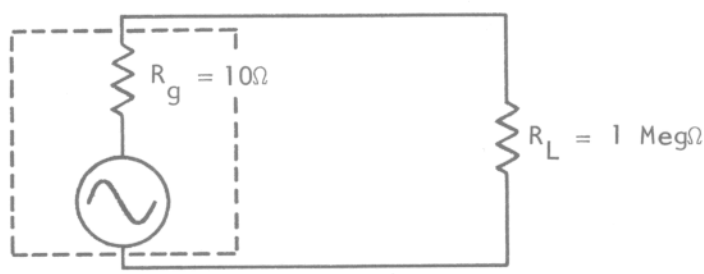
2.5 A d-c supply with a very high internal resistance with respect to its load is essentially a d-c ___________ supply rather than a ____________ supply.

high

2.6 For maximum transfer of power, the impedance of the generator or supply should be equal to the load impedance. This ____________ the case when
(is, is not)
it is desired to drive with current or voltage.

current
voltage

2.7 The generator shown can be considered a constant* ______________ generator. (* referring to magnitude)



is not

2.8 d-c biasing can be accomplished with a ______________ supply as well as a voltage supply.

voltage

2.9 If the resistance of the biasing supply is very high with respect to the device to be biased, the device can be said to be biased with ________.

current

2.10 Using a much higher than needed voltage and adding a high value of series resistance results in a near constant ______________ biasing supply. (NOTE: At Tektronix, this approach is typically referred to as long tailing.)

current

2.11 By using a large value of resistance in series with a high voltage to bias a device results in the series resistor having control of the _________ in the circuit.

current

2.12** Biasing and driving a circuit or device can be essentially current, voltage, or power depending on the relationship of the ______________ in the circuit.

current

2.13 END OF SET

impedances

3 Forward biasing a junction results in some carriers traveling well beyond the junction before recombining. The average time they exist after crossing the junction is termed minority carrier __________.

3.1 Forward bias reduces the potential difference across a PN junction and results in majority carriers crossing the junction. Electrons in the N side and holes in the P side cross the junction when forward bias is applied. Once across the junction, these carriers are existing as ____________________ carriers.

lifetime

3.2 After crossing the junction, carriers must find imperfections in the covalent structure to accomplish recombination. With few ______________ near the junction, some carriers must move well beyond the junction before recombining.

minority

3.3 After crossing the junction and before recombination occurs, the carriers are existing as _____________ _____________.

imperfections

3.4 The longer the carriers exist as minority carriers, the more opportunity they will have to spread out in the opposite side before recombining. With few imperfections near the junction, the carriers will ____________ out in the opposite side.

minority carriers

3.5 The average time that the carriers exist as minority carriers before recombining is termed minority carrier lifetime. The fewer the imperfections near the junction, the longer the _____________ ______________ ____________.

spread

3.6 If the minority carrier lifetime is long, some of the carriers will spread out through the entire opposite side of the junction without ________________.

minority carrier lifetime

3.7** Forward bias results in majority carriers crossing the junction. After crossing the junction, they exist as __________ ____________. The average time they exist after crossing the junction is termed ___________ __________ ____________.

recombining

3.8 END OF SET

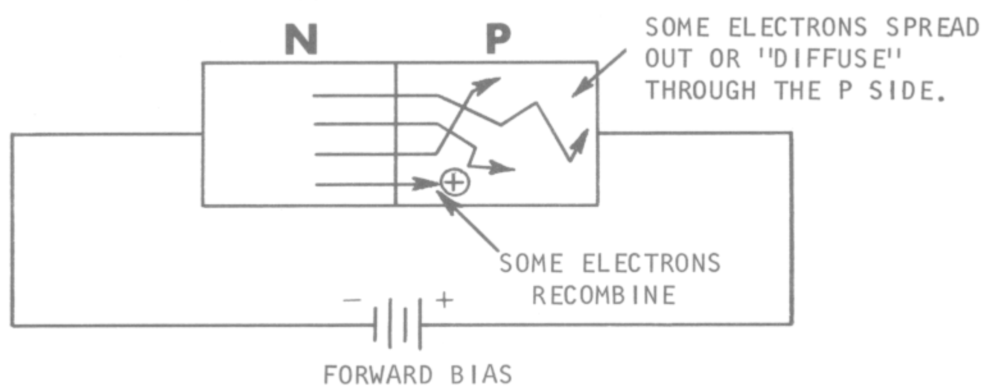
minority carriers
minority carrier lifetime

4 Applying forward bias to a PN junction with the P side doped much lighter than the N side results in some of the electrons recombining with holes in the P side, but some of the electrons will __________ through the P side without _____________.

4.1 Electrons crossing the junction as a result of applied forward bias must find imperfections before they can recombine. If the electrons do not find imperfections, they will not _________________.

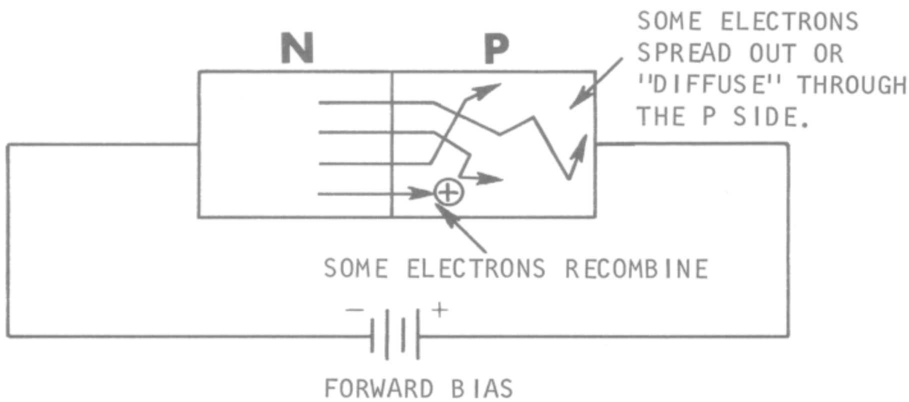
diffuse
recombining

4.2 Electrons injected into the P side as a result of applied forward bias, but unable to find _____________________, spread out or "diffuse" in the P side and no not recombine.



recombine

4.3 Doping the P side much lighter than the N side results in many electrons injected into the P side by forward bias that cannot find imperfections to recombine. These electrons will __________ or spread out in the P side.

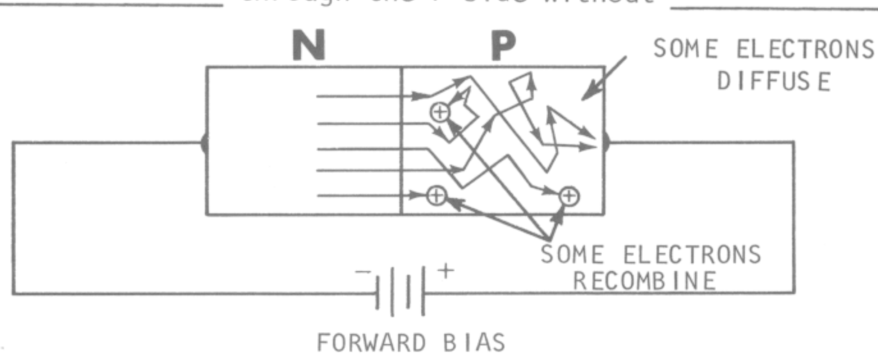


imperfections

4.4 Doping the P side with less impurities than the N side, results in forward bias injecting electrons into the P side that cannot readily recombine. These electrons are existing as __________ carriers while in the P side.

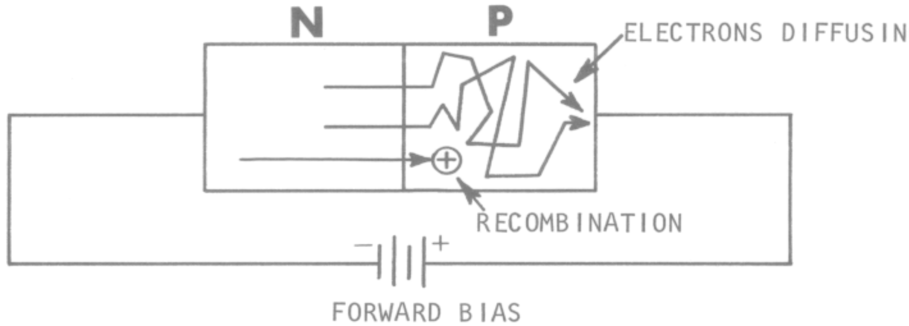
diffuse

4.5 Electrons crossing the junction (as a result of forward bias) that do not find imperfections, diffuse through the P side without recombining. Doping the P side with fewer imperfections than the N side results in some electrons ______________ through the P side without ______________.



minority

4.6 Some electrons diffusing through the P side are attracted to the positive side of the bias source. Doping the P side much lighter than the N side results in some of the current in the external circuit being the result of ____________ current in the diode.



diffusing
recombining

4.7 Current transported by both recombination and __________________ will result when electrons are injected into the P side and find insufficient imperfections to recombine.

diffusion

4.8** Doping the P side much lighter than the N side results in injected electrons that ____________ through the P side without _______________.

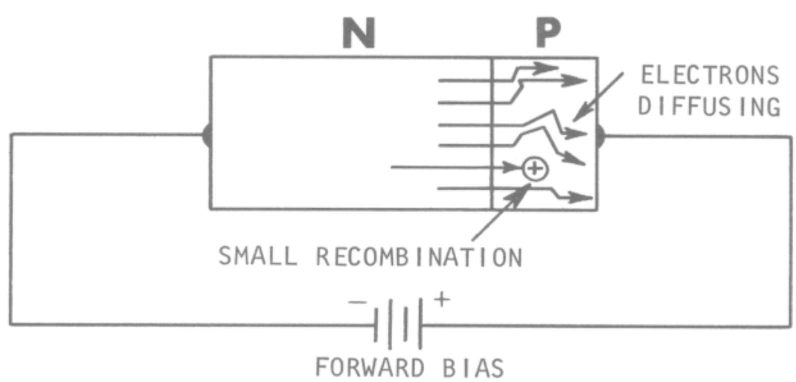
diffusion

4.9 END OF SET

diffuse
recombining

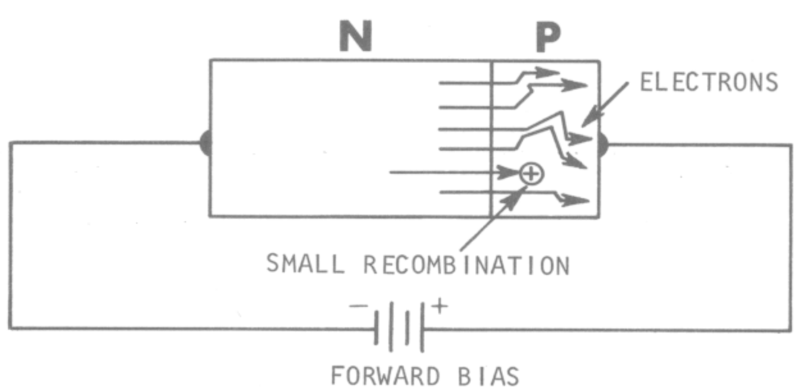
5 Doping the P side much ________________ than the N side and making the
(heavier, lighter)
P side very ____________ results in most of the injected electrons
(wide, narrow)
diffusing through the P side without recombining.

5.1 Only a few of the electrons forced across the junction by applied forward bias find imperfections and ____________________ when the P side is doped much lighter than the N side.



lighter
narrow

5.2 The electrons forced across the junction by forward bias diffuse in the lightly doped P side. If the P side is made very narrow, most of the diffusing _______________ pass through the P side without _____________.

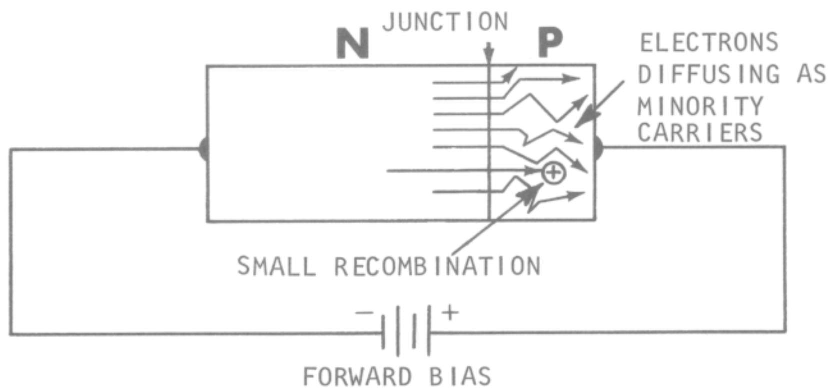


recombine

5.3 Electron current in the external circuit results when electrons diffuse through the P side. The greater the number of diffusing electrons that cross the P material, the greater the external ________________________ ________________________.

electrons
recombining

5.4 Electrons forced across the junction by forward bias and diffusing through the P side are existing as minority carriers. Forward bias current is made up primarily of ____________________ ____________________ when the P side is doped <u>much</u> lighter than the N side.



electron current

5.5** Doping the P side much lighter than the N side and making the P side narrow results in most of the electrons that cross the junction __________ through the P side as __________ carriers.

minority carriers
or
diffusion current

5.6 END OF SET

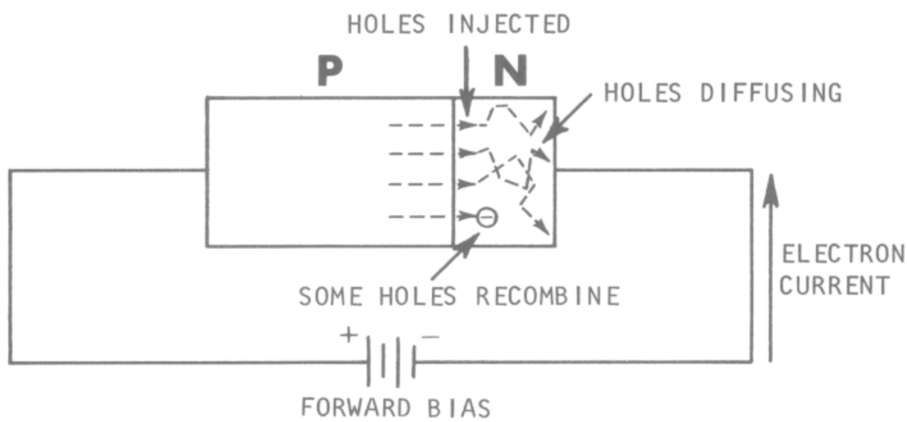
diffusing
minority

6 Doping the N side of the junction much lighter than the P side and making the N side very narrow results in ___________ diffusing through the ___________ side when forward bias is applied.

6.1 Doping the N side much lighter than the P side of the junction results in more holes being injected into the N side than there are imperfections for recombination. If the holes do not find ________________________, they will not ______________________.

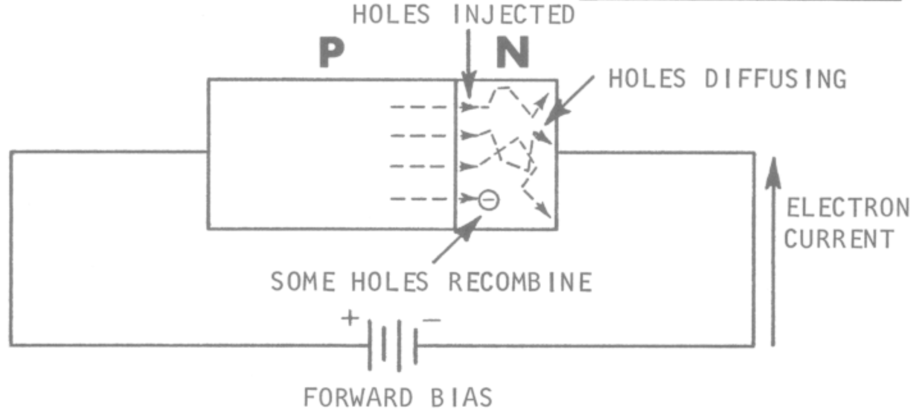
holes
N

6.2 Holes injected into the N side that do not find imperfections, ____________________ through the N side.



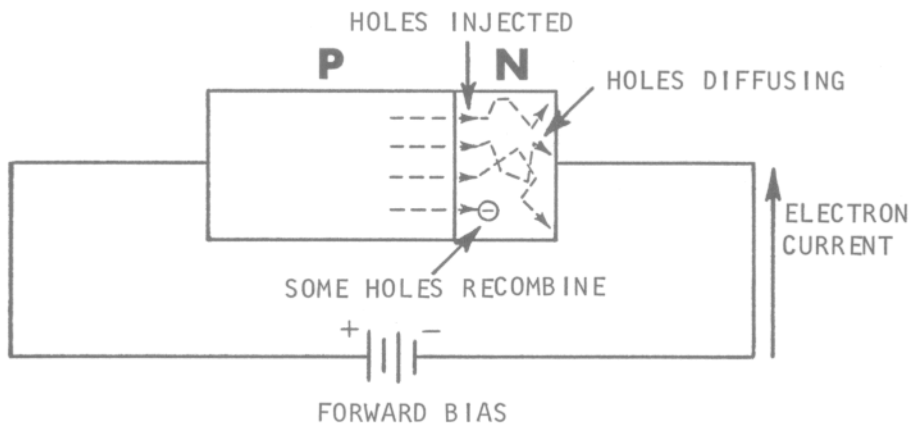
imperfections
recombine

6.3 If the N side is made very narrow, most of the injected holes will __________ across the lightly doped N side without ____________________.



diffuse

6.4 Doping the N side much lighter than the P side and making the N side very narrow results in current by ________________ of holes.



diffuse
recombining

6.5 Applying forward bias to a junction with a lightly doped, narrow N side, injects __________________ into the N side that ______________________ through without ______________________.

diffusion

6.6** The application of forward bias to a junction with a narrow and lightly doped N side results in current made up primarily of _____________ that _______________ through the N side.

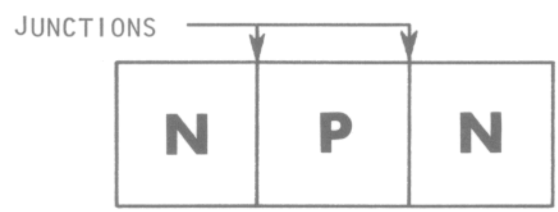
holes
diffuse
recombining

6.7 END OF SET

holes
diffuse

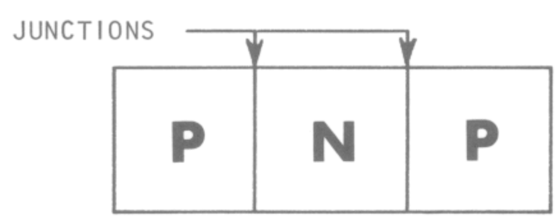
7 Two junctions can be formed in a single piece of semiconductor material in either a __________ or __________ arrangement. Forming two junctions in the same semiconductor results in holes and electrons at each junction, _________ until a state of ___________ exists at both junctions.

7.1 If a piece of semiconductor has the two ends dopes with N type impurities and the center with P type impurities, there will be two distinct __________ in the material.



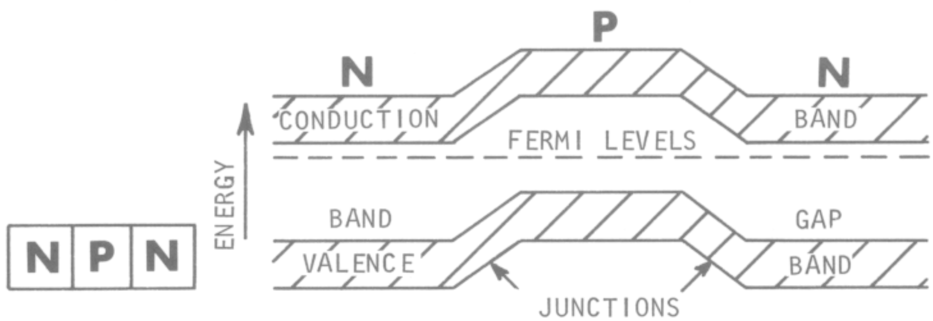
PNP or NPN
recombining
equilibrium or balance

7.2 Doping the two ends of the semiconductor with P type impurities and the center with N type impurities will also result in two distinct _________ in the material.



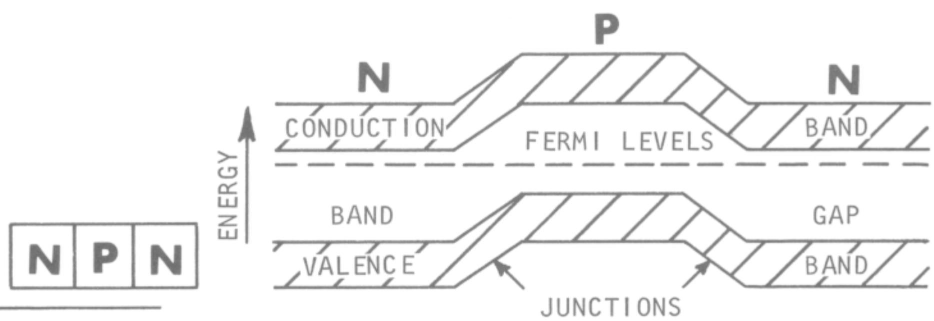
junctions

7.3 With two junctions formed in the same semiconductor, recombination occurs at both junctions until the fermi levels line up. The alignment of the fermi levels indicates a state of ____________.



junctions

7.4 With no external energy applied to a semiconductor containing two junctions, a potential difference exists across both junctions. The __________ ___________ must be overcome to have current.



equilibrium or balance

7.5 When two junctions are formed in one piece of semiconductor, the same action occurs at both junctions as when a single ____________________ is formed.

potential difference

7.6** When two junctions are formed in a single piece of semiconductor, ____________ occurs at both junctions until a state of ________________ exists across both junctions.

junction

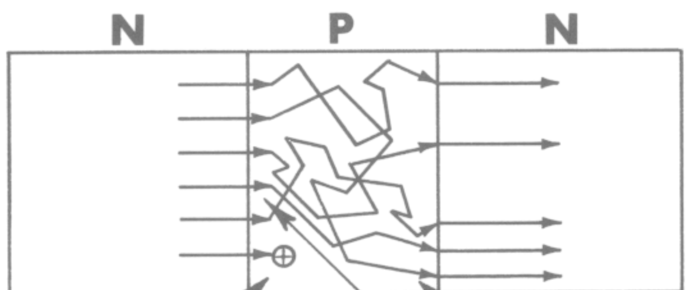
7.7 END OF SET

recombination
equilibrium or balance

8 Junction transistors are manufactured by forming two junctions in a single semiconductor, The center is doped much ________________ (heavier, lighter) than the ends to enhance __________________ current in the center.

8.1 A junction transistor functions by one end injecting carriers into the center portion and these carriers traveling as minority carriers through the center portion. Current in junction transistors relies on __________ current in the center portion.

lighter
diffusion



8.2 Diffusion results when majority carriers are forced across the junction and are not able to find imperfections to recombine. Carriers forced across a junction that cannot imperfections, cannot ______________ and, therefore, exist as __________________ carriers.

diffusion (minority carrier)

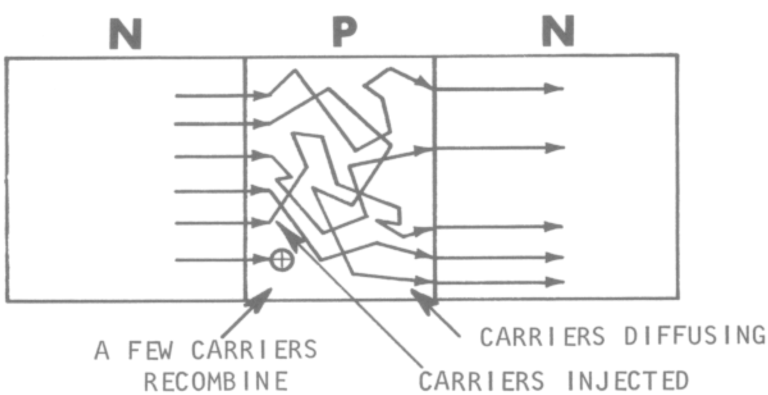
8.3 Diffusing carriers are majority carriers that have been forced across a junction and are existing as minority carriers in the opposite side. Diffusing carriers unable to find __________ are existing as __________ carriers.

recombine
minority

8.4 The center of the junction transistor is doped much lighter than the ends to enhance diffusion of carriers in the center portion. Carriers forced into the center portion will exist as __________ carriers and will __________ through the center portion.

imperfections
minority

8.5 With the center portion doped much lighter than the ends, some carriers will recombine in the center portion, but most of the carriers will __________ through the center.



minority
diffuse

8.6** Junction transistors are constructed by forming __________(#) junctions in the one piece of semiconductor. The center is doped much lighter than the ends to enhance _________________ in the center.

diffuse

8.7 END OF SET

2
diffusion

9 Junction transistors are manufactured by forming two junctions in a single piece of semiconductor. The width of the center portion between the two junctions is made very _________ to further enhance ________ by reducing ___________.

9.1 Junction transistors are made by doping the two ends of a semiconductor different than the center and forming two distinct ____________.

narrow, thin, etc.
diffusion
recombination

9.2 The center of the semiconductor is doped much lighter than the ends to enhance diffusion in the center. The wider the center portion, the more carriers will recombine and the less will ___________.

junctions

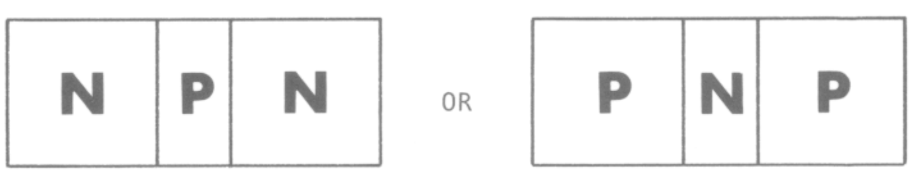
9.3 The aim in junction transistors is to cause many of the carriers injected into the center portion to diffuse across the center region. The ____________ the center portion for given doping levels, the more
(wider, narrower)
carriers will diffuse across.

diffuse

9.4 Doping the center lightly results in a long minority carrier lifetime and enhances __________ of carriers.

narrower

9.5 The transistor utilizes diffusion of carriers through the center portion of the device. The center portion is made very ________ to reduce recombination and increase __________.



diffusion

9.6 The center of the transistor is doped much lighter than the ends to enhance diffusion in the center. The center is made very narrow to enhance carrier ___________ and to reduce recombination.

narrow, thin, etc.
diffusion

9.7 Light doping in the center results in a long minority carrier lifetime and less carrier ________________.

diffusion

9.8** The center portion of a junction transistor is made very __________ to enhance carrier ___________ and reduce carrier ______________.

recombination

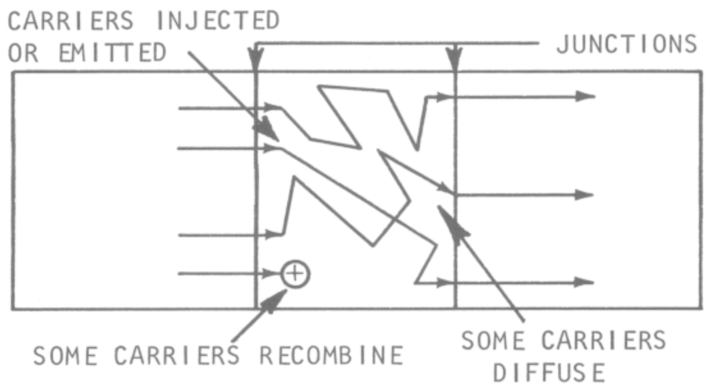
9.9 END OF SET

narrow, thin, etc.
diffusion
recombination

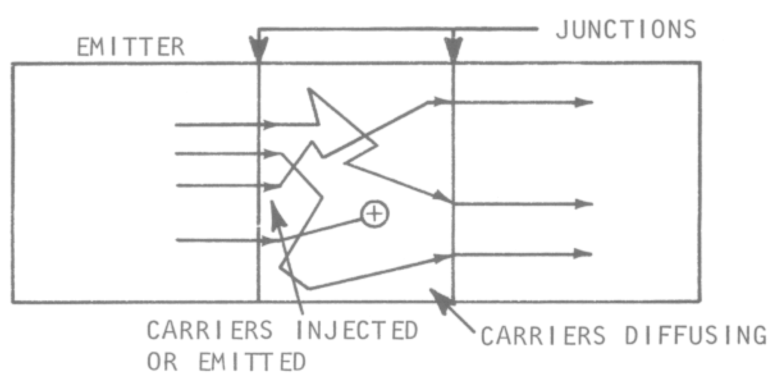
10 That part of the transistor considered the source of current carriers is termed the ___________ and the center part, the ___________. The remaining part is termed the ___________. The current carriers move through the parts of the transistor in ___________________ order as/than just stated.
(the same, a different)

10.1 The transistor works on the principle of one end of the device injecting or emitting carriers into the center portion. Once injected, the carriers either recombine or __________ through the center portion.

emitter
base
collector
the same

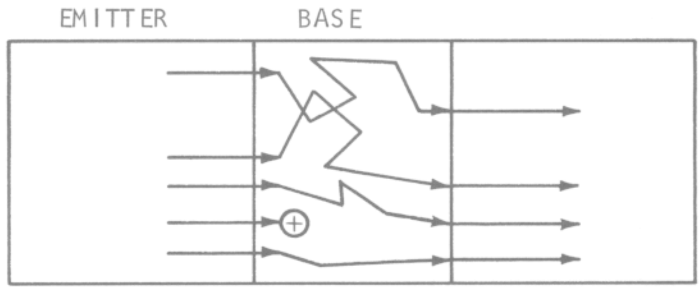


10.2 Since one end injects or emits carriers into the center portion, it is called the ____________ and is considered the source of current carriers in the transistor.



diffuse

10.3 The center portion of the transistor is termed the base. The emitter injects carriers into the ____________.

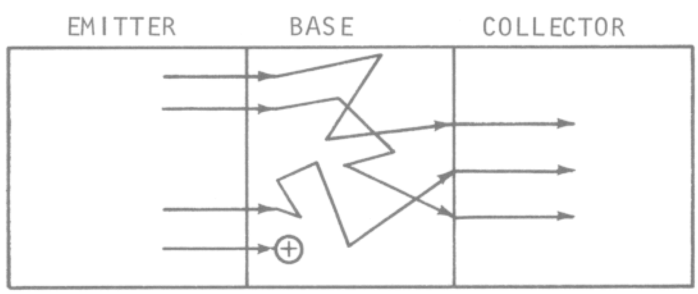


emitter

10.4 The emitter injects carriers into the base. Some of the carriers recombine but, due to the base being made very thin, most of them _______________ through the base.

base

10.5 The carriers that diffuse through the base are collected by the remaining end of the transistor. The three parts of the transistor are the emitter, base and the ____________.



diffuse

10.6 The emitter injects carriers into the base; the injected carriers diffuse through the base, and those that do not recombine are collected by the ________.

collector

10.7 Those carriers that recombine in the base become base lead or simply base current. Base lead current is ________________ current.
(recombination, diffusion)

collector

10.8** Carriers are injected by the emitter into the ________ and diffuse to the ________. Those carriers that recombine in the base become ________ lead current.

recombination

10.9 END OF SET

base
collector
base

11 The emitter-base junction can be forward biased by a current or voltage source. A high resistance d-c source with respect to the d-c resistance of the emitter base junction will be essentially a d-c ______________ source and a low resistance d-c source will be essentially a d-c ______________ source.

11.1 The emitter-base junction must be forward biased to have current. To accomplish this, the current through the junction or the voltage across the junction can be controlled for biasing purposes.

current
voltage

11.2 A high resistance d-c source (with respect to the emitter-base junction) will essentially control the junction ______________ for biasing purposes.

no answer needed

11.3 A low resistance d-c source (with respect to the emitter-base junction) will essentially control the junction ______________ for biasing purposes.

current

11.4 A vacuum tube has the controlling circuit reversed biased* and uses a d-c voltage source normally for biasing purposes *(grid made negative with respect to the cathode).

voltage

11.5 A transistor has the emitter-base junction (its controlling circuit) forward biased in most cases and the junction resistance varies with voltage changes.

no answer needed

11.6 It is common to find a high resistance d-c source used to bias a transistor's emitter-base junction since it is a ______________ (forward, reverse) biased junction.

no answer needed

11.7 Controlling the ____________ in the emitter-base junction of a transistor for biasing purposes is common, since the emitter-base junction is normally ______________ biased.

forward

11.8 Forward biasing a junction with current requires that the current source force majority carriers to cross the junction to recombine.

---

current
forward

11.9 When a biasing source is shown or referred to in this program, it can be either a voltage or current source, depending on its internal ________________.

---

no answer needed

11.10 Forward biasing the emitter base junction can refer to forcing current with a current source or voltage with a voltage source. In either case, the junction potential difference must be ________________.
(increased, reduced)

---

resistance (impedance)

11.11** Forward bias applied to the emitter-base junction can be essentially a current or voltage source depending on its internal ____________ with respect to the emitter-base d-c resistance. A high resistance source will be essentially a ________________ biasing source.

---

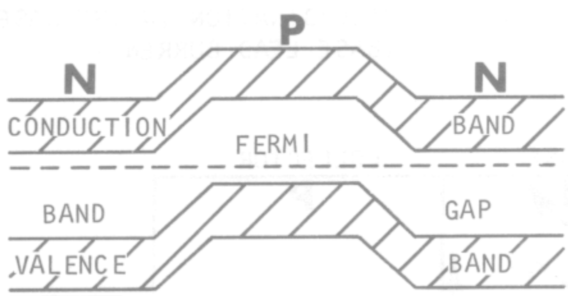
reduced

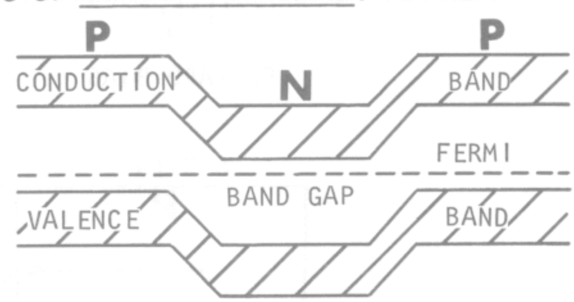
11.12 END OF SET

resistance
current

12 The potential difference at the emitter-base junction must be reduced for the emitter to inject carriers into the base. This is done by applying ____________ bias to the emitter-base junction. Those injected carriers that ____________ (do, do not) recombine, diffuse through the base. Those carriers that do recombine make up what is termed ____________ current.

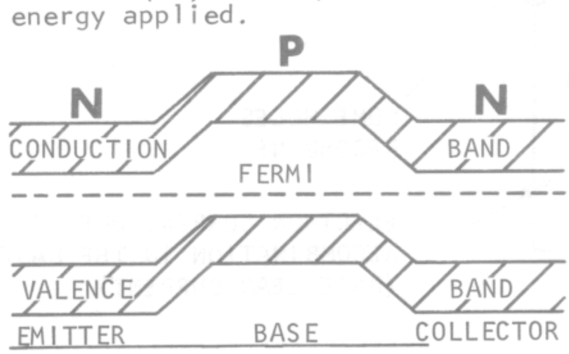
12.1 Recombination occurs at both junctions until the fermi levels line up after two junctions are formed in a single piece of semiconductor. The fermi levels line up indicating a state of ________________.

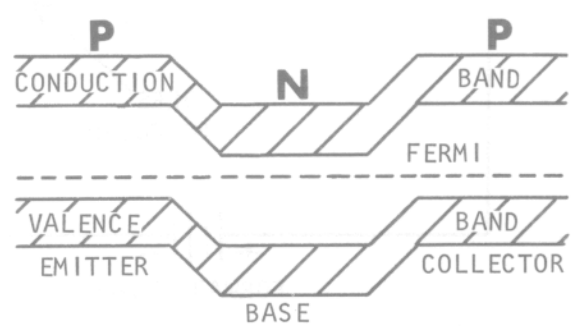




forward
do not
base

12.2 Both junctions are at equilibrium with no external energy applied. The emitter ____________ (is, is not) injecting carriers into the base without external energy applied.





equilibrium, balance, etc.

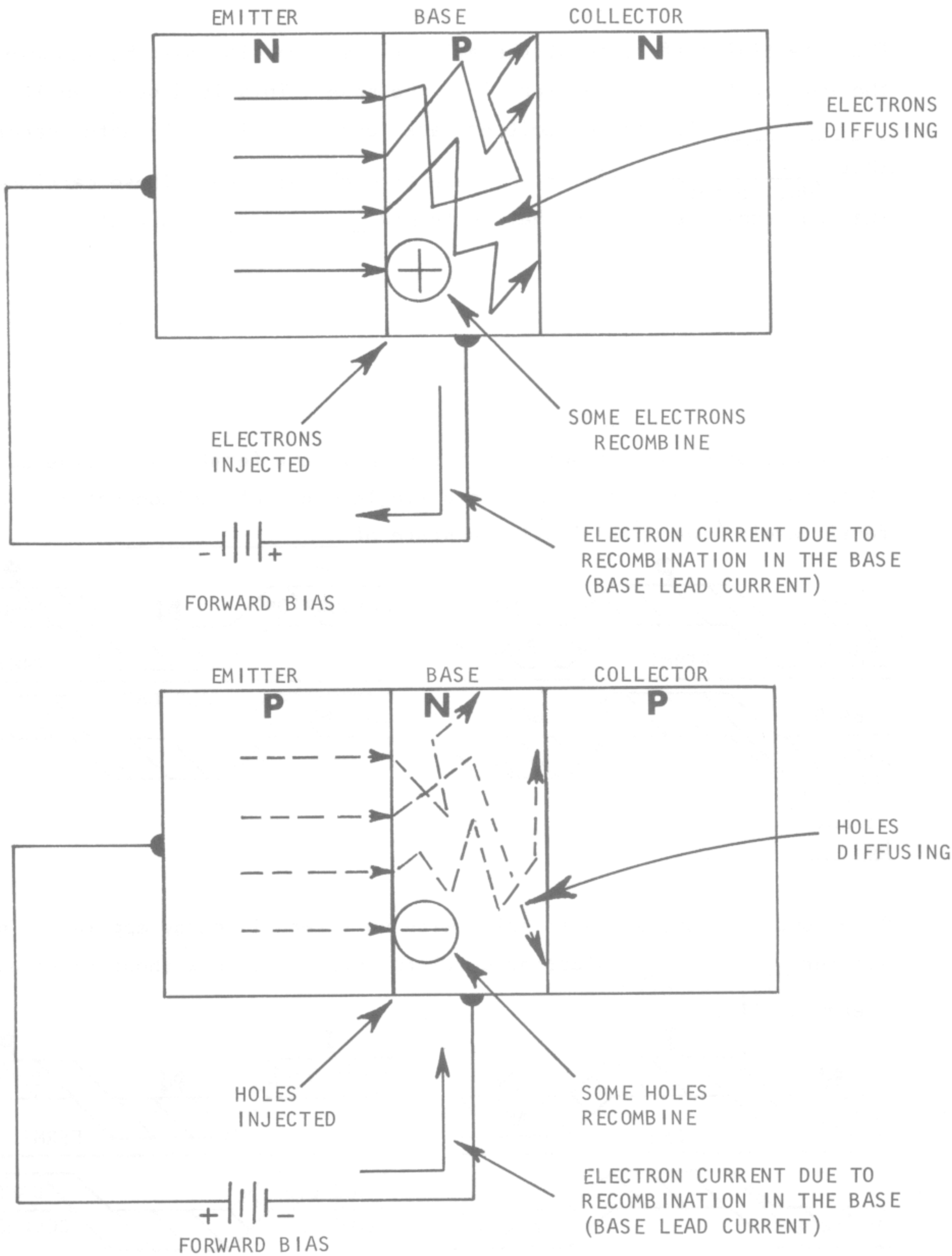

EMITTER
BASE
COLLECTOR
N
P
N
ELECTRONS
DIFFUSING
ELECTRONS
INJECTED
SOME ELECTRONS
RECOMBINE
ELECTRON CURRENT DUE TO
RECOMBINATION IN THE BASE
(BASE LEAD CURRENT)
-
+
FORWARD BIAS
EMITTER
BASE
COLLECTOR
P
N
P
HOLES
DIFFUSING
HOLES
INJECTED
SOME HOLES
RECOMBINE
ELECTRON CURRENT DUE TO
RECOMBINATION IN THE BASE
(BASE LEAD CURRENT)
+
-
FORWARD BIAS

FIGURE 12

12.3 Forward bias applied reduces the potential difference between emitter and base, allowing majority carriers to move across the junction. Majority carriers become minority carriers, and those that do not recombine ________________ through the base as shown in figure 12.

is not

12.4 Forward bias injects many carriers into the base that cannot find imperfections and recombine. This is a result of the base being doped much lighter than the ________________.

diffuse

12.5 Figure 12 shows both a PNP and an NPN transistor with forward bias applied, emitter to base. For both PNP and NPN transistors, the emitter-base junction is ________________ biased to inject carriers into the base.

emitter

12.6 The carriers that do recombine make up base lead current. This current is generally referred to simply as ________________ current.

forward

12.7 The term base current refers to the current in the base lead as a result of carrier __________ in the base.

base

12.8 Carriers injected into the base that do not recombine exist as minority carriers and __________ through the base.

recombination

12.9** Injection of majority carriers from the emitter into the base is accomplished by application of __________ __________ to the emitter-base junction. Injected carriers that do not recombine, __________ through the base as __________ carriers. Carriers that recombine in the base result in a current in the base connecting lead that is termed __________ current.

diffuse

12.10 END OF SET

forward bias
diffuse
minority
base

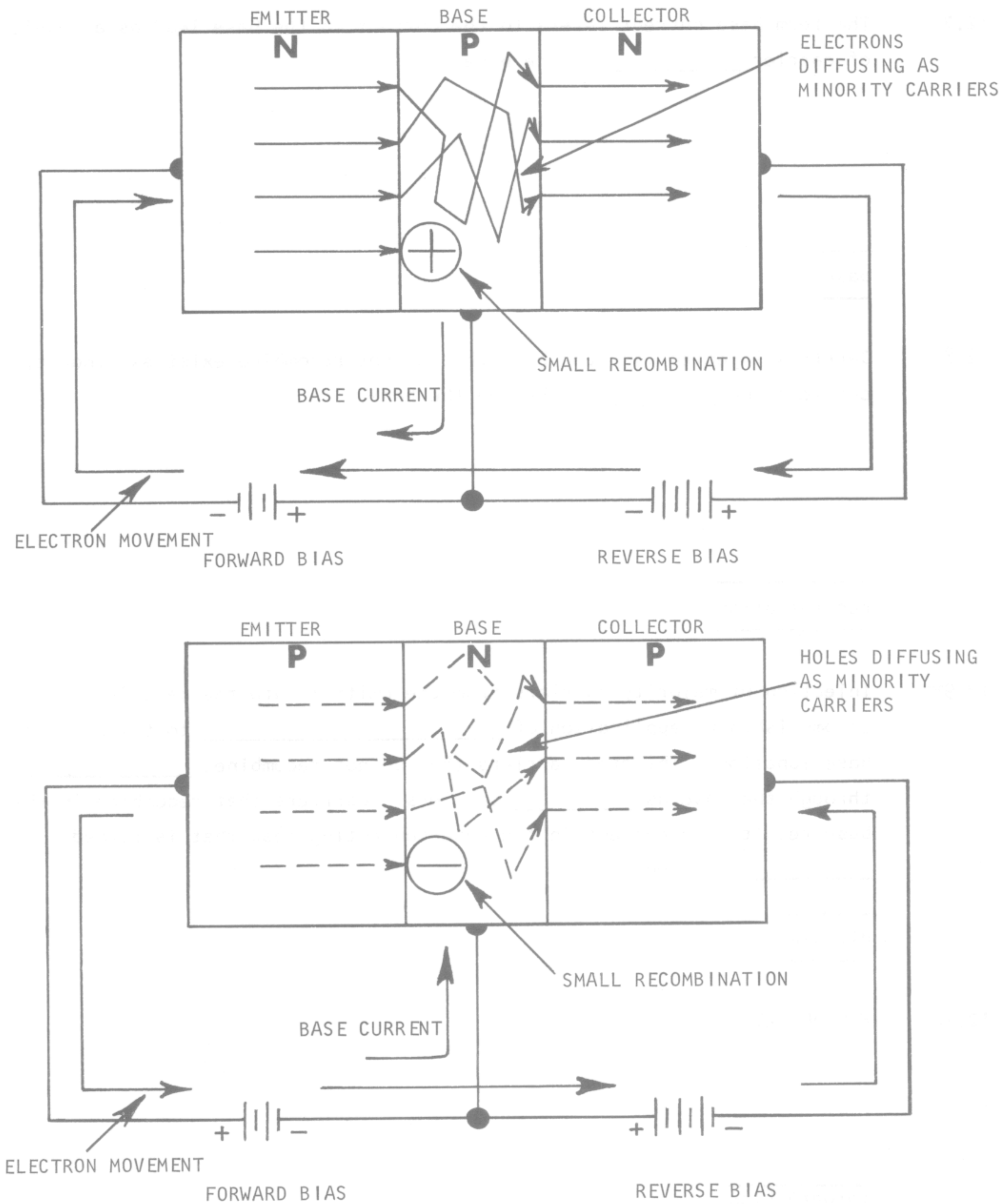

EMITTER
N
BASE
P
COLLECTOR
N
ELECTRONS DIFFUSING AS MINORITY CARRIERS
SMALL RECOMBINATION
BASE CURRENT
ELECTRON MOVEMENT
FORWARD BIAS
REVERSE BIAS
EMITTER
P
BASE
N
COLLECTOR
P
HOLES DIFFUSING AS MINORITY CARRIERS
SMALL RECOMBINATION
BASE CURRENT
ELECTRON MOVEMENT
FORWARD BIAS
REVERSE BIAS

FIGURE 13

13 The collector to base junction of a transistor is __________ biased and its current depends on minority carriers present due to thermal energy or carriers that are injected into the base from the ______________________ that do not recombine.

13.1 The carriers injected into the base that do not recombine are existing as minority carriers. In order to collect them, the collector-base junction is __________________ biased, as shown in figure 13.

reverse
emitter

13.2 Figure 13 shows both a NPN and a PNP transistor with biasing. Reverse biasing the collector-base junction causes this junction's current to be dependent on the number of minority carriers available in the ____________.

reverse

13.3 Collector current is dependent on minority carriers in the base. Varying the number of injected minority carriers will vary the ____________ in the collector junction.

base

13.4 The magnitude of the current in the reverse biased collector junction is dependent on the number of ________________ carriers available in the base.

current

13.5 Reverse bias to the majority carriers will accelerate minority carriers across the junction if they enter the transition region.

minority

13.6 Without injected carriers from the emitter, the collector current is limited by the number of minority carriers in the base as a result of ________________ energy.

no answer needed

13.7 The carriers injected from the emitter into the base that do not recombine are existing as ________________ carriers in the base.

heat, thermal, etc.

13.8 The diffusing carriers in the base, injected by the emitter, provide a supply of minority current carriers for the ________________ junction.

minority

13.9** The collector-base junction is ________ biased; its current magnitude is governed by the ________ carriers in the base as a result of heat energy or injection from the ___________.

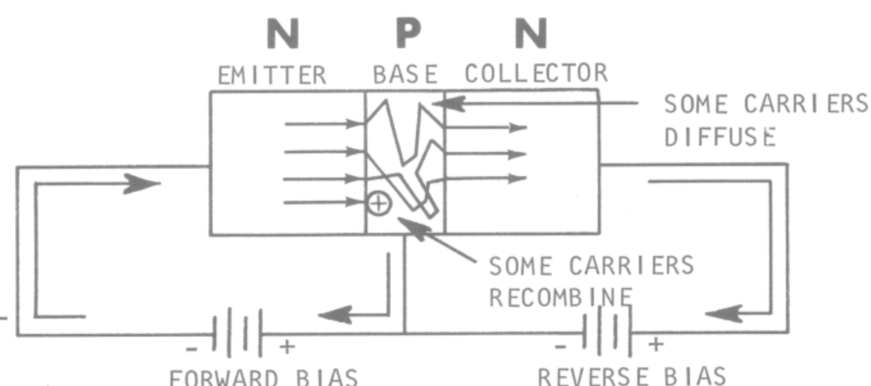
collector

13.10 END OF SET

reverse
minority
emitter

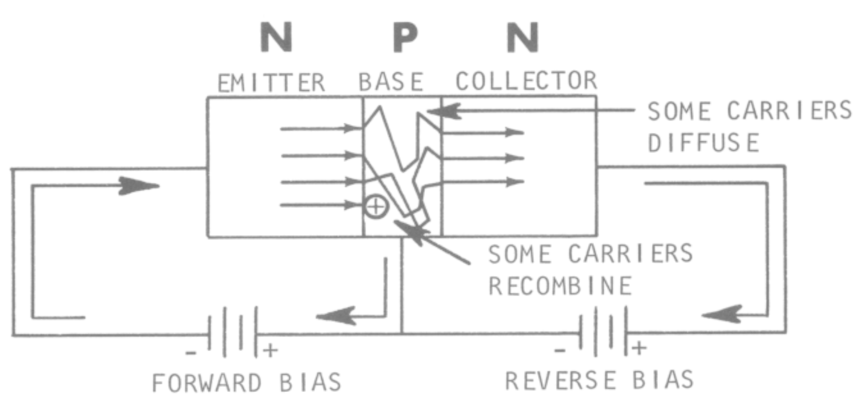
14 Base current is the result of ________ in the base and collector current is made up of carriers that ________ through the base. The emitter current in a transistor is the sum of ________ and ________ current.

14.1 Forward biasing the emitter-base junction injects carriers into the base. Some carriers recombine and the rest ________ through the base.



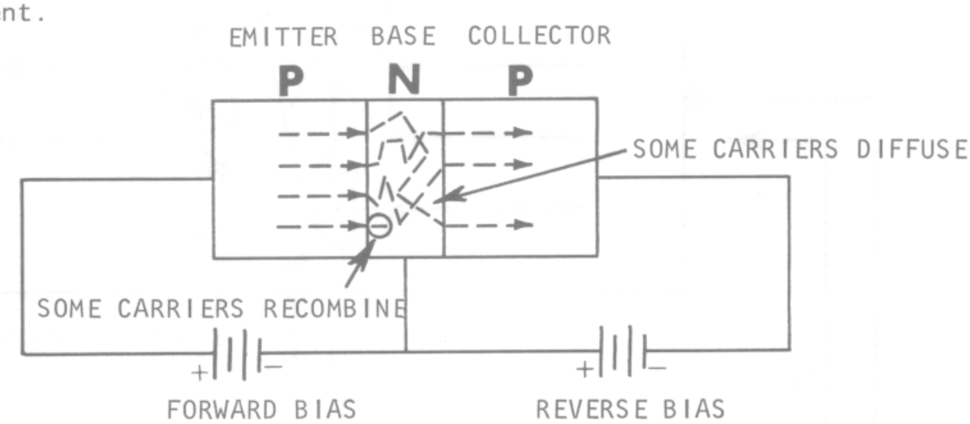
recombination
diffuse
collector (diffusion)
base (recombination)

14.2 Those injected carriers that do not recombine in the base and become base lead current diffuse through the base to the ________.



diffuse

14.3 The carriers injected into the base from the emitter either recombine and become base lead current or ______________ to the collector and become collector current.



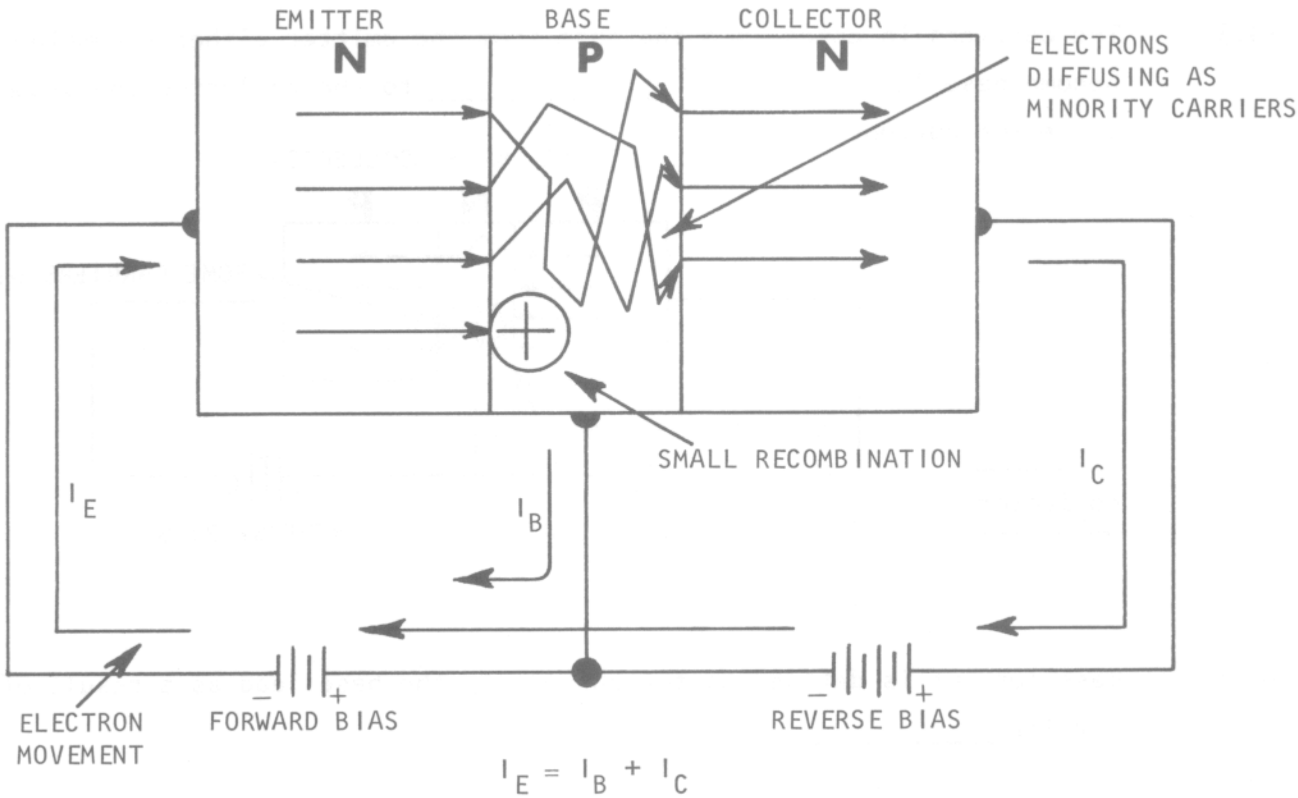
collector

14.4 Base current is defined as the current in the base lead as a result of carrier ________________.

diffuse

14.5 Collector current is the current in the collector lead that has __________ across the base.

recombination


EMITTER
BASE
COLLECTOR
N
P
N
ELECTRONS DIFFUSING AS MINORITY CARRIERS
SMALL RECOMBINATION
I_E
I_B
I_C
ELECTRON MOVEMENT
FORWARD BIAS
REVERSE BIAS
$I_E = I_B + I_C$

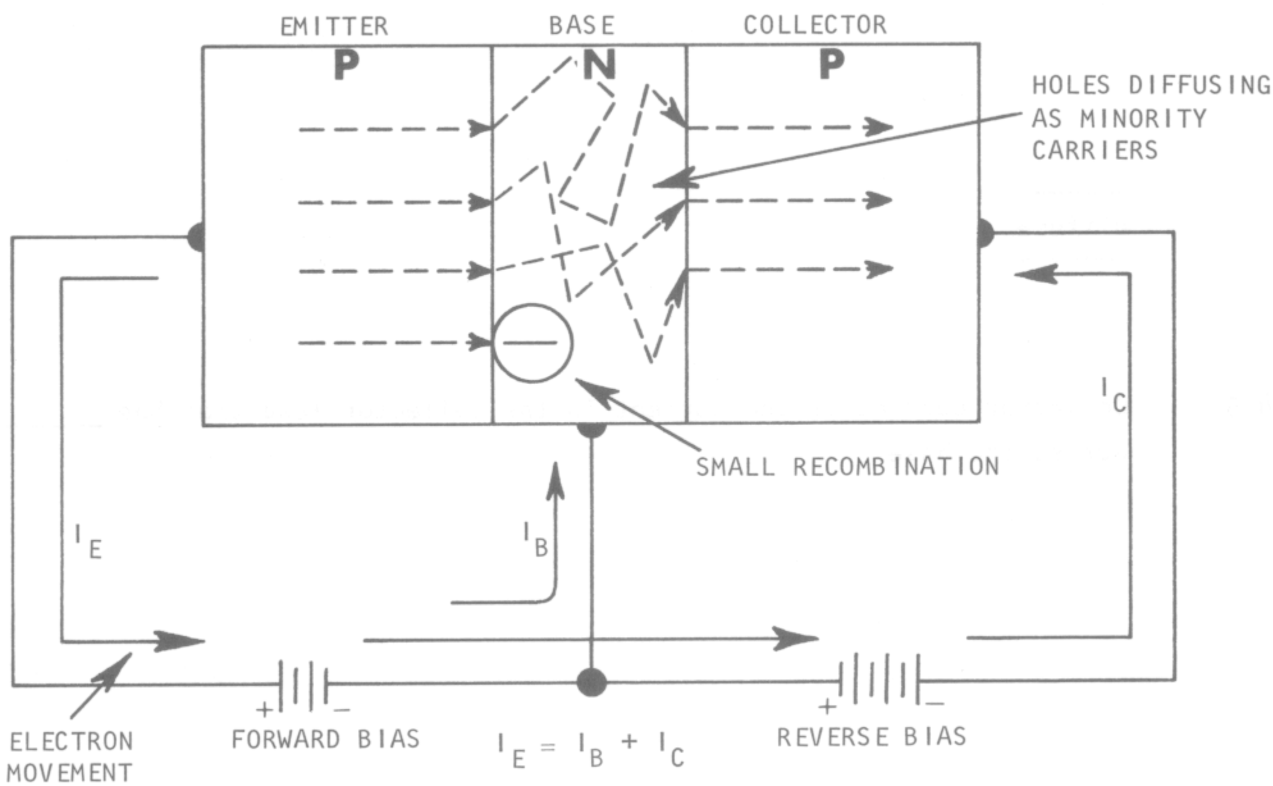
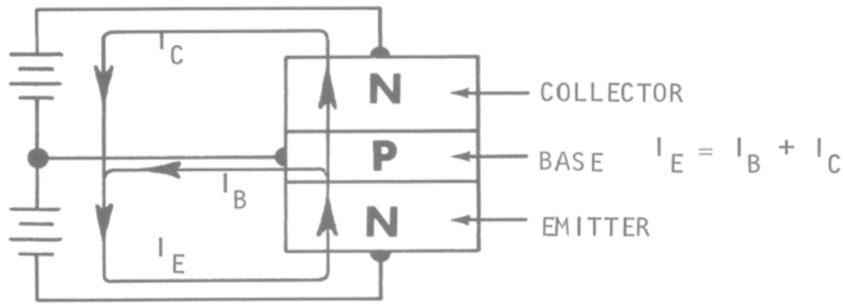

EMITTER
BASE
COLLECTOR
P
N
P
HOLES DIFFUSING AS MINORITY CARRIERS
SMALL RECOMBINATION
I_E
I_B
I_C
ELECTRON MOVEMENT
FORWARD BIAS
REVERSE BIAS
$I_E = I_B + I_C$

FIGURE 14

14.6 The sum of the carriers diffusing to the collector and the carriers that recombine in the base is equal to the ______________ current.



diffused

14.7 Figure 14 shows both a NPN and a PNP transistor indicating currents. I_E (d-c emitter current) is equal to the sum of I_C (d-c collector current) and I_B (d-c base current). $I_C = 20$ ma, $I_B = 1$ ma, $I_E =$ ______________.

emitter

14.8** $I_E = 50$ ma, $I_B = 2$ ma, therefore $I_C =$ ____________. I_B refers to the current in the base lead as a result of carrier ____________ in the base.

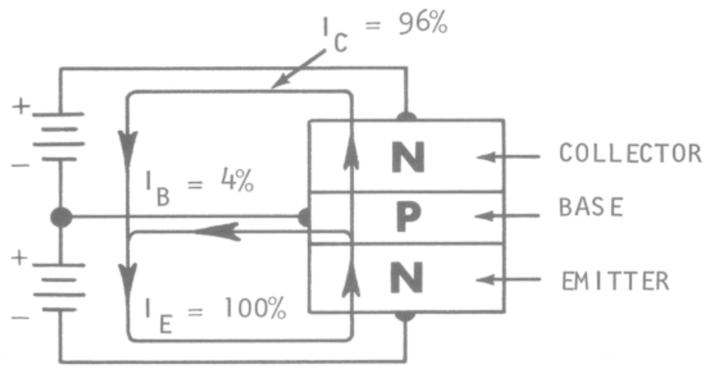
21 ma

14.9 END OF SET

48 ma
recombination

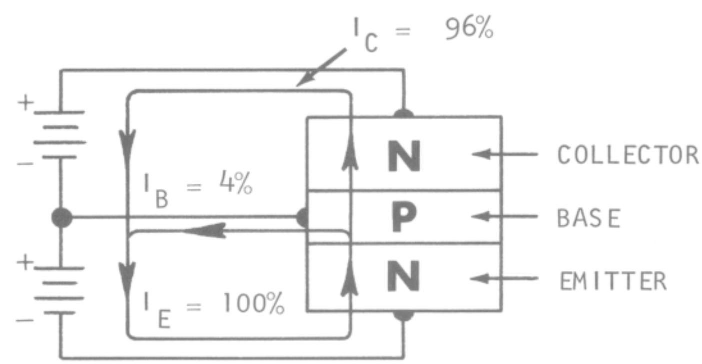
15 The d-c current in the collector (I_C) can be calculated by taking the product of d-c emitter current (I_E) and the d-c current gain factor, emitter to collector. This factor is referred to as ____________ or ______________.

15.1 The d-c current in the collector (I_C) is a percentage of the current in the emitter. In the diagram, collector current is ________% of emitter current.



alpha
h_{FB}

15.2 If the current in the emitter (I_E) in the diagram is 10 milliamperes, the current in the collector (I_C) is ___________ milliamperes.



96

15.3 The product of emitter current and the percentage of the emitter current that flows in the collector will give the value of __________ current.

9.6

15.4 If 92% of the emitter current flows in the collector, and the emitter current is 5 milliamps, the collector current is __________ milliamps.

collector

15.5 The d-c current gain from emitter to collector will be less than unity and the collector current will be __________ (more, less) than the emitter current.

4.6

15.6 The fraction of emitter current that flows in the collector is called d-c alpha. The d-c current gain factor, emitter to collector, is termed d-c __________.

less

15.7 The symbol that indicates d-c alpha is h_{FB} and this is the current gain from ____________ to collector.

alpha

15.8 The h in the symbol for d-c current gain stands for "hybrid" and simply indicates that it is a hybrid parameter.

emitter

15.9 The term "hybrid" indicates an approach to analyzing transistor circuits and the h indicates that the particular parameter so designated can be used with the ____________ approach.

no answer needed

15.10 The "F" in the d-c current gain symbol indicates "forward d-c current gain" and the "B" indicates the common point for measurement.

hybrid

15.11 The symbol "h_{FB}" indicates hybrid forward current gain from emitter to collector since the B indicates that the __________ is the common point.

no answer needed

15.12 The product of "d-c alpha" or "h_{FB}" and the emitter current will give the value of collector current. If alpha is 0.97 and emitter current is 2 milliamps, collector current is __________ milliamps.

base

15.13 The symbol h_{FB} represents the d-c current gain factor of a transistor, from emitter to collector. h_{FB} will always be less than ______________.

1.94

15.14** The symbol for d-c current gain emitter to collector is ________________ and the product of d-c current gain and emitter current is equal to

_____________ ______________.

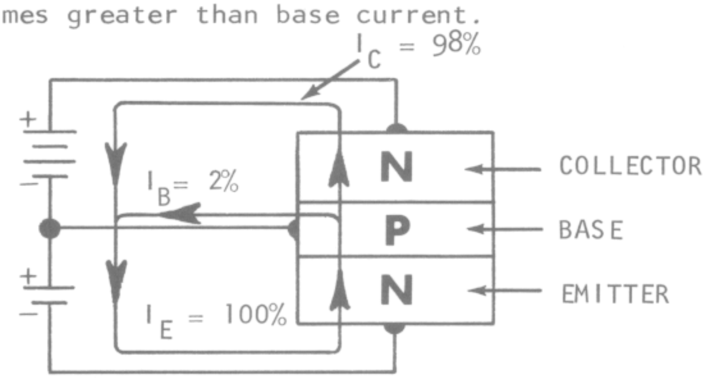
one, unity, etc.

15.15 END OF SET

h_{FB}
collector current (I_C)

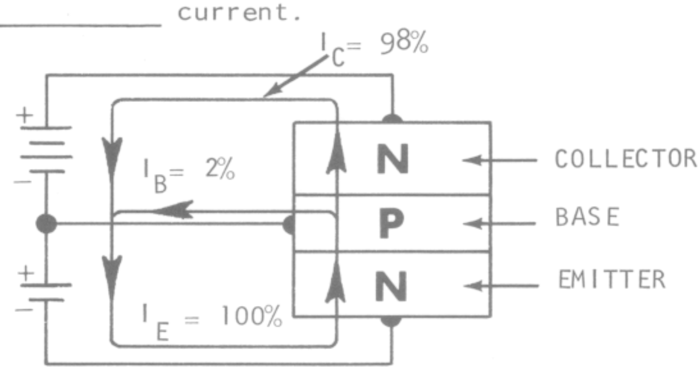
16 The product of the d-c base current (I_B) and the d-c current gain factor from base to collector will give the value of ____________ current. This current transfer factor is given the symbol _____________ and called "d-c _________".

16.1 The collector current in the diagram is 98% of emitter current. The base current is 2% of emitter current. This means the collector current is __________# times greater than base current.



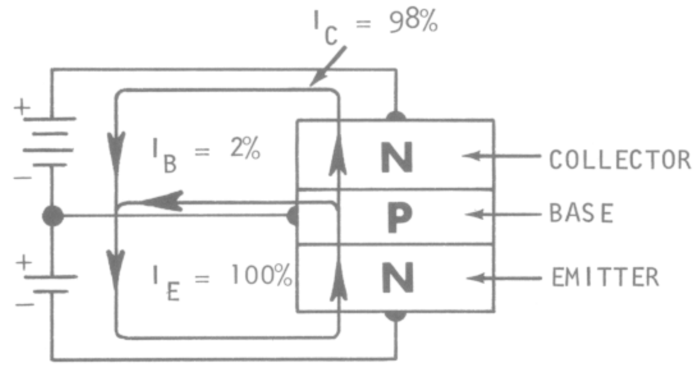
collector
h_{FE}
beta

16.2 The d-c current gain, base to collector, of the transistor in the diagram is 49. This means that the d-c collector currents is 49 times greater than the d-c ____________ current.



49

16.3 If the base current in the diagram is 10 milliamps, the collector current is __________ milliamps.



base

16.4 The symbol given the d-c current gain factor is h_{FE} and is termed "d-c beta". $I_B \times h_{FE}$ = ______________.

490

16.5 "h_{FE}" indicates hybrid forward d-c current gain, base to collector, since the E indicates that the _____________ is the common point.

I_C

16.6 If a transistor has an h_{FE} or d-c "beta" of 60 and a d-c base current of 15 milliamps, the collector d-c current will be __________ milliamps.

emitter

16.7 h_{FE} or d-c beta can be found by dividing the d-c collector current by the d-c base current. ______________ (symbol) $= \frac{I_C}{I_B}$

900

16.8** The d-c current gain factor, base to collector, is given the symbol __________. The product of _____________ and d-c base current will give the value of d-c collector current.

h_{FE}

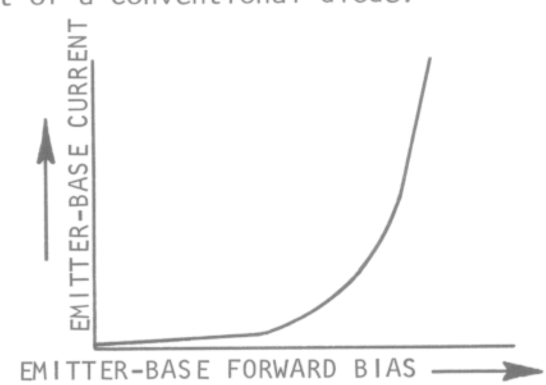
16.9 END OF SET

h_{FE}

h_{FE}

17 The emitter base junction of a transistor is the controlling circuit and changes in emitter-base current or voltage will be accompanied by a change in the ____________ current. A change in the base-emitter __________ will have the more linear effect.

17.1 The emitter-base junction of a transistor has a voltage versus current curve resembling that of a conventional diode.



collector
current

17.2 Once the potential difference of the emitter-base junction has been reduced, majority carriers cross the junction.

no answer needed

17.3 Due to the difference in the doping levels in the emitter and the base, only a few of the carriers from the emitter find imperfections and accomplish ______________.

no answer needed

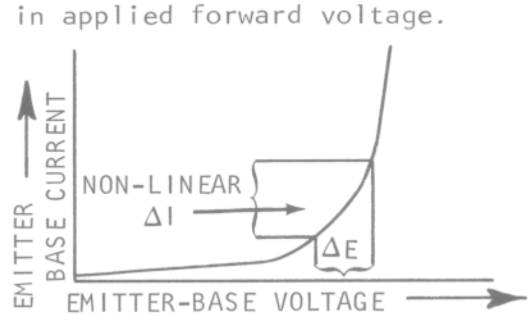
17.4 Those carriers that do not recombine, ______________ to the collector and become collector current.

recombination

17.5 A change in the emitter-base junction voltage will change the number of carriers injected from the emitter and thus change the number diffusing to the ________________.

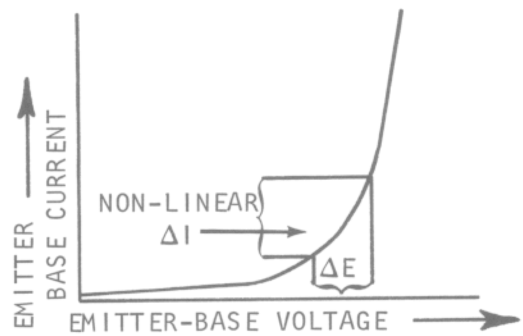
diffuse

17.6 The emitter-base junction EI curve shows that the current <u>does</u> <u>not</u> change linearly with changes in applied forward voltage.



collector

17.7 When the applied forward voltage on the emitter-base junction is varied to change the current, the resultant change is non-______________.



no answer needed

17.8 Since driving the emitter-base junction with voltage results in a non-linear result, it is common to find transistors driven with ______________ sources.

linear

17.9 Driving the transistors emitter-base junction with a high impedance source is essentially ________________ drive.
(current, voltage)

current

17.10 Current driving the emitter base junction allows linear changes to be accomplished. This requires a ________ (high, low) impedance input generator.

current

17.11** The emitter base junction is typically ____________ (voltage, current) driven to give the most linear change in the transistor currents.

high

17.12 END OF SET

current

18 Carriers are injected from the emitter into the base when the emitter-base junction is forward biased. The collector junction is ________ biased and depends on the injected carriers in the base for current. A change in emitter or base current will be accompanied by a change in collector current. For a given change in emitter and base current, varying ____________ current will have the largest effect on collector current.

18.1 The emitter-base junction is normally forward biased. Since the base is doped much lighter than the emitter, only a few of the injected carriers find imperfections and recombine. The remaining carriers diffuse in the base as ____________ carriers.

reverse
base

18.2 The collector junction is reverse biased and depends on minority carriers for current. There are a few minority carriers present in the base at room temperature due to heat energy, but most minority carriers in the base have been injected from the ____________.

minority

18.3 The number of minority carriers present in the base can be changed by varying either emitter or base current. Varying the number of ______ carriers in the base will vary collector current.

emitter

18.4 Consider that the base is doped with only one tenth as many imperfections as the emitter. Ten units of current flowing in the emitter will inject ten units of current into the base; one unit recombines in the base and the remaining nine units will ____________ to the collector.

minority

18.5 With the base doped one tenth as much as the emitter, increasing the emitter current by ten units of current will increase the base current by one unit and the collector current by ___________ units.

diffuse

18.6 If a ten unit change in the emitter current results in a nine unit change in collector current, the a-c signal current gain, emitter to collector, is less than __________.

nine

18.7 Increasing the base current (of the same transistor as frame 18.6) by one unit of current causes an increase of ten units to be injected into the base from the emitter. One unit recombines in the base while the other nine add to ___________ current.

one, unity

18.8 The a-c signal current gain, base to collector, of the transistor in frame 18.7 is ______________.

collector

18.9 The current gain, emitter to collector, will always be ______________ (greater, less) than one, while the current gain, base to collector, can be ______________ (greater, less) than one.

nine

18.10** A change in ______________ or ______________ current will be accompanied by a change in collector current. For the same amount of variance, a change in ______________ current will be accompanied by the largest change in collector current.

less
greater

18.11 END OF SET

emitter
base
base

19 With the collector-base junction reverse biased, there will be some collector current flow (I_{CBO}) without the emitter injecting carriers into the base. This current is made up of __________ ______ and, for a given bias, will vary with a change in __________.

19.1 At room temperature, there are some holes in the N material and some free electrons in the P material as a result of heat energy forming hole-electron pairs. These are __________ carriers.

minority carriers
temperature

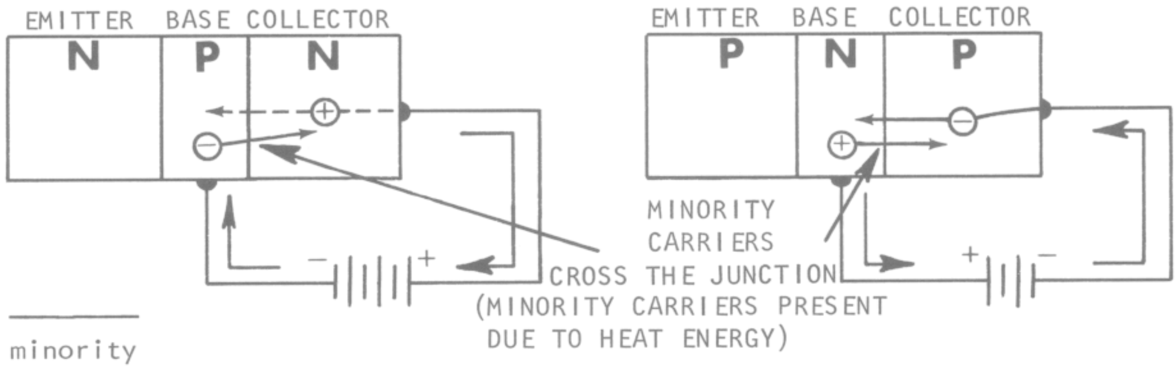
19.2 The emitter-base junction is forward biased (in the majority of applications) to the majority carriers and this opposes the movement of __________ carriers across the emitter-base junction.

minority

19.3 The collector-base junction is reversed biased (in most applications) to the majority carriers and enhances the movement of __________ carriers across the collector junction.

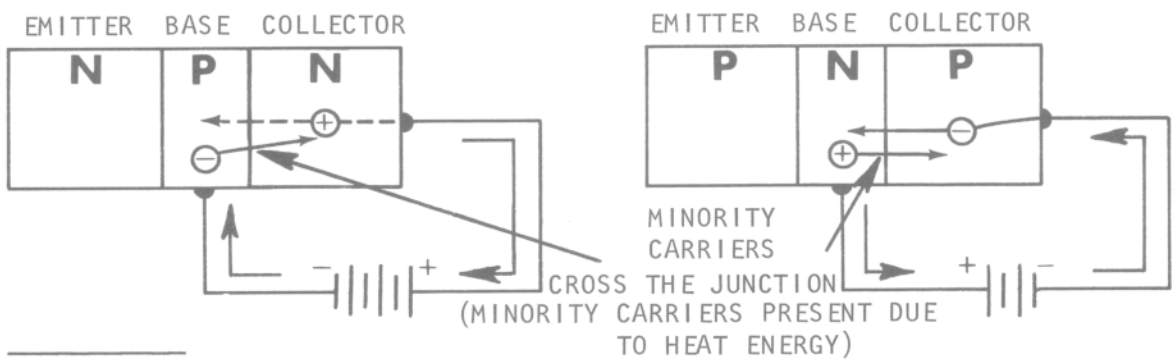
minority

19.4 There will be some current in the collector circuit when it is reverse biased (even if the emitter is open), because of the minority carriers present due to ________ __________.



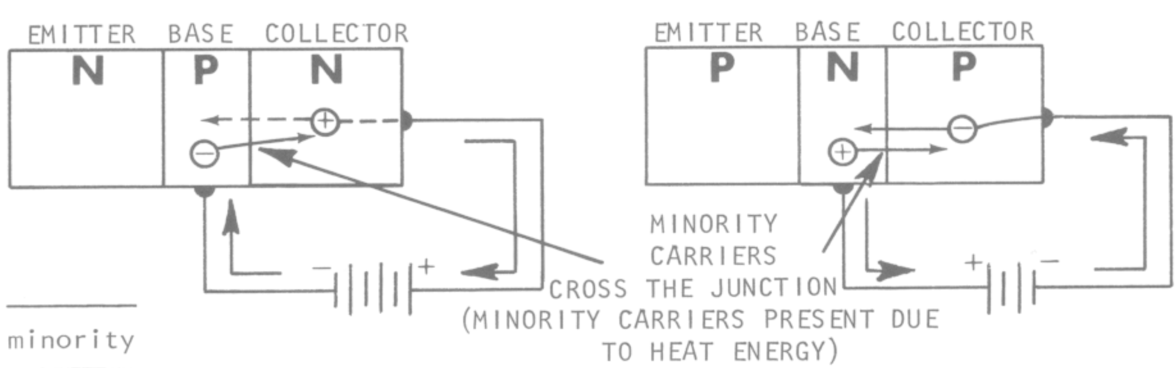
minority

19.5 The current in the diagram is temperature dependent as a change in temperature changes the number of ____________ carriers available.



heat energy

19.6 The current in the diagram is given the symbol I_{CBO} indicating d-c current between collector and base with the emitter open. I_{CBO} is the result of "hole - _______ _________".



minority

19.7 In the symbol I_{CBO}, the capital I indicates d-c current, the subscripts CB indicate that the current is between collector and base, and the subscript 0 indicates that the remaining element, the ________________, is open circuited.

electron pairs

19.8 I_{CBO} is the current at the collector junction carried by ______________ carriers present as a result of thermal energy. I_{CBO} will flow with the emitter lead ________________ circuited.

emitter

19.9** There is current in the collector junction when it is reverse biased, even if the ________________ lead is open circuited. This current is given the symbol ______________. A change in temperature will change the magnitude of ______________.

minority
open

19.10 END OF SET

emitter
I_{CBO}
I_{CBO}

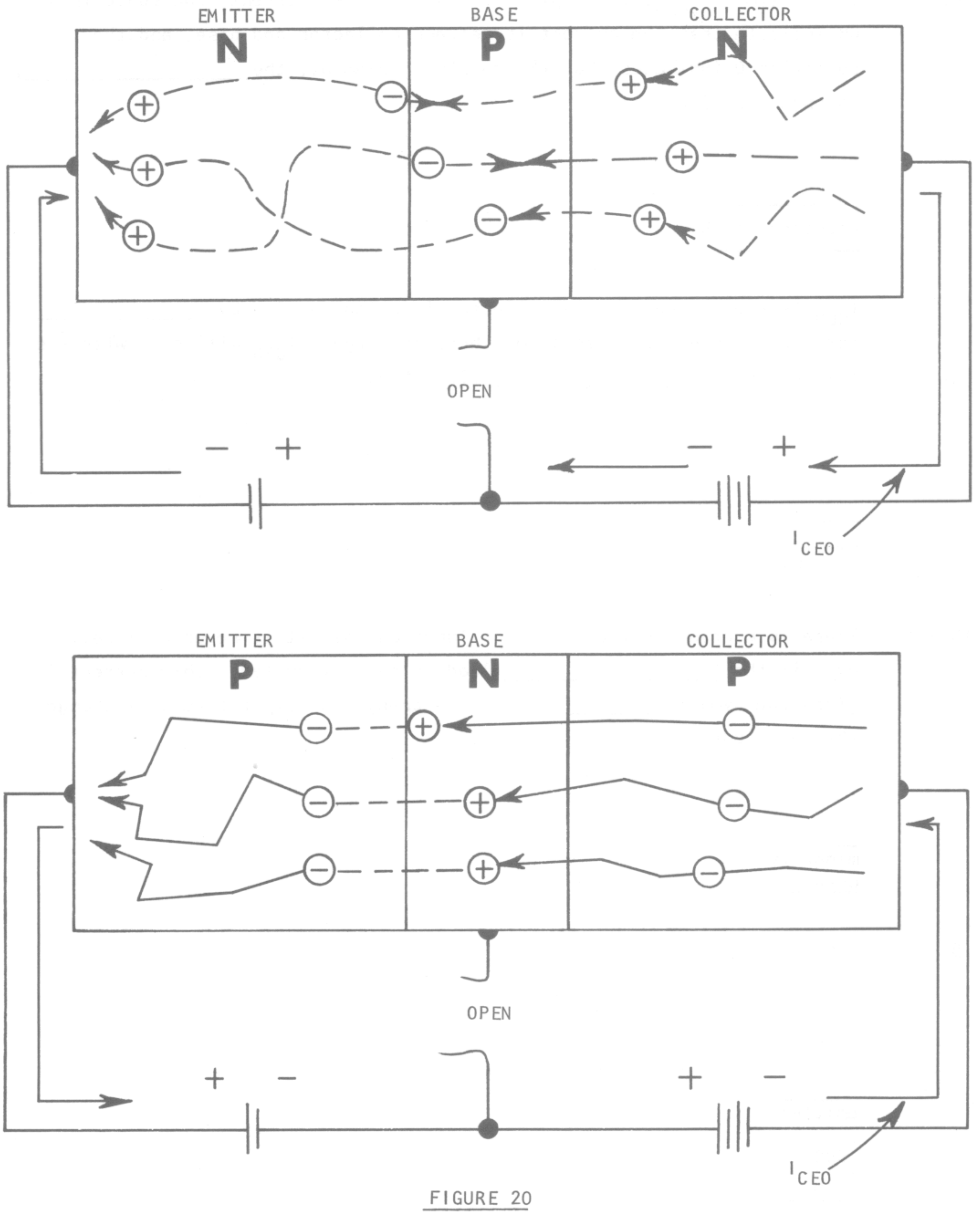

EMITTER
BASE
COLLECTOR
N
P
N
OPEN
- +
- +
I_{CEO}
EMITTER
BASE
COLLECTOR
P
N
P
OPEN
+ -
+ -
I_{CEO}

FIGURE 20

20 With bias voltages applied, there is some collector current with the base lead open circuited. This current is made up of minority carriers and is given the symbol __________. It is approximately equal to __________ x I_{CBO}.

20.1 Figure 20 shows both an NPN and a PNP transistor with bias supplies, but with the base lead open circuited. The current is made up of __________ carriers.

I_{CEO}
h_{FE}

20.2 Opening the base lead as shown in figure 20 results in minority carriers crossing both junctions. With the base doped much lighter than the emitter, many minority carriers are injected into the base from the emitter with the condition in figure 20.

minority

20.3 I_{CBO} is limited by the carriers present due to heat energy. With the condition in figure 20, the number of minority carriers in the base is increased by approximately d-c beta or __________ (symbol).

no answer needed

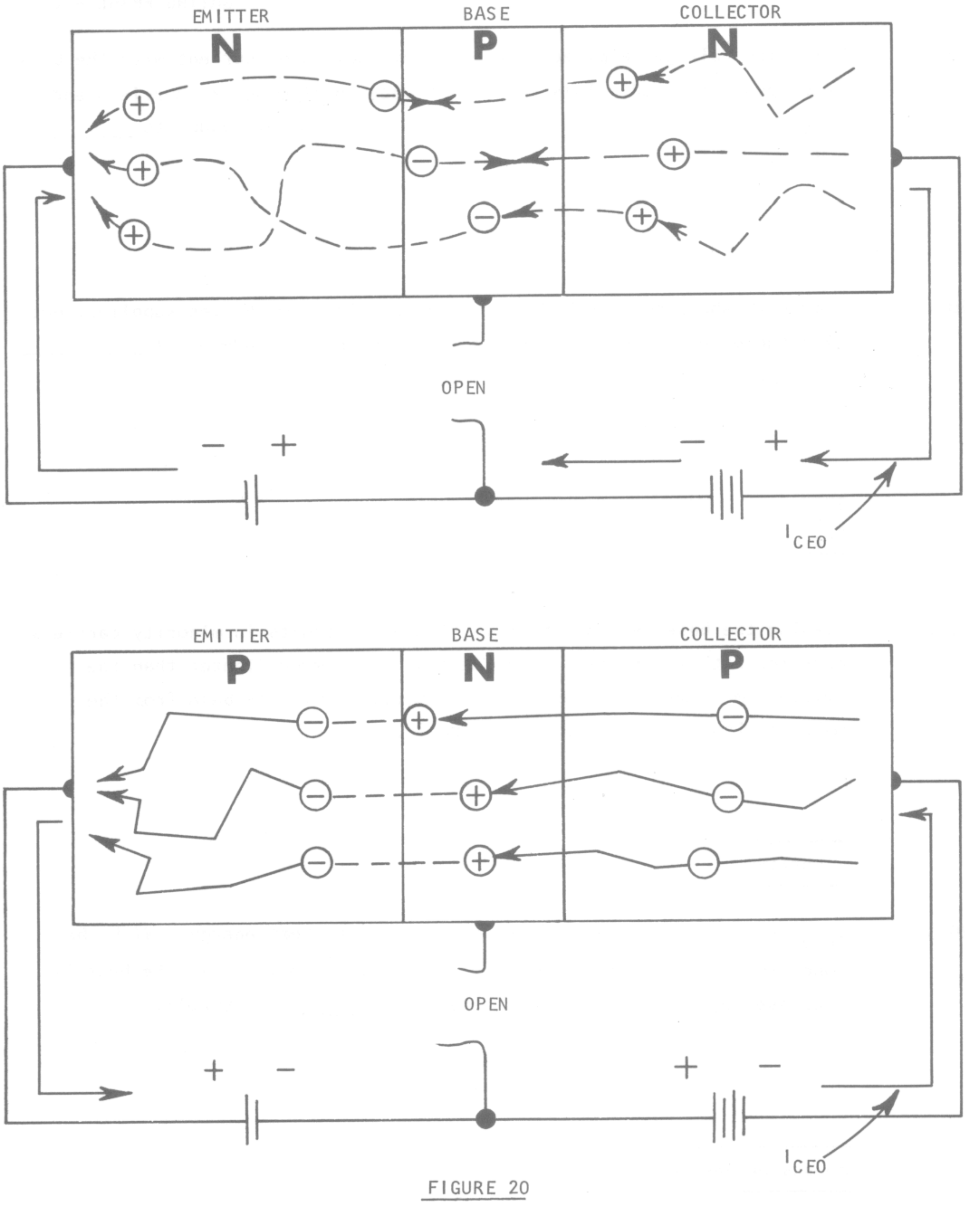

EMITTER
BASE
COLLECTOR
N
P
N
OPEN
- +
- +
I CEO
EMITTER
BASE
COLLECTOR
P
N
P
OPEN
+ -
+ -
I CEO

FIGURE 20

20.4 The minority carriers in the base are increased by approximately the d-c current gain of the transistor when the condition in figure 20 exists. There will be more ________ carriers available in the base than for the I_{CBO} condition.

h_{FE}

20.5 The current in figure 20 is between collector and emitter with the base lead open. It is given the symbol I_{CEO}. I_{CEO} will be ________ (larger, smaller) than I_{CBO}.

minority

20.6 The current termed I_{CBO} is magnified by $\approx h_{FE}$ with the conditions in figure 20. $I_{CBO} \times h_{FE} \approx$ ________.

larger

20.7** I_{CEO} indicates d-c current between ________ and ________ with the base lead open circuited. It is approximately equal to the product of I_{CBO} and ________.

I_{CEO}

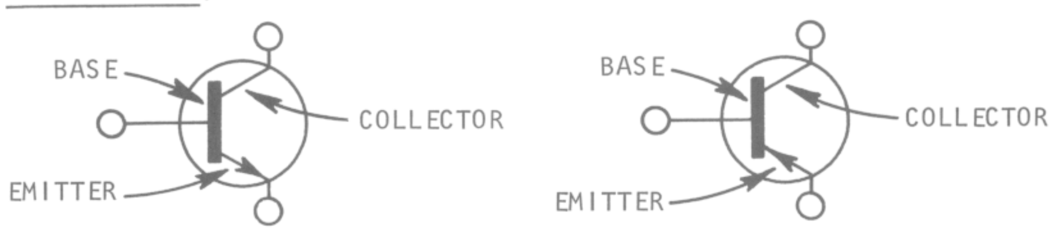
20.8 END OF SET

collector
emitter
h_{FE}

21

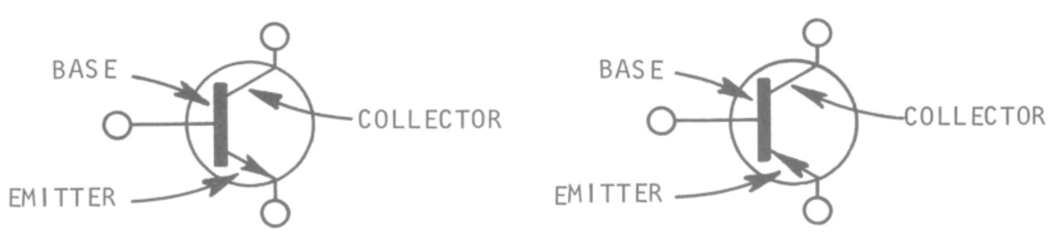
Symbol 1 is for a/an ____________ transistor, and symbol 2 is for a/an ____________ transistor. E indicates the __________.

21.1 The solid vertical line in the transistor symbol indicates the base. The line (without the arrow head) intersecting the base at an angle indicates the __________.



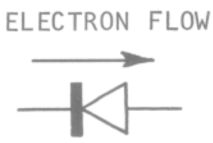
NPN
PNP
emitter

21.2 The line containing an arrow head that intersects the base at an angle indicates the _____________.



collector

21.3 In an NPN transistor, the carriers are electrons injected from the emitter into the base. In the diode symbol, electrons flow ____________ (out of, into) the symbol arrow point as shown in the diagram.



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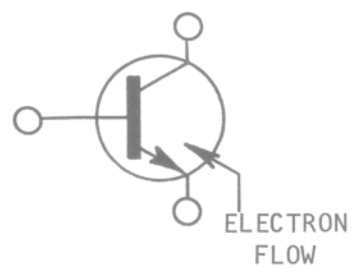
emitter

21.4 The emitter-base of a transistor is a PN junction and in the symbol electrons will flow ____________ (into, out of) the tip of the arrow.



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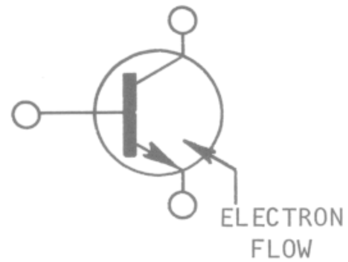
into

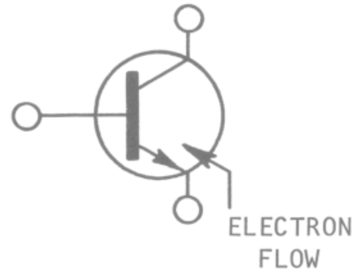
21.5 The symbol shown has electrons flowing into the tip of the arrow. The arrow indicates that electrons are flowing from the emitter into the ____________.



---

into

21.6 An NPN transistor has the emitter injecting electrons into the base. The symbol shown must be a/an __________ transistor.



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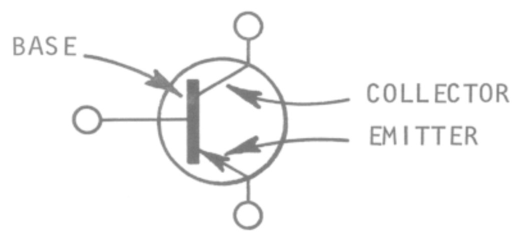
base

21.7 The emitter of a PNP transistor injects holes into the base. Holes move in the direction that the arrow is pointing in a diode symbol. The transistor shown must be a/an ___________ transistor.

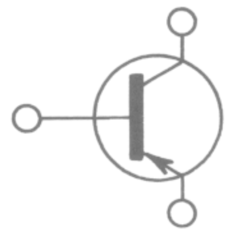


NPN

21.8 PNP transistors have the emitter arrow pointing _________________ (toward, away from) the base and NPN transistors have their emitter arrow pointing _________________ (toward, away from) the base.

PNP

21.9** The symbol shown is a/an ___________ transistor. If the emitter arrow were pointing the other way, it would be the symbol for a/an ___________ transistor. The part of the symbol containing the arrowhead indicates the ___________.

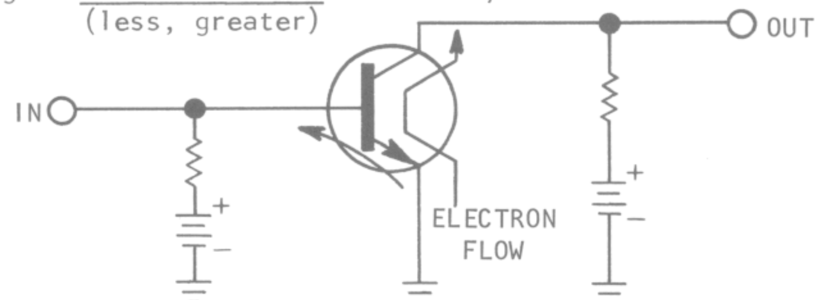


toward
away from

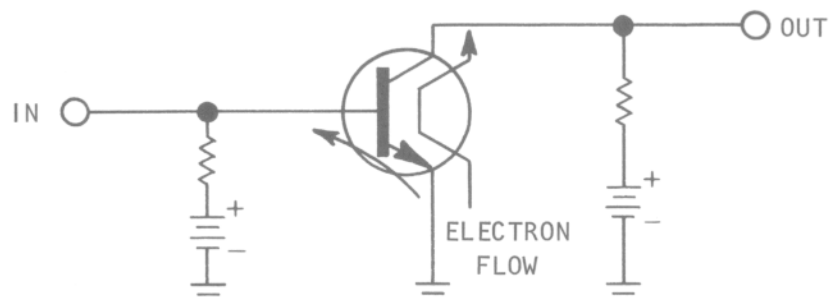
21.10 END OF SET

PNP
NPN
emitter

22 The transistor in the diagram is a/an ___________ type and is in a common ______________ configuration. A transistor in this configuration will give current gain ______________ than unity.
(less, greater)



22.1 The transistor in the diagram has the arrow indicating the emitter pointing away from the base. Electrons flow ______________ the arrow in the symbol.
(with, against)

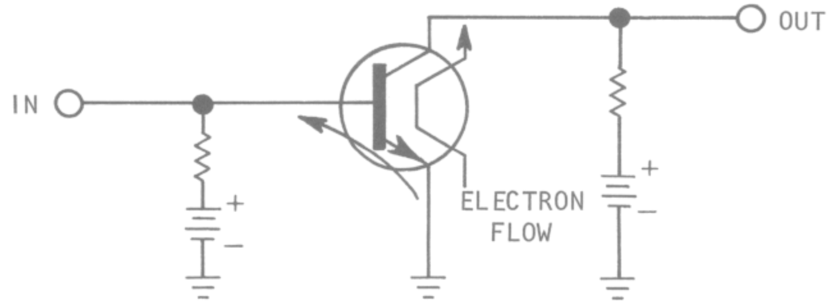


NPN
emitter
greater

22.2 Electrons are injected into the base from the emitter in an NPN transistor. The diagram shown is a/an _____________ transistor.

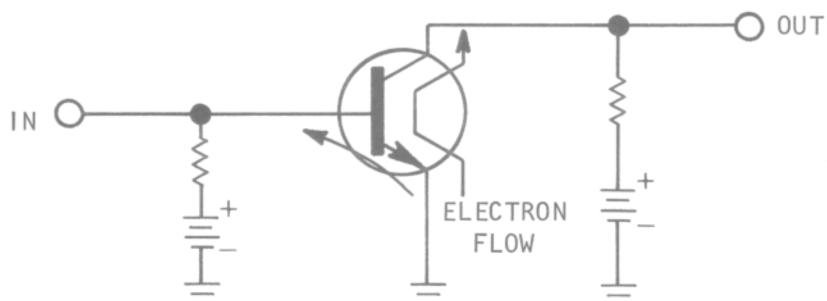
against

22.3 Grounding the emitter makes it <u>common</u> to both the input and output circuits. The transistor in the diagram has its emitter ____________ to both the input and output circuits.



PNP

22.4 The grounded or common emitter circuit has the transistors' ____________ as its input point, and the transistors' ____________ as its output point.



common

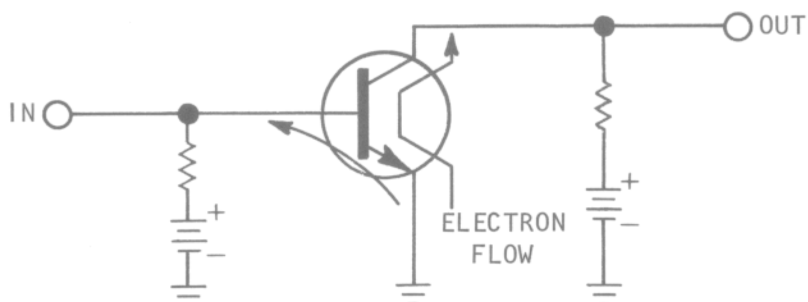
22.5 A small change in input (base) current in the common emitter circuit will be accompanied by a ____________ (larger, smaller) change in output (collector) current.

base
collector

22.6 It is possible for the common emitter configuration to give a current gain greater than unity. The output (collector) current change can be larger than the change in the ______________ current.

larger

22.7** The transistor in the diagram is an NPN type. The emitter injects __________ into the base. The current gain of this common ___________ configuration can be greater than unity.



input (base)

22.8 END OF SET

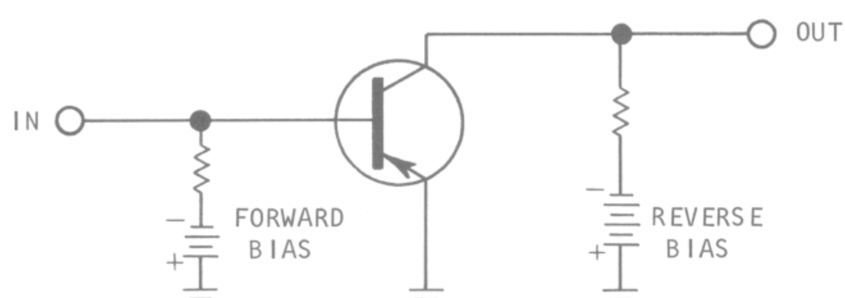
electrons
emitter

23 Voltage gain along with current gain can be accomplished with the common ____________ configuration making possible a high power gain.

23.1 The common emitter configuration allows a current gain greater than unity. The signal current in the output can be ____________ than the signal current in the input.

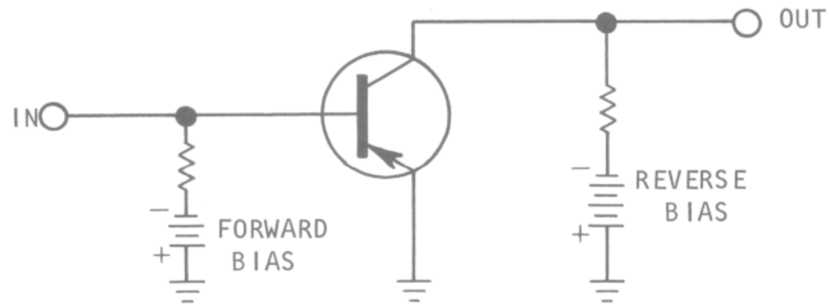
emitter

23.2 The emitter junction is forward biased while the collector junction is ____________ biased in most amplifier configurations.



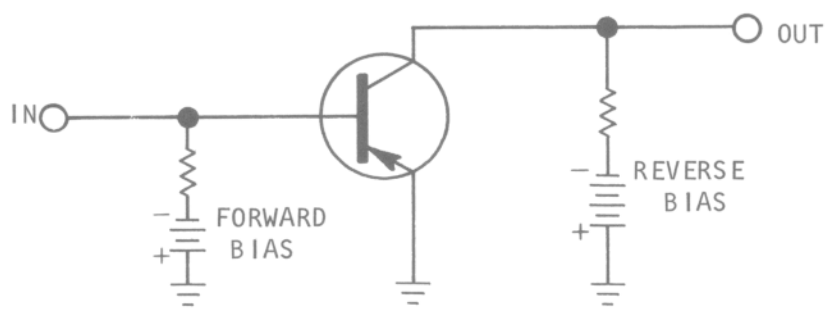
greater, larger, etc.

23.3 Forward bias is necessary at the emitter junction for carrier injection into the base. The emitter junction has a low impedance because it is __________ biased.



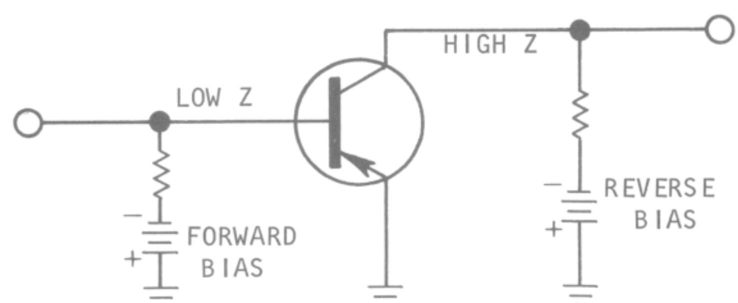
reverse

23.4 The collector junction offers a higher impedance than the emitter junction because the collector junction is __________ biased.



forward

23.5 By ohms law, a current through a high impedance will develop a larger voltage than the same current through a low impedance. There is a higher impedance at the __________ junction than at the __________ junction.



reverse

23.6 Voltage gain is possible with the common emitter configuration. Since the ____________________ is a higher impedance circuit, the current in the collector circuit develops a larger voltage than at the base.

collector
emitter

23.7 A small voltage change applied to the base to emitter circuit of a common emitter configuration can cause a larger voltage change at the _____________.

collector

23.8 The common emitter configuration offers a high power gain because both current and __________ gain are possible.

collector

23.9** The common emitter configuration offers both ___________ and ___________ gain, making possible a large power gain.

voltage

23.10 END OF SET

current
voltage

24 The small signal, a-c current gain of the transistor in a common emitter configuration is given the symbol ________. This parameter ________ (does, does not) include circuit effects on current gain.

24.1 Small signal indicates that the transistor will operate only over a small portion of its possible operating range. Forcing a transistor to operate to the extremes of its operating range of currents and voltages ________ (is, is not) considered small signal.

h_{fe}
does not

24.2 Small signal characteristics are expressed by small or incremental changes. The small signal current gain indicates the amount that a/an ________ current change will be amplified.

is not

24.3 The common emitter configuration has the ________ as its input and the collector as its output with the ________ common to both.

small, incremental

24.4 A change in the base current of a common emitter configuration will be accompanied by a larger current change in the __________ circuit.

base
emitter

24.5 Varying the voltage on the collector junction will also cause a change in collector current. The effect of a collector voltage change on collector current will be much smaller than the effect of a/an __________________ current change on collector current.

collector

24.6 In order to gain an accurate measurement of the control of input current on the output current, the output ___________ must be held constant.

input (base)

24.7 The current gain of the transistor in a common emitter configuration can be measured by varying the input current, noting the change in output current while holding output ____________ constant.

voltage

24.8 The symbol h_{fe} indicates the small signal, a-c current gain of the transistor in a common __________________ configuration.

voltage

24.9 The transistor current gain parameter, h_{fe} is referred to as small signal "beta". The small signal current gain from base to collector is called _____________.

emitter

24.10 h_{fe} may be calculated by dividing the change in collector current by the applied change in base current while holding collector voltage constant.

$$h_{fe} = \left. \frac{\Delta I_c}{\Delta I_b} \right| \Delta V_{ce} = 0$$

Δ = Incremental change

I_c = Collector current

I_b = Base current

V_{ce} = Voltage __________ to emitter

beta

24.11 h_{fe} is the current gain of the transistor only when placed in a common emitter configuration. The effects of the __________ will also have to be taken into account when calculating total circuit current gain.

collector

24.12

$$h_{fe} = \frac{\Delta I_c}{\Delta I_b} \bigg| \Delta V_{ce} = 0$$

The current gain parameter h_{fe} ______________ (does, does not) take into account losses encountered in the circuit.

circuit

24.13** The symbol h_{fe} indicates a transistor current gain parameter. It ______________ (would, would not) be used with a transistor in a common base configuration. It ______________ (does, does not) take into account the effects of the circuit on current gain.

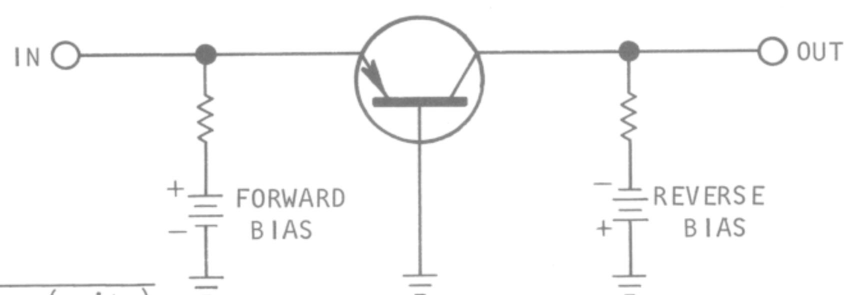
does not

24.14 END OF SET

would not
does not

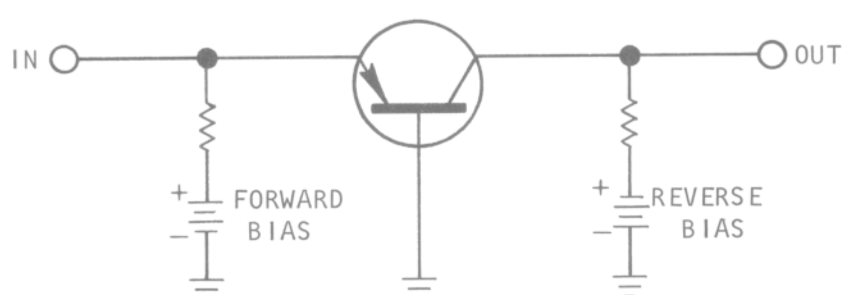
25 A transistor in a common base configuration will give a current gain ________ ________ ________. The small signal, a-c current gain of the transistor in a common base configuration is given the symbol ________________. This parameter ____________ (does, does not) take into account the effects of the circuit on current gain.

25.1 The common base configuration has the emitter as the input, the collector as the output, and the ____________ common to both.



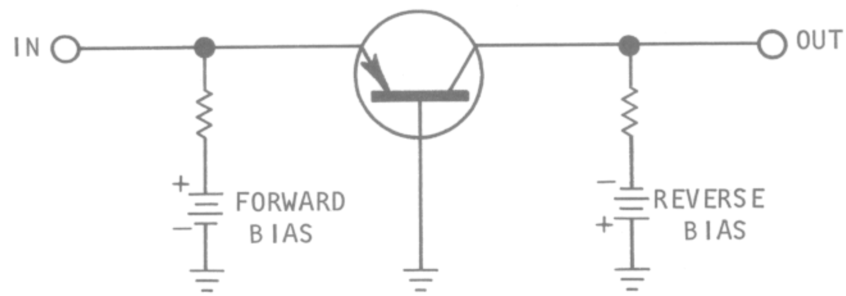
less than one (unity)
h_{fb}
does not

25.2 Comparing the common base to the common emitter, the emitter junction is ____________ biased in both and the collector junction is ____________ biased in both. Only the configuration or orientation of the transistor is different.



base

25.3 A change in the emitter (input) current in the circuit in the diagram will result in a _______________ (larger, smaller) change in the collector (output) circuit.



forward
reverse

25.4 The output current will always be smaller than the input current in a common _________ configuration.

smaller

25.5 The current gain of the common base configuration can be said to be less than one (unity), since the output current will be __________ than the input current.

base

25.6 A change in the emitter current will be accompanied by a change in the collector current. A change in the voltage on the collector junction will also result in a change in __________ current.

---

less, smaller, etc.

25.7 To make an accurate measurement of the relation of a varying emitter current to collector current, the collector ___________ must be held constant.

---

collector

25.8 The small signal, a-c current gain of the transistor in a common base configuration is referred to as small signal "alpha" and given the symbol h_{fb}. This parameter ______________ (does, does not) take into account the effects of the circuit on current gain.

---

voltage

25.9 h_{fb} can be calculated by dividing the output current by the input current while holding the output ___________ constant.

$$h_{fb} = \frac{\Delta I_c}{\Delta I_e} \bigg| \Delta V_{cb} = 0$$

Δ = Incremental change
I_c = Collector current (output)
I_e = Emitter current (input)
V_{cb} = Voltage collector to base (output)

---

does not

25.10** The small signal current gain of the transistor in a common base configuration is given the symbol ________. This current gain parameter ____________ (would, would not) be used for a transistor in a common emitter configuration. The effects of the circuit __________ (are, are not) taken into account by this parameter.

---

voltage

25.11 END OF SET

---

h_{fb}
would not
are not

---

26 Since the collector junction is a ______________ impedance circuit and the emitter junction is a ______________ impedance circuit, voltage gain can be accomplished with the common base configuration and a corresponding ______________ gain.

26.1 Common base current gain is less than unity. The current in the collector (output) circuit will be __________ than the current in the emitter (input) circuit.

high
low
power

26.2 Reverse biasing the collector results in a high impedance collector circuit with respect to the low impedance, ____________ biased emitter circuit.

less

26.3 The product of collector impedance and collector current can be greater than the product of emitter current and emitter impedance. This indicates that voltage gain is possible.

forward

26.4 Although current gain is less than unity in the common base configuration, voltage gain greater than unity is possible and a corresponding _________ gain may be realized.

no answer needed

26.5 The product of current gain (less than unity) and voltage gain (greater than unity) will give the __________ gain.

power

26.6** Power gain is possible with the common base configuration although the current gain is ________ __________ ________ since there is the possibility of _________ gain.

power

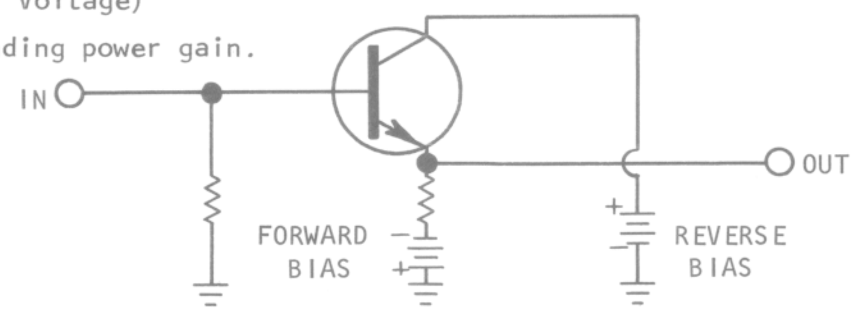
26.7 END OF SET

less than unity
voltage

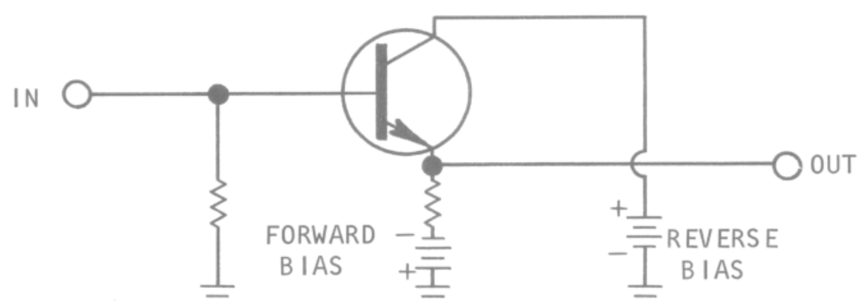
27 The transistor shown is in a common ______________ configuration.

______________ gain is possible with this configuration with a
(Current, Voltage)

corresponding power gain.

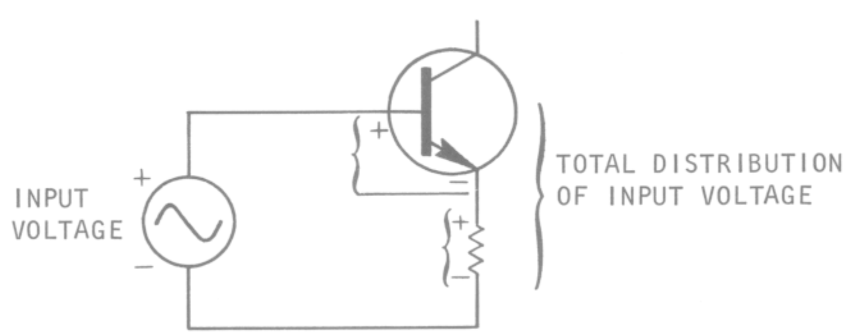


27.1 The ____________ serves as the input, the __________ serves as the output, and the ____________ is common to both in this configuration.



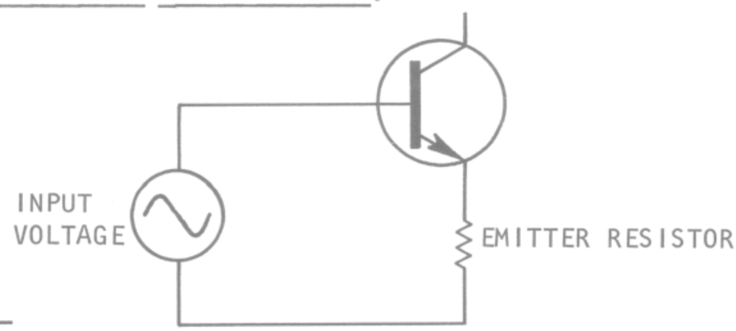
collector
Current

27.2 The input signal voltage is applied at the base and will be distributed across the emitter-base junction and the resistance in the emitter circuit.



base
emitter
collector

27.3 If the emitter resistor has a high resistance with respect to the resistance of the emitter-base junction, most of the input voltage will be across the ____________ ____________.



---

no answer needed

27.4 Since the voltage across the emitter resistor is only <u>part</u> of the input voltage, the voltage across the emitter resistor will always be less than the input voltage.

---

emitter resistor

27.5 Signal voltage at the emitter can never be equal to or larger than the applied signal voltage at the __________ terminal of a transistor in the common collector configuration.

---

no answer needed

27.6 The emitter is the output point and the base is the input point. Since the emitter signal voltage can never equal the base signal voltage, the voltage gain is less than ____________.

base

27.7 The emitter current is the sum of base and collector current. The ____________ handles the greatest amount of current in the transistor.

one, unity

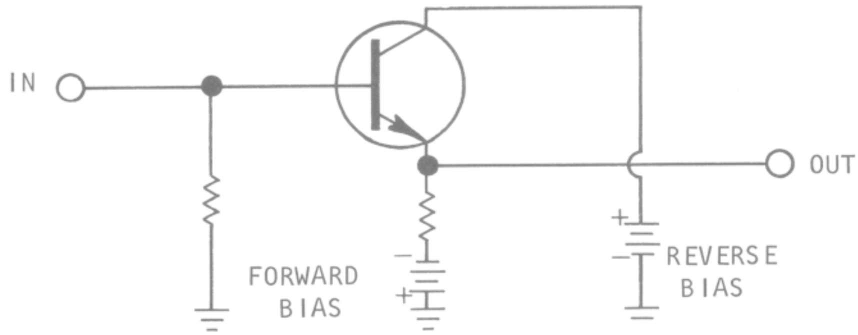
27.8 The current gain of a transistor in a common collector configuration is greater than unity. The current in the emitter is greater than the current in the ____________.

emitter

27.9 The voltage gain of a common collector configuration is less than unity. Power gain is possible, however, as this configuration yields __________ gain.

base (input)

27.10 Since the emitter current is equal to collector current plus base current of the transistor in the diagram, its current gain can be greater than ____________________.



current

27.11 The common collector configuration has the largest potential current gain of the three transistor configurations, since the input is at the lowest current point on the transistor while the output is taken from the ____________ current point.

one, unity

27.12** The common collector configuration can yield power gain even though its voltage gain is less than unity, since ____________ gain is possible.

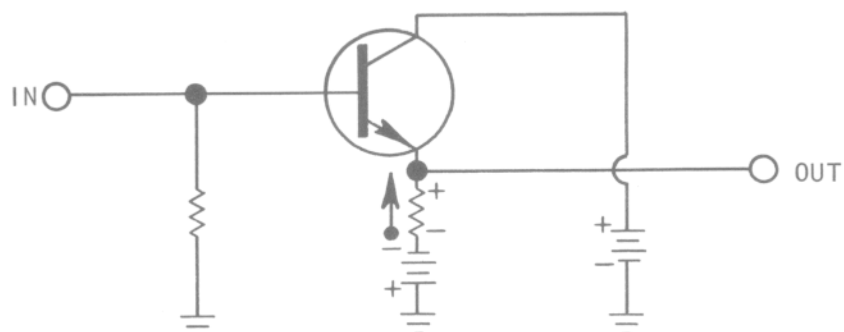
highest, largest, etc.

27.13 END OF SET

current

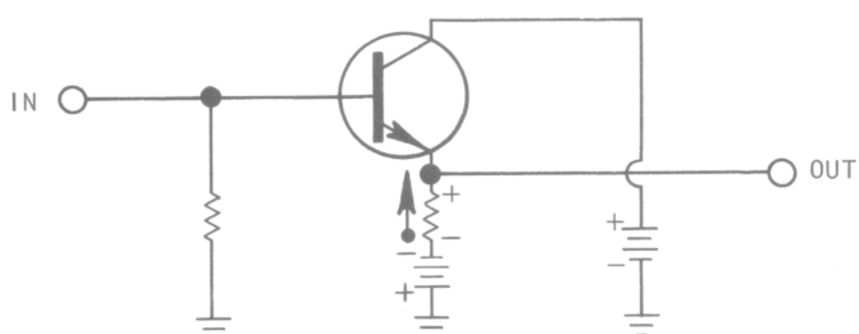
28 The common collector configuration is also referred to as an emitter ____________ since the emitter will ______________ the base.

28.1 An increase in base current will be accompanied by an increase in collector and emitter currents. In the transistor shown, an increase in input current will be accompanied by an ______________ in the output current.



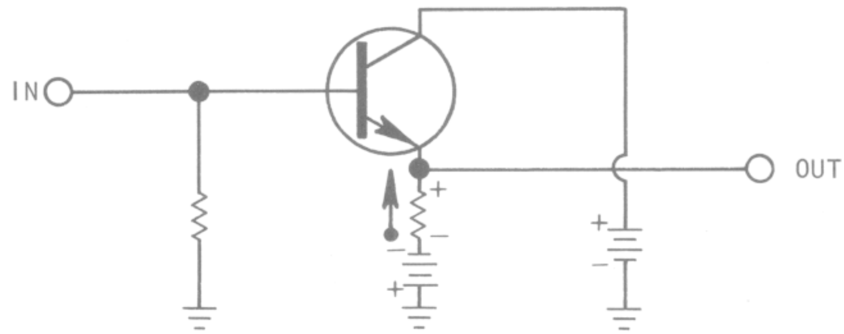
follower
follow

28.2 A positive voltage change on the base will be accompanied by an increase in base current and an increase in collector and _____________ current.



increase

28.3 A positive voltage change on the base will cause an increase in emitter current and a positive ____________ change at the emitter.



emitter

28.4 The voltage and current changes at the emitter will follow the changes at the base. The ____________ follows the ____________.

voltage

28.5 The voltage changes at the emitter of an emitter follower configuration can never be larger than the voltage changes at the base. The current changes at the emitter, however, can be much larger than the current changes at the ____________.

emitter
base

28.6** The emitter changes follow the base changes in the common collector configuration. This configuration is commonly referred to as an ____________ ____________.

base (input)

28.7 END OF SET

emitter follower

29 The small signal, low frequency current gain parameter for the transistor in a common collector configuration is given the symbol ____________. It is equal to h_{fe} + ______________.

29.1 A change in base current in an emitter follower will give a collector current change equal to $h_{fe} \times \Delta I_B$. The change in emitter current is equal to the sum of the collector current change and the ______________ current change.

h_{fc}
1

29.2

$$\Delta I_E = \Delta I_C + \Delta I_B$$

$$\Delta I_C = h_{fe} \ \Delta I_B$$

$$\Delta I_E = h_{fe} \ \Delta I_B + \Delta I_B$$

$$\Delta I_E = (h_{fe} + 1) \ \Delta I_B$$

$$\Delta I_E = h_{fc} \ \Delta I_B$$

h_{fc} is the same as ____________

base

29.3 Since h_{fc} is the same as h_{fe} + 1, the potential current gain is greatest for the common ____________ configuration.

$h_{fe} + 1$

29.4** Emitter follower small signal current gain parameter is given the symbol ___________. It has the same value as __________.

collector

29.5 END OF SET

h_{fc}
$h_{fe} + 1$

30 The common collector configuration offers a high __________ resistance and a low __________ resistance.

30.1 The output from the common collector (emitter follower) configuration is taken at the emitter. The emitter is a __________ (high, low) current point with respect to the other transistor terminals.

input
output

30.2 The input to an emitter follower is applied at the base, a __________ (high, low) current point with respect to the other transistor terminals.

high

30.3 Since the emitter follows the base, some of the input voltage change is, in effect, cancelled due to the emitter moving in a/the __________ (different, same) polarity direction as/than the base.

low

30.4 In comparing the common collector to the common emitter configuration, it will take a greater voltage change at the base to cause the same current change in the common collector configuration.

same

30.5 The requirement of a larger voltage change to cause the same current change indicates the input resistance is ______________ (greater, smaller) in the emitter follower than in the common emitter configuration.

no answer needed

30.6 The output point of the emitter follower has nearly the same voltage change as at the input, but a much larger current change. This indicates a much ______________ (higher, lower) resistance at the output than the input.

greater

30.7** The emitter follower offers a high __________ resistance and a low __________ resistance.

lower

30.8 END OF SET

input
output

31 The emitter follower configuration with its high input resistance and low output resistance finds use in applications requiring high output ____________ to drive capacitance.

31.1 The emitter follower input resistance is made large by the negative feedback (emitter following the base) from the emitter. The base is a high resistance, ___________ (high, low) current point.

current

31.2 The emitter has a low resistance and is a ___________ (high, low) current point. Taking the output at the emitter allows high output currents, with respect to other points in the emitter follower circuit.

low

31.3 The emitter follower finds much use as an impedance matching circuit that also offers __________________ (current, voltage) gain greater than unity.

high

31.4 Since the emitter follower offers a high output current, it is often used to drive circuits with high input capacitance. The emitter follower can provide current to charge ____________ that would load down the output of other configurations.

current

31.5 The emitter follower configuration offers a high input resistance and a low output resistance and is able to drive a larger ____________________ than most configurations for the same loading.

capacitance

31.6** The __________ ___________ configuration is noted for high input resistance and low output resistance and its ability to drive capacitance because it can supply a high output _________________.

capacitance

31.7 END OF SET

common collector (emitter follower)
current

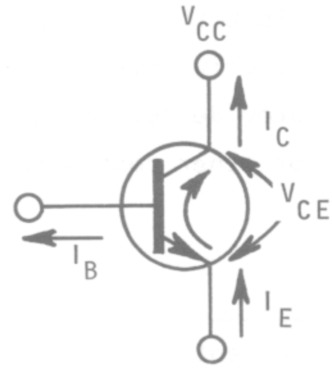
V_{CC} = COLLECTOR SUPPLY VOLTAGE

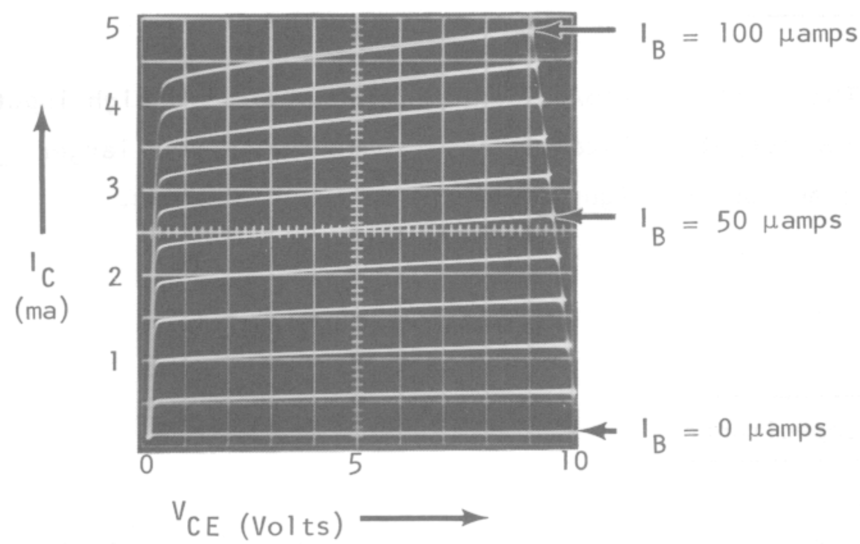
I_B = d-c BASE CURRENT

I_C = d-c COLLECTOR CURRENT

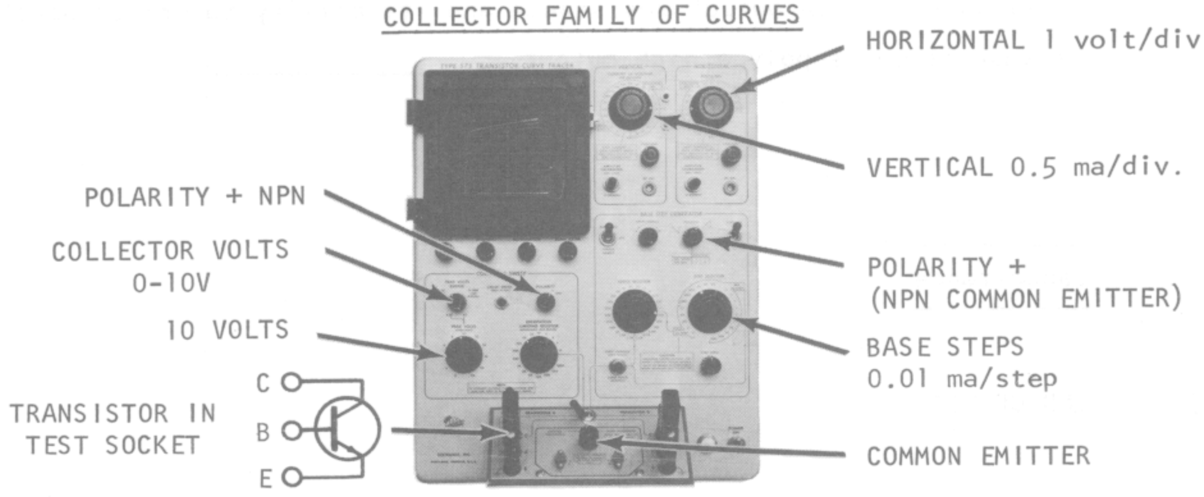
I_E = d-c EMITTER CURRENT

V_{CE} = d-c VOLTAGE, COLLECTOR TO EMITTER





COLLECTOR FAMILY OF CURVES



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
TOP PHOTO TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

FIGURE 32

32 A chart such as the one in figure 32 shows the transistor's characteristics over a range of currents and voltages. The "collector ____________ of curves" shown is for the common ________________ configuration. Each curve represents a value of __________________ current and allows a cross reference of the transistor's currents and voltages.

32.1 The horizontal scale in figure 32 is in units of collector to emitter voltage. ______________ current is plotted vertically.

family
emitter
base

32.2 Each individual curve on the chart in figure 32 is for a given value of base current. Another way of stating this is to say that _____________ current is the running parameter.

Collector

32.3 The chart in figure 32 is called a collector family of curves. The voltages and currents in the collector circuit are shown at several values of __________________ current resulting in a group or family of curves.

base

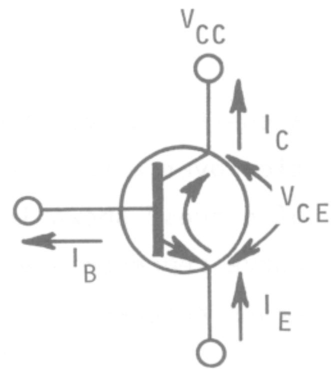
V_{CC} = COLLECTOR SUPPLY VOLTAGE

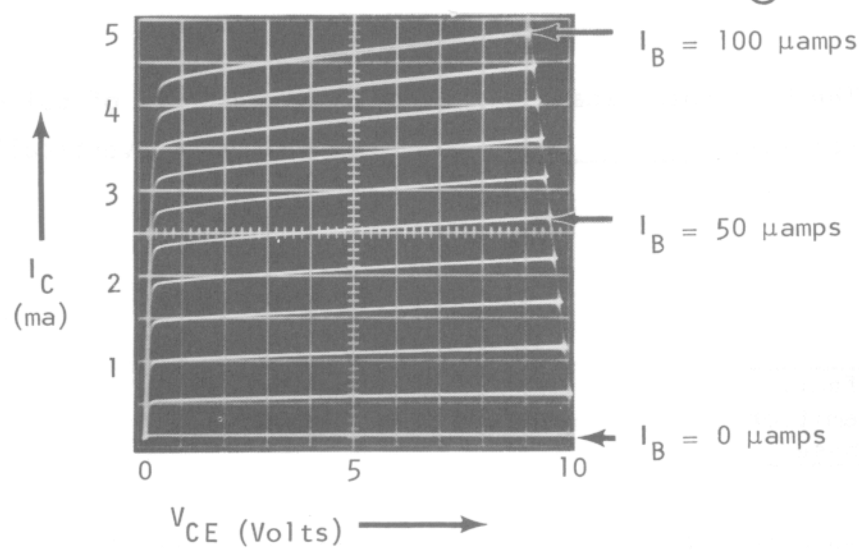
I_B = d-c BASE CURRENT

I_C = d-c COLLECTOR CURRENT

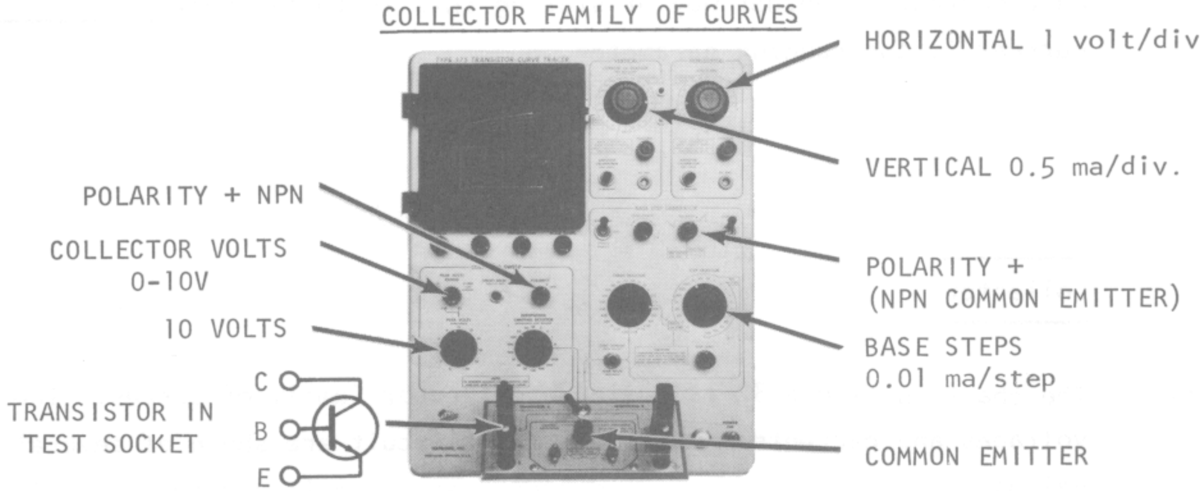
I_E = d-c EMITTER CURRENT

V_{CE} = d-c VOLTAGE, COLLECTOR TO EMITTER





COLLECTOR FAMILY OF CURVES



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
TOP PHOTO TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

FIGURE 32

32.4 A given point on a base current curve gives a cross reference of collector current and collector ______________.

base

32.5 The base current in the collector family of curves in figure 32 varies between zero and 100 µamps. The base current curve near the bottom of the chart indicates ____________ base current.

voltage

32.6 According to the chart in figure 32, for a given value of V_{CE}, an increase in base current results in a/an ____________________ (increase, decrease) in collector current.

zero

32.7 Each curve in the chart in figure 32 indicates a given value of base current. The slope of the base current curve indicates the effect of ____________ voltage on collector current.

increase

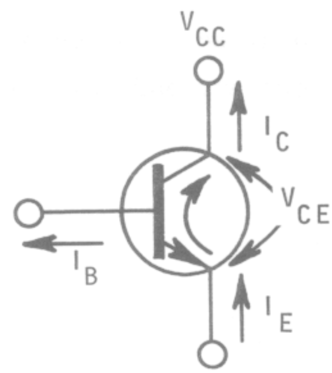
V_{CC} = COLLECTOR SUPPLY VOLTAGE

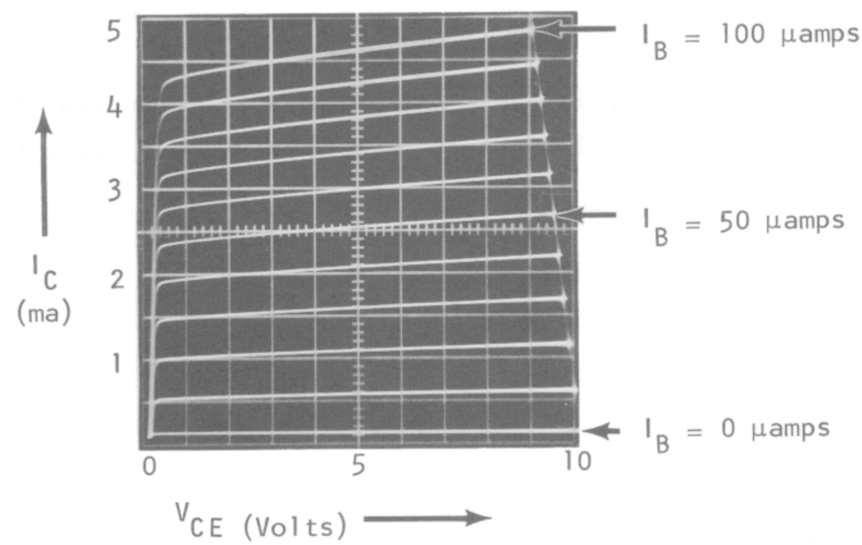
I_B = d-c BASE CURRENT

I_C = d-c COLLECTOR CURRENT

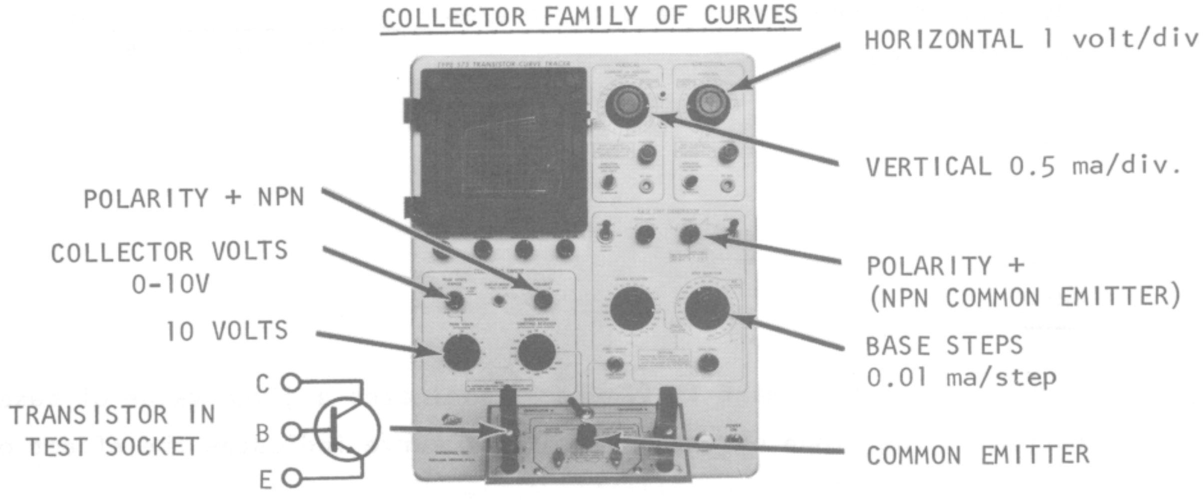
I_E = d-c EMITTER CURRENT

V_{CE} = d-c VOLTAGE, COLLECTOR TO EMITTER





COLLECTOR FAMILY OF CURVES



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
TOP PHOTO TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

FIGURE 32

32.8 An increase in collector voltage causes a/an __________ in collector current for a given value of base current as shown by the curves in figure 32.

collector

32.9 Each curve in the collector family of curves in figure 32 represents a value of base current. When base current (I_B) is 60 μamps and collector voltage (V_{CE}) is 5 volts, collector current (I_C) is ______________ma.

increase

32.10 Any point along a base current curve gives a cross reference of collector current and voltage. The 30 μamp base current curve crosses the 1.6ma collector current point at _________ volts of collector voltage.

3

32.11 From the collector family of curves in figure 32 , with a collector voltage of 7 volts and a collector current of 3.5ma, there is _________ μamps of base current.

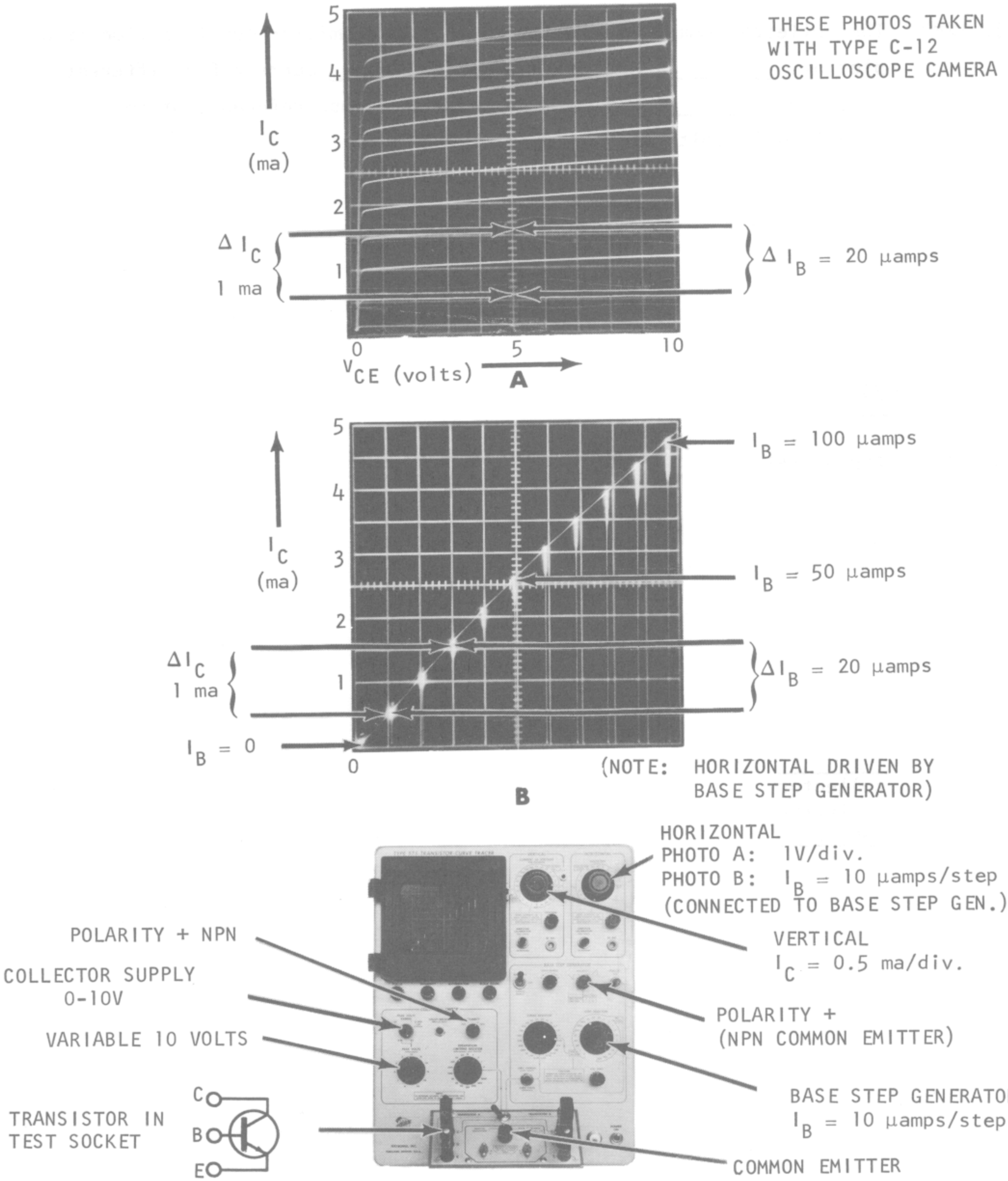
5

32.12** The collector family of curves for a common emitter configuration is a plot of __________ voltage versus __________ current for different values of __________ current, allowing a cross reference of the transistor's voltages and currents.

70

32.13 END OF SET

collector
collector
base



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER

FIGURE 33

33 h_{fe} may be calculated from data gained from the collector family of curves of the transistor. It may also be calculated from data gained by plotting collector current versus __________ current directly on the 575 Transistor-Curve Tracer.

33.1 h_{fe} can be calculated from data gained by varying base current while holding collector voltage constant and noting the change in collector current.

base

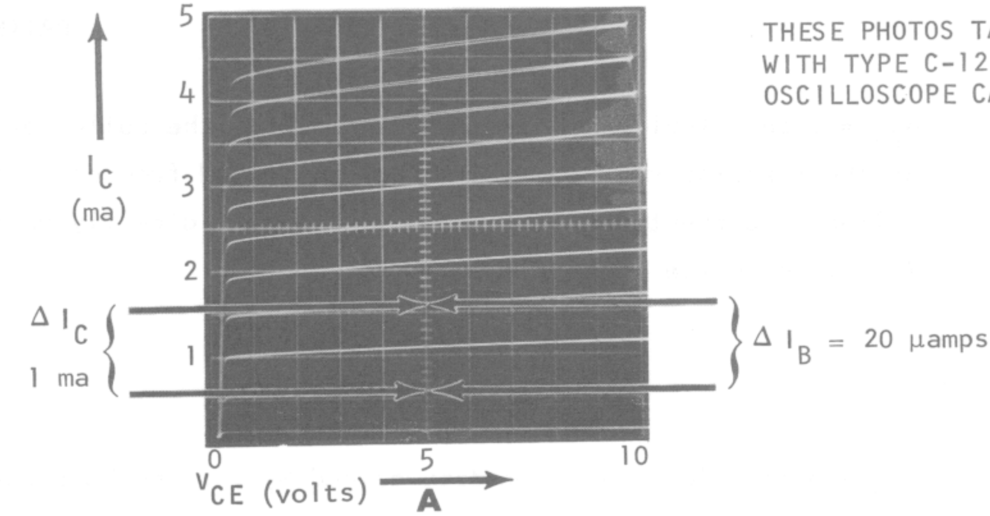
33.2 To hold collector voltage constant on a collector family of curves, the measurements are made along only one vertical line indicating collector voltage.

no answer needed

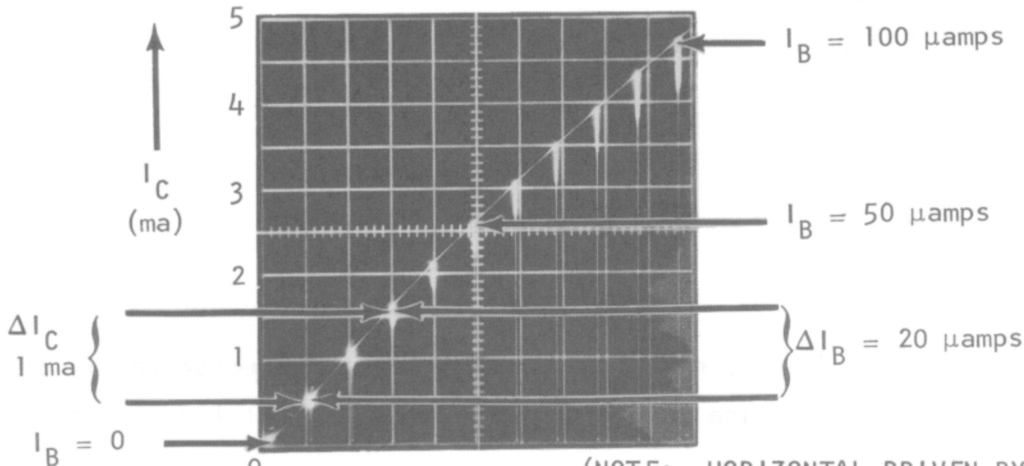
33.3 The measurements made on the collector family of curves in figure 33 are made along the vertical line indicating _________ volts of V_{CE}.

no answer needed

THESE PHOTOS TAKEN
WITH TYPE C-12
OSCILLOSCOPE CAMERA

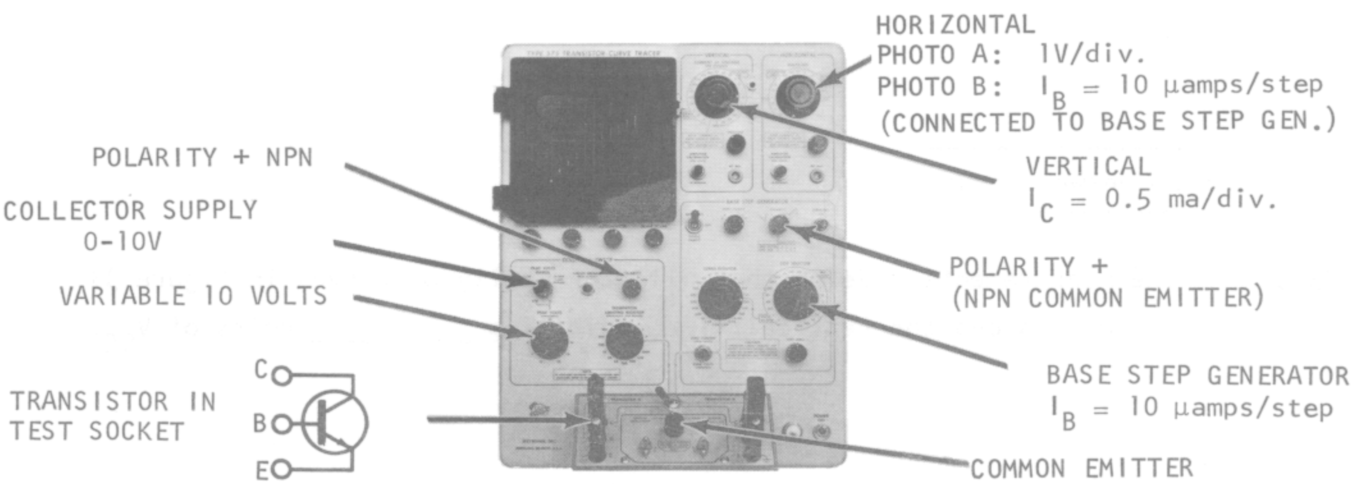


A



(NOTE: HORIZONTAL DRIVEN BY
BASE STEP GENERATOR)

B



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
FIGURE 33

33.4 The assumed change in base current in figure 33 is ________ μamps. This is accompanied by a change in collector current (along the 5 volt V_{CE} line) of ________ ma.

5

33.5

$$h_{fe} = \left.\frac{\Delta I_C}{\Delta I_B}\right| \Delta V_{CE} = 0$$

At the point selected for measurement on the collector family of curves in figure 33, h_{fe} = ______________.

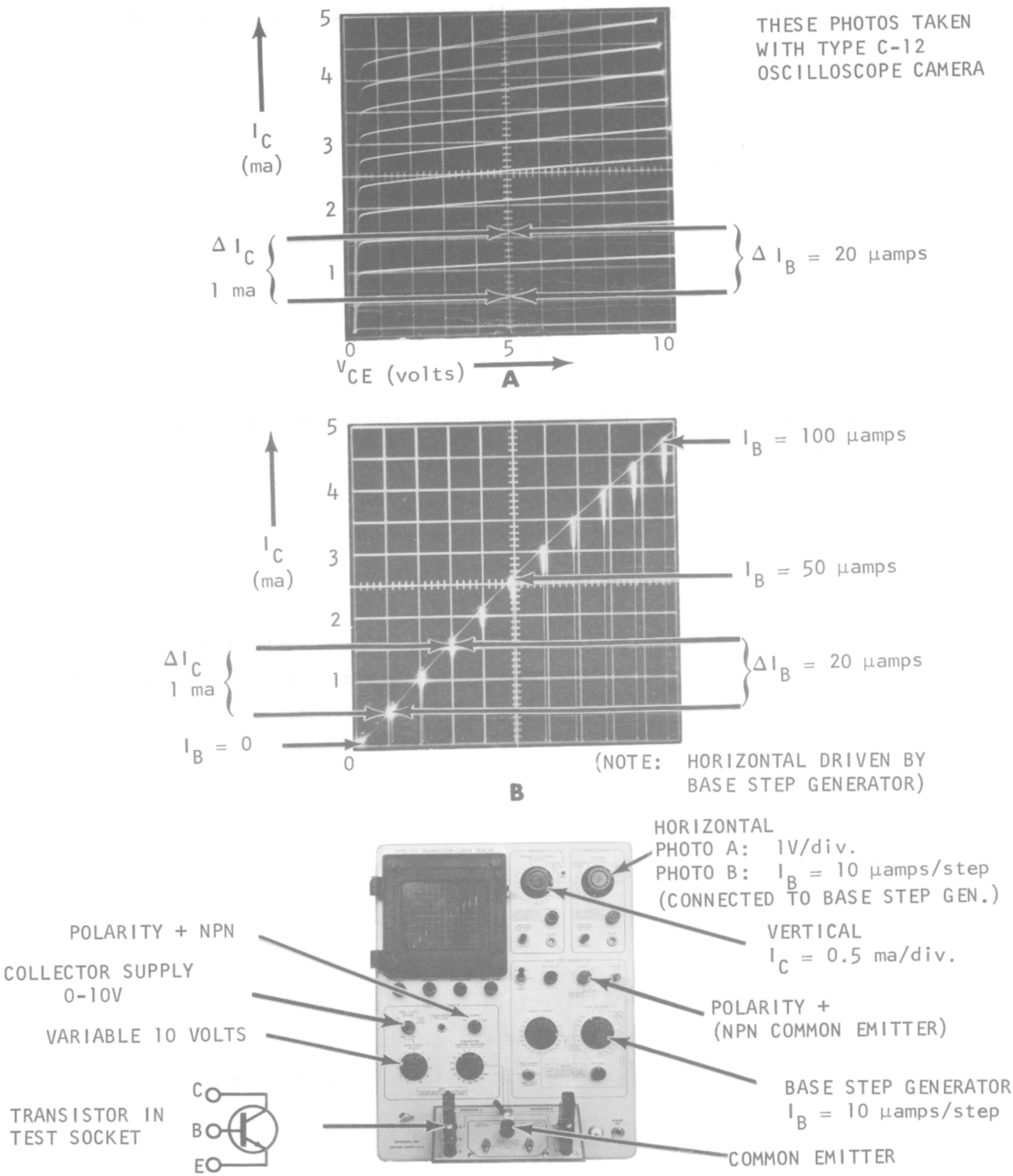
20
1

33.6 In the second display in figure 33, base current is plotted directly against collector current and the slope of the line indicates h_{fe}. Each step represents ___________ μamps of base current.

$$\frac{\Delta I_C}{\Delta I_B} = \frac{\Delta 1 \text{ ma}}{\Delta 20\ \mu\text{a}} = 50$$

33.7 Photo B in figure 33 is a direct plot of base current versus collector current. The horizontal scale is not given a dimension because each step in the display corresponds to a given value of base current.

10



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER

FIGURE 33

33.8 Photo B in figure 33 provides a plot collector current versus __________ __________ instead of collector voltage as shown in photo A.

no answer needed

33.9 The measurement used to determine h_{fe} from the collector family of curves in figure 33 was made between a base current of 10 and 30 μamps. To gain the same results from photo B in figure 33, the measurements should be made between __________ and __________ μamps of base current.

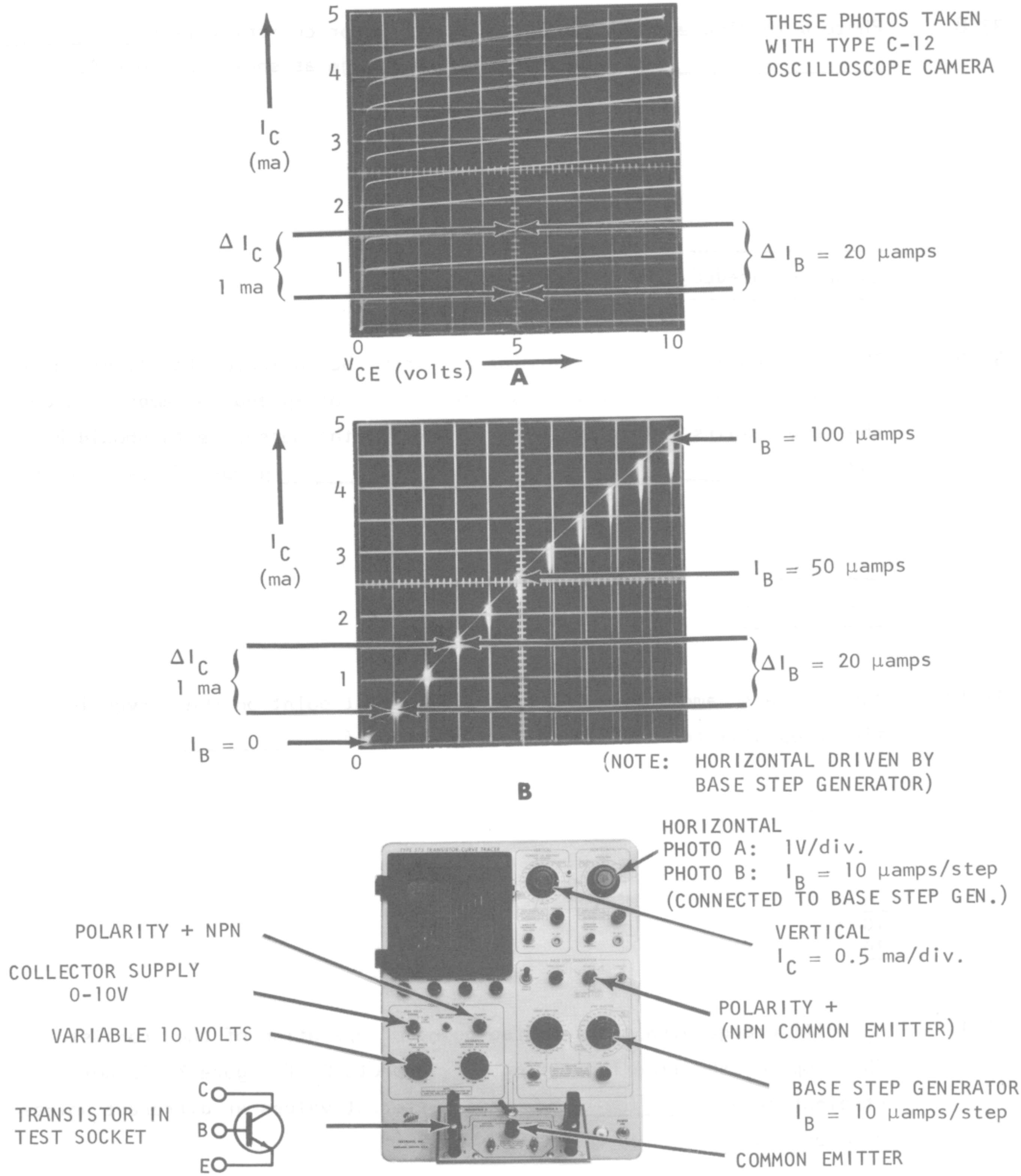
base current

33.10 Making these same measurements at a different point on the curves in figure 33 will result in a different value of __________.

10
30

33.11 h_{fe} will change with the selected point of operation of the transistor. The slope of the line indicating h_{fe} in photo B of figure 33 is not straight because __________ has different values at different points of operation.

h_{fe}



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER

FIGURE 33

33.12 Make a few measurements of h_{fe} at different points on the curves in figure 33.

---

h_{fe}

33.13 To have the transistor whose curves are shown in figure 33 operate with a collector current of 2.5 ma and a collector voltage of 4 volts, there must be _________ μa of base current.

---

no answer needed

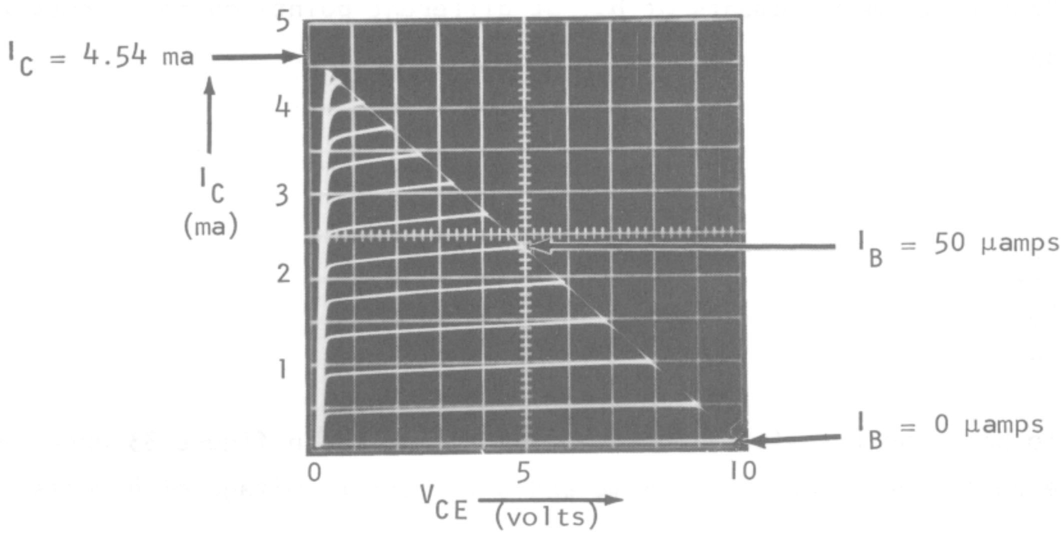
33.14** h_{fe} may be found from the collector ______________ of curves. When base current is plotted directly against collector current on the 575, the slope of the line indicates ________________.

50

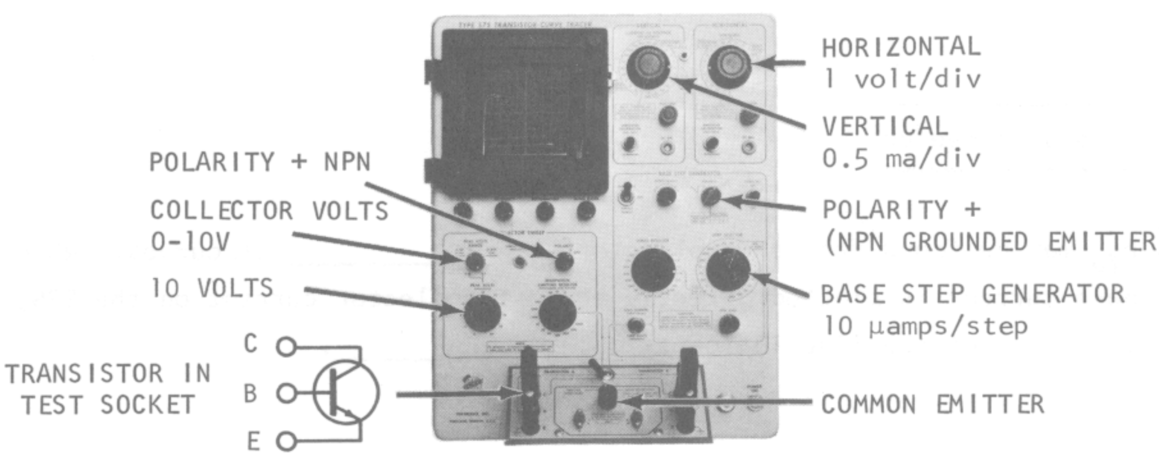
33.15 END OF SET

---

family
h_{fe}



COLLECTOR FAMILY OF CURVES
WITH 2.2K LOAD LINE



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
TOP PHOTO TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

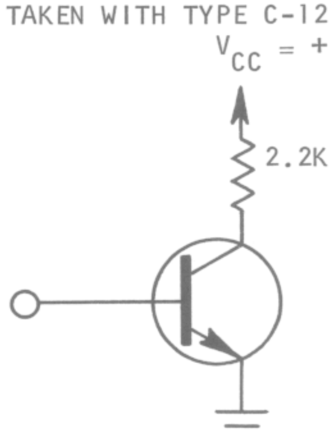


FIGURE 34

34 To gain information on the operation of the transistor in a circuit, a load line may be drawn on the collector family of curves. The slope of the d-c load line is determined by the ____________________ in series with the transistor.

34.1 With supply voltages applied to the transistor and the transistor non-conducting, the full collector supply voltage appears across the transistor. One limit of the transistor's operation is the collector _________ ___________.

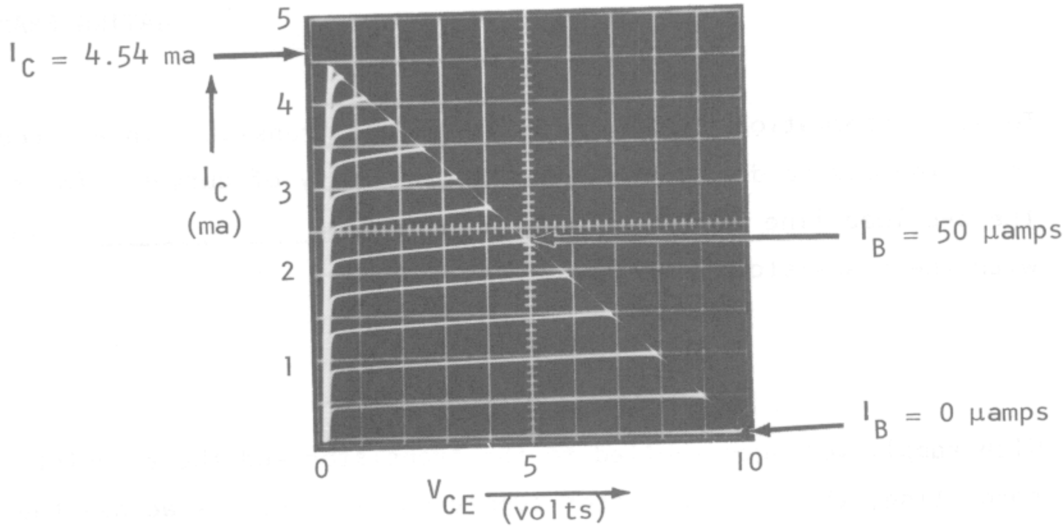
resistance

34.2 Considering that the transistor is short circuited, the amount of current flowing is governed by the value of collector supply voltage and the total series resistance. One limit of the transistor's operation may be found by dividing the collector supply voltage by the total ____________ ____________.

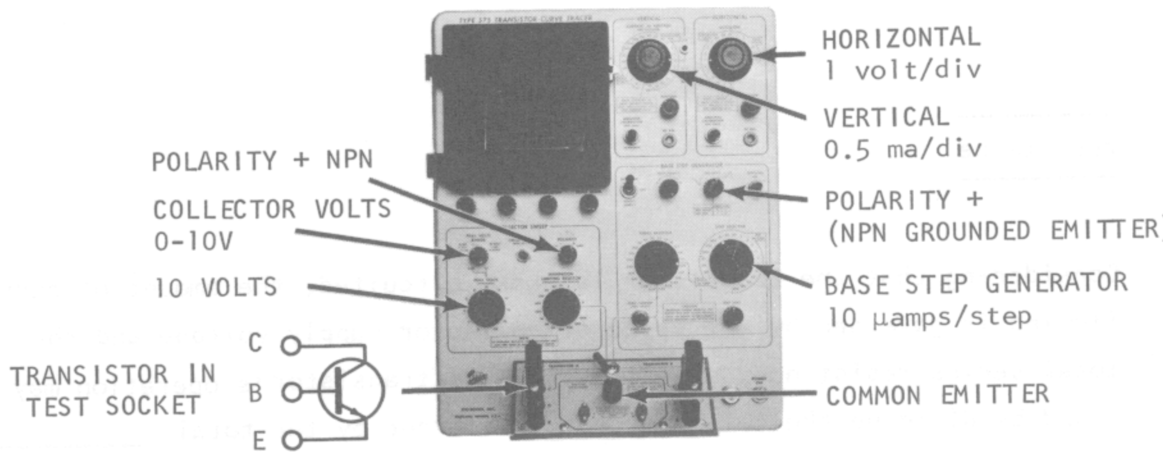
supply voltage

34.3 Figure 34 shows a transistor with a resistance in series to the collector supply. The slope of the line on the collector family of curves is determined by the ___________.

series resistance



COLLECTOR FAMILY OF CURVES
WITH 2.2K LOAD LINE



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
TOP PHOTO TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

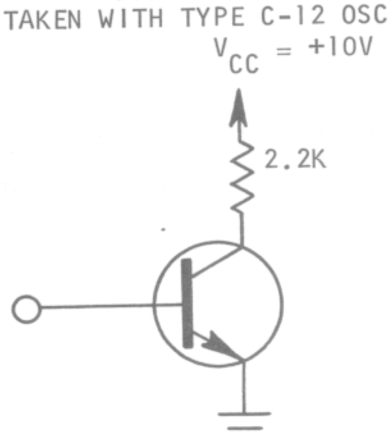


FIGURE 34

34.4 The load line in figure 34 intersects the base line at 10 volts on the collector family of curves. If the transistor is non-conducting, there will be __________ volts, collector to emitter.

resistor

34.5 Considering that the transistor is a short circuit, current is limited by the series resistance in the circuit; in the case in figure 34, __________K ohms.

10

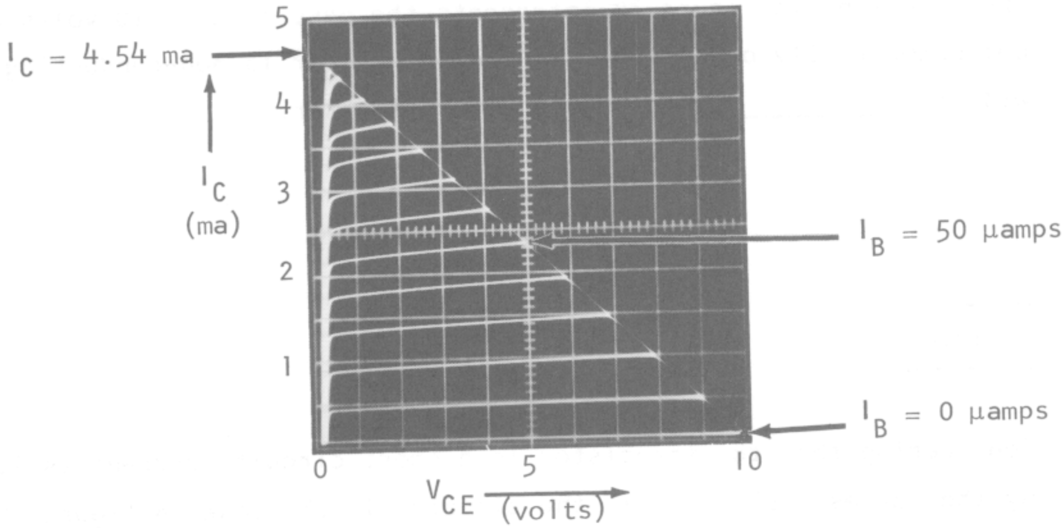
34.6 With the transistor shorted, the full supply voltage is across the series resistance. With the transistor in figure 34 shorted, there are _____________ volts across 2.2K ohms.

2.2

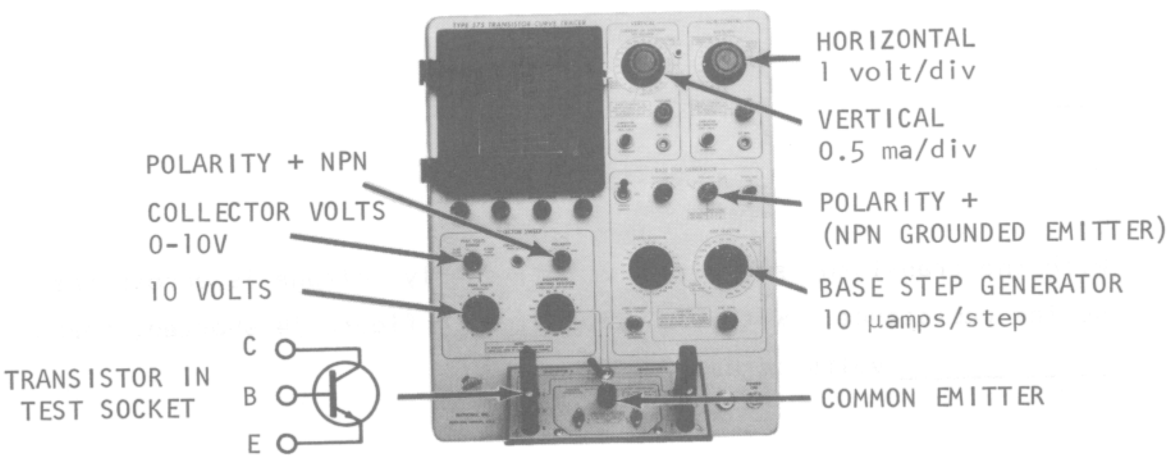
34.7 With the transistor shorted, the current flow is calculated by dividing the voltage across the series resistance by the resistance. With the transistor in figure 34 shorted, the current is __________m amps.

$$I = \frac{V_R}{R} = \frac{10V}{2.2K} = \underline{\ ?\ }$$

10



COLLECTOR FAMILY OF CURVES WITH 2.2K LOAD LINE



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
TOP PHOTO TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

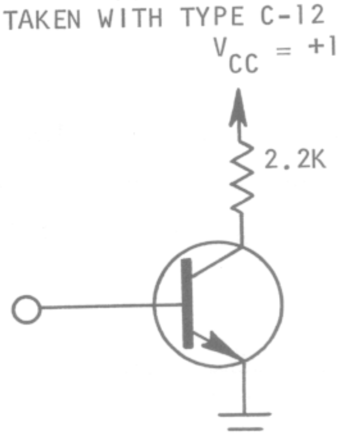


FIGURE 34

34.8 The load line is constructed between the two extremes calculated in the previous frames and shown in figure 34. The extremes are ________ m amps and __________ volts.

4.54

34.9 Construct a load line on the collector family of curves in figure 34 for the same circuit if the collector supply were 5 volts instead of 10.

4.54
10

34.10 The load line constructed in frame 34.9 __________ (is, is not) parallel to the load line for a supply voltage of 10 volts.

THE LOAD LINE SHOULD EXTEND BETWEEN
2.27ma on the vertical scale and
5 volts on the horizontal scale.

34.11 The slope of the load line does not change when a different supply voltage is used, since the slope is determined by the value of __________.

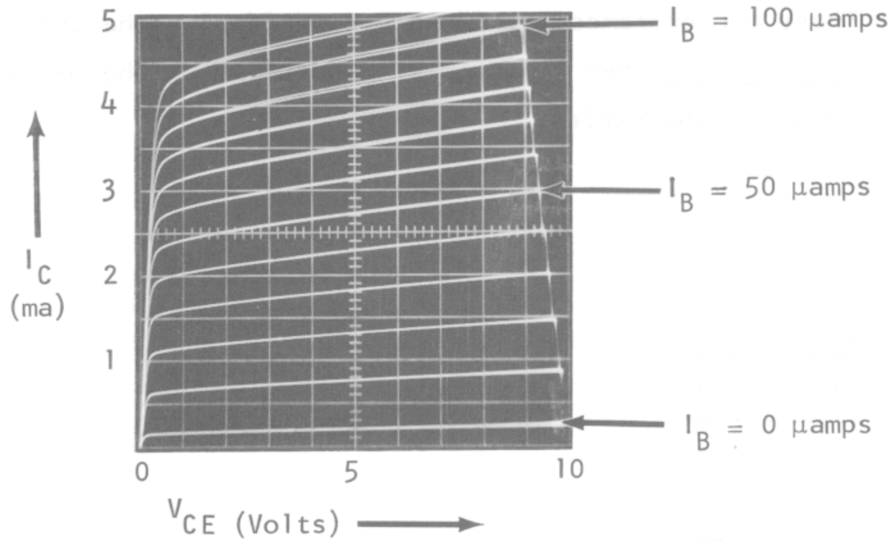
is

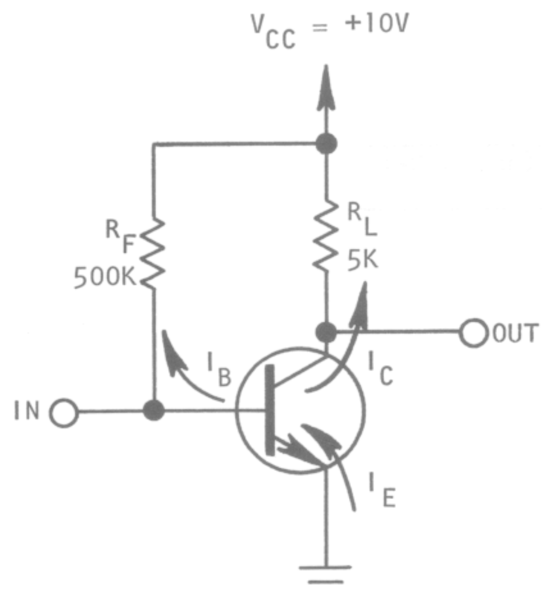
34.12** The d-c load line is constructed between the two extremes of d-c operation. These two extremes are found by considering the transistor is first ___________ then __________. The slope of the d-c load line is determined by the series ____________________.

resistance

34.13 END OF SET

open, shorted (any order)
resistance





TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
TOP PHOTO TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

R_L = COLLECTOR LOAD RESISTOR

R_F = BASE BIASING RESISTOR

V_{CC} = COLLECTOR SUPPLY VOLTAGE

FIGURE 35

35 Construct a d-c load line for the circuit in figure 35. R_F sets the operating point base current at a value of ________ μamps.

35.1 Consider that the transistor in figure 35 is open circuited. The voltage across the transistor will be the collector supply voltage or ________ volts.

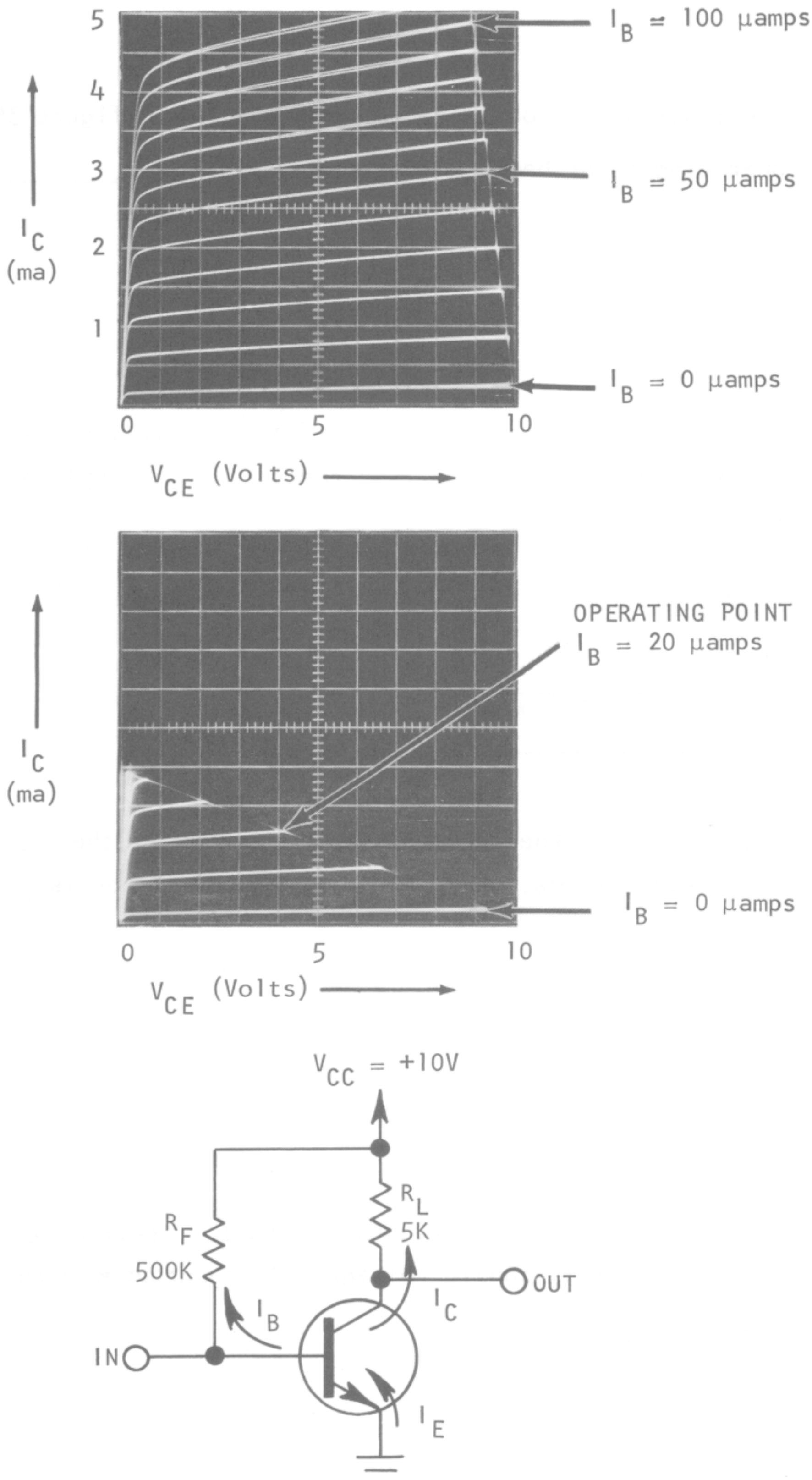
load line on following page
20

35.2 One extreme of the transistor's operation is the supply voltage. To find the other extreme, consider that the transistor is ________ circuited.

10

35.3 With the transistor in figure 35 short circuited, the current is limited by R_L. The full supply voltage will be dropped across R_L and the current will be ________ ma.

short



5
4
3
2
1
I_C (ma)
0
5
10
V_{CE} (Volts)
$I_B \simeq 100$ μamps
$I_B \simeq 50$ μamps
$I_B \simeq 0$ μamps
I_C (ma)
OPERATING POINT
$I_B \simeq 20$ μamps
$I_B = 0$ μamps
0
5
10
V_{CE} (Volts)
$V_{CC} = +10V$
R_F
500K
R_L
5K
I_B
I_C
I_E
IN
OUT

FIGURE 35-A

35.4 The two extremes for the transistor in figure 35A are: (1) 10 volts V_{CE} with zero collector current and, (2) __________ma I_C with zero collector volts. A line connecting these points is the d-c load line.

$\frac{10V}{5K} = 2$ ma

35.5 Since the voltage, base to emitter, is a very small value (a few tenths of a volt), consider that the full supply voltage is across R_F. The current through R_F is then ____________.

$$\frac{V_{RF}}{R_F} = \frac{10V}{500K} = \underline{\quad ? \quad}$$

2

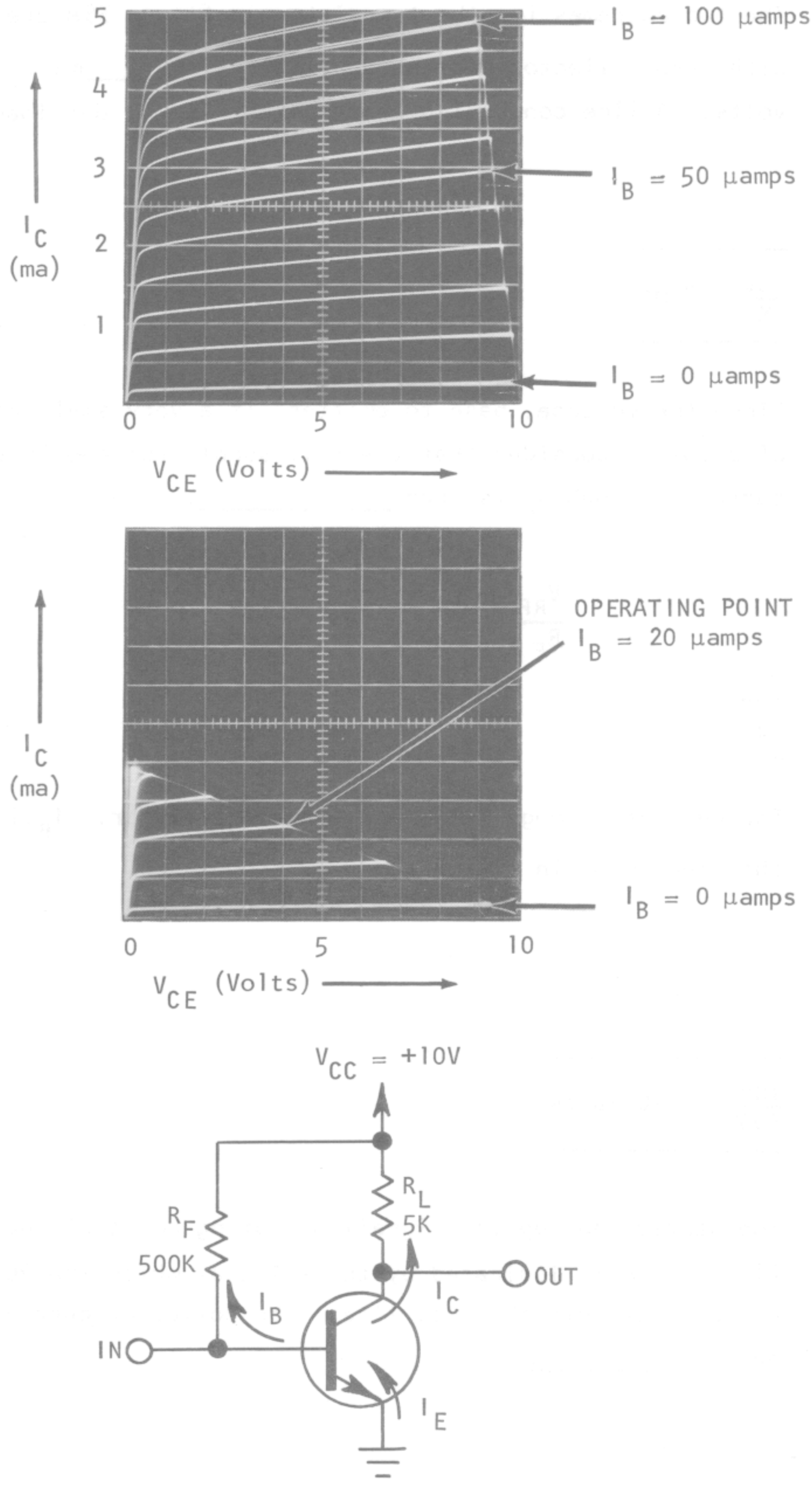
35.6 The current through R_F is I_B of the transistor. I_B is ____________ for the transistor in figure 35-A.

$\frac{10V}{500K} = 20$ μamps

35.7 The static (no applied signal) operating point of the transistor in figure 35-A is indicated by the point at which the 20 μamp base current curve intersects the load line. The collector current at this point is about __________.

---

20 μamps



5
4
3
2
1
I_C
(ma)
0
5
10
V_CE (Volts)
I_B ≃ 100 μamps
I_B = 50 μamps
I_B = 0 μamps
I_C
(ma)
OPERATING POINT
I_B = 20 μamps
I_B = 0 μamps
0
5
10
V_CE (Volts)
V_CC = +10V
R_F
500K
R_L
5K
I_B
I_C
I_E
IN
OUT

FIGURE 35-A

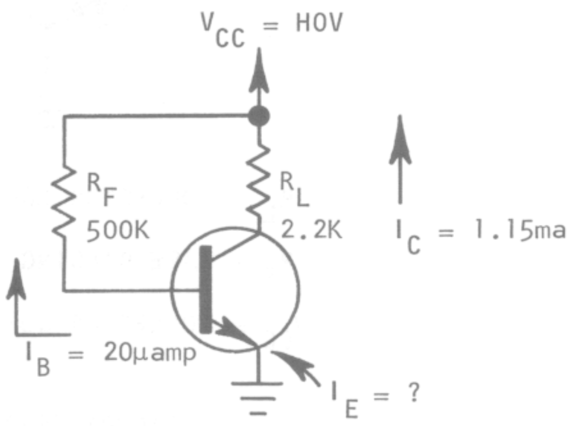
35.8 Figure 35-A shows the load line and operating point for the circuit in figure 35. The collector voltage at the operating point is about ______ volts.

1.15ma

35.9 The static or no input signal conditions of the transistor in figure 35-A are: I_B = ____________, I_C = ______________, and V_{CE} = ______________.

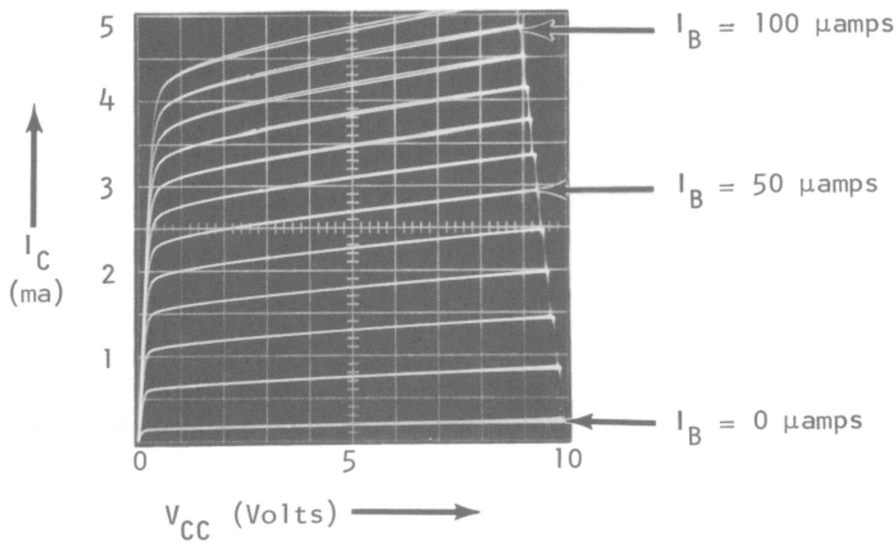
4.2V

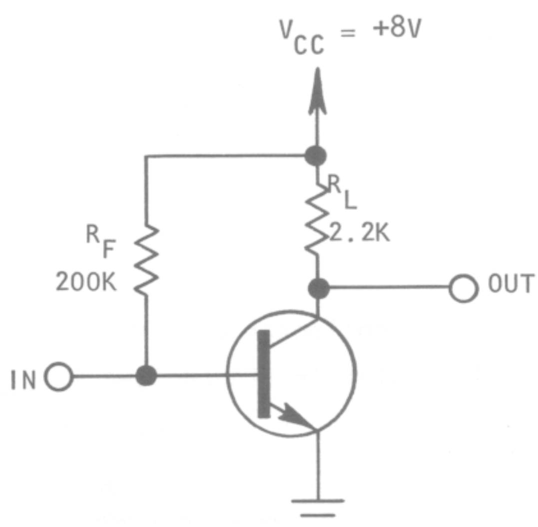
35.10 Since I_E is the sum of collector and base current, the emitter current at the static operating point in figure 35-A is _________ma.



20 µamps
1.15 ma
4.2 volts

Turn to figure 35C for answer





R_L = COLLECTOR LOAD RESISTOR

R_F = BASE BIASING RESISTOR

V_{CC} = COLLECTOR SUPPLY VOLTAGE

FIGURE 35-B

36 A transistor is termed in __________ when the collector junction becomes forward biased. The collector to emitter voltage at which this occurs is given the symbol ________. The current gain at saturation is given the symbol __________.

36.1 In most small signal amplifier applications, the transistor remains in the most linear portion of its operating characteristics. This falls somewhere between the non-conducting or cut-off state, and the condition where the collector junction becomes forward biased which is termed saturation.

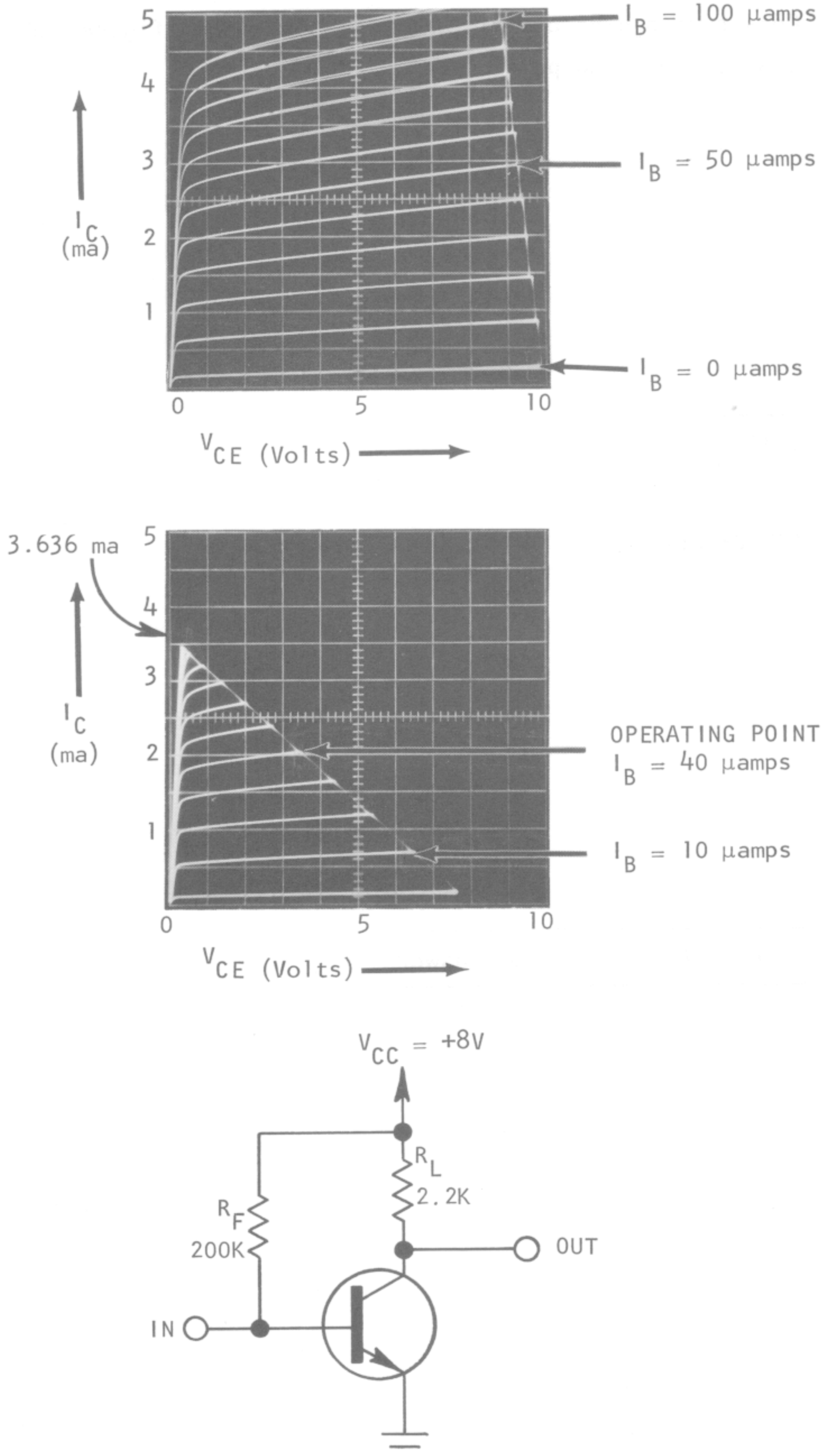
saturation
V_{CE} (sat)
h_{FE} (sat)

36.2 In the cut-off state, the only current flowing is the result of hole-electron pairs and perhaps some surface leakage current. The transistor offers a very high resistance (near open circuit) and the voltage across the transistor approaches the collector supply voltage.

no answer needed

36.3 As the base current is increased, collector current increases and added voltage is dropped across the series resistance in the circuit. As base current increases, the voltage across the transistor __________________ .
(increases, decreases)

no answer needed



5
4
3
2
1
I_C (ma)
0
5
10
V_{CE} (Volts)
I_B = 100 µamps
I_B = 50 µamps
I_B = 0 µamps
3.636 ma
OPERATING POINT
I_B = 40 µamps
I_B = 10 µamps
V_{CC} = +8V
R_L
2.2K
R_F
200K
OUT
IN

FIGURE 35-C

36.4 Changes in collector voltage have only a small effect on collector current as long as the collector junction is reverse biased. When the collector junction becomes forward biased, the transistor is said to be in ________.

decreases

36.5 When the collector junction becomes forward biased, collector current is reduced as shown in figure 36. The sharp change occurs at approximately ________ volts, V_{CE}, when I_B = 100 μamps.

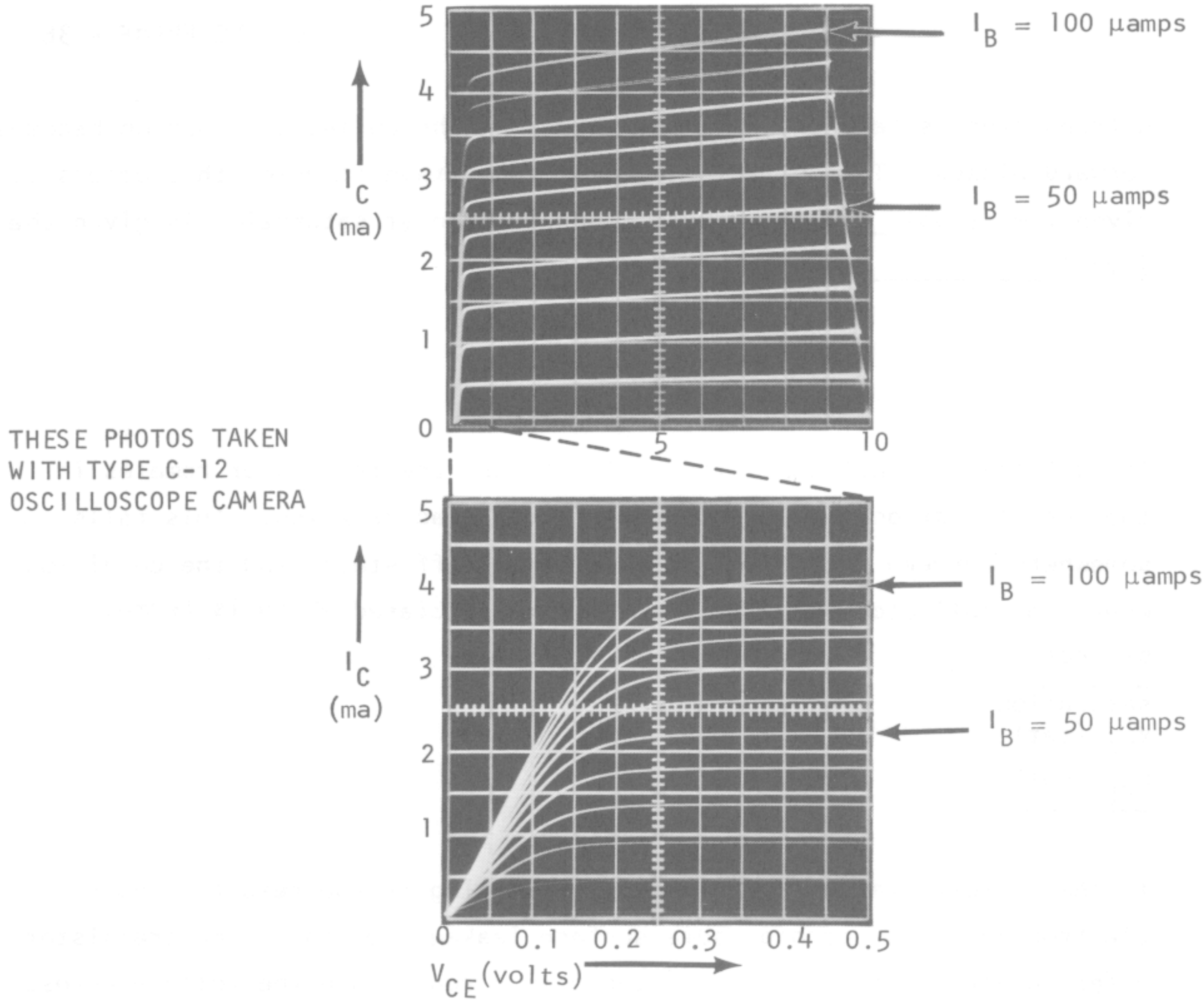
saturation

36.6 The transistor in the common emitter configuration starts to enter saturation when the voltage collector to emitter (V_{CE}) is equal to the voltage, base to emitter (V_{BE}). On the 100 μamp base current curve in figure 36, $V_{BE} = V_{CE} =$ ________ volts when the transistor enters saturation.

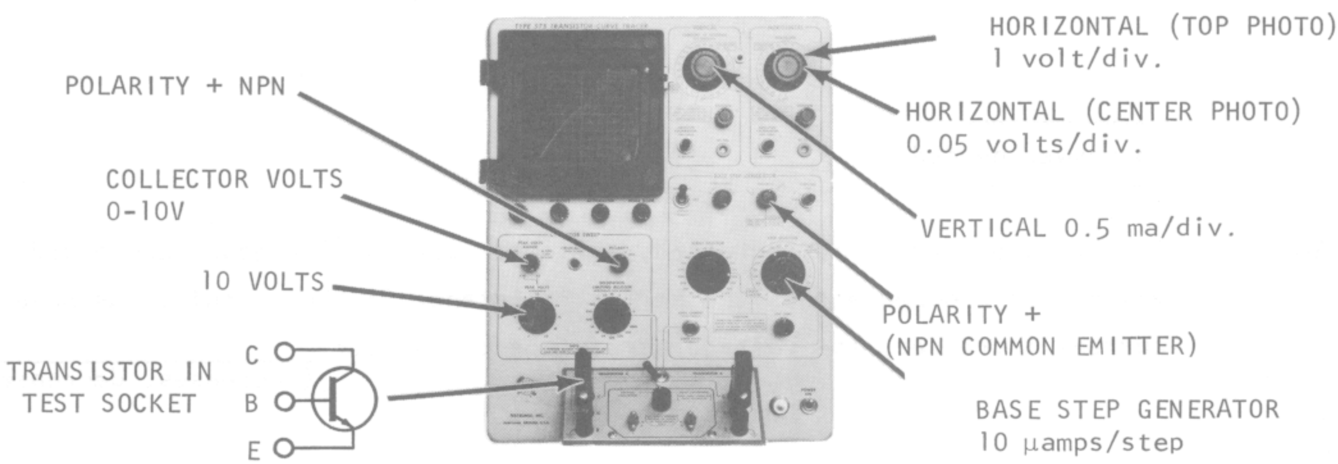
0.3

36.7 The collector to emitter voltage at the point the transistor enters saturation is given the symbol V_{CE} (sat). ________ is given at a specified value of I_B and I_C in manufacturers specifications.

0.3



COLLECTOR FAMILY OF CURVES
EXPANDED AREA AROUND SATURATION



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER

Figure 36

36.8 In figure 36, V_{CE} (sat) ≈ 0.3 volts at I_B = 100 μamps and I_C ≈ 4 ma. When I_B = 90 μamps and I_C = 3.5ma, V_{CE} (sat) ≈ ____________.

V_{CE} (sat)

36.9 h_{FE} (sat) is the current gain of the transistor at saturation.

h_{FE} (sat) = $\frac{I_C \text{ (sat)}}{I_B \text{ (sat)}}$. On the 100 μamp base current curve in figure 36, h_{FE} (sat) = __________.

0.25V

36.10** The current gain at saturation is given the symbol h_{FE} (sat). When the collector junction is reverse biased, the transistor __________ (is, is not) in saturation and V_{CE} is __________ (less, greater) than V_{CE}(sat).

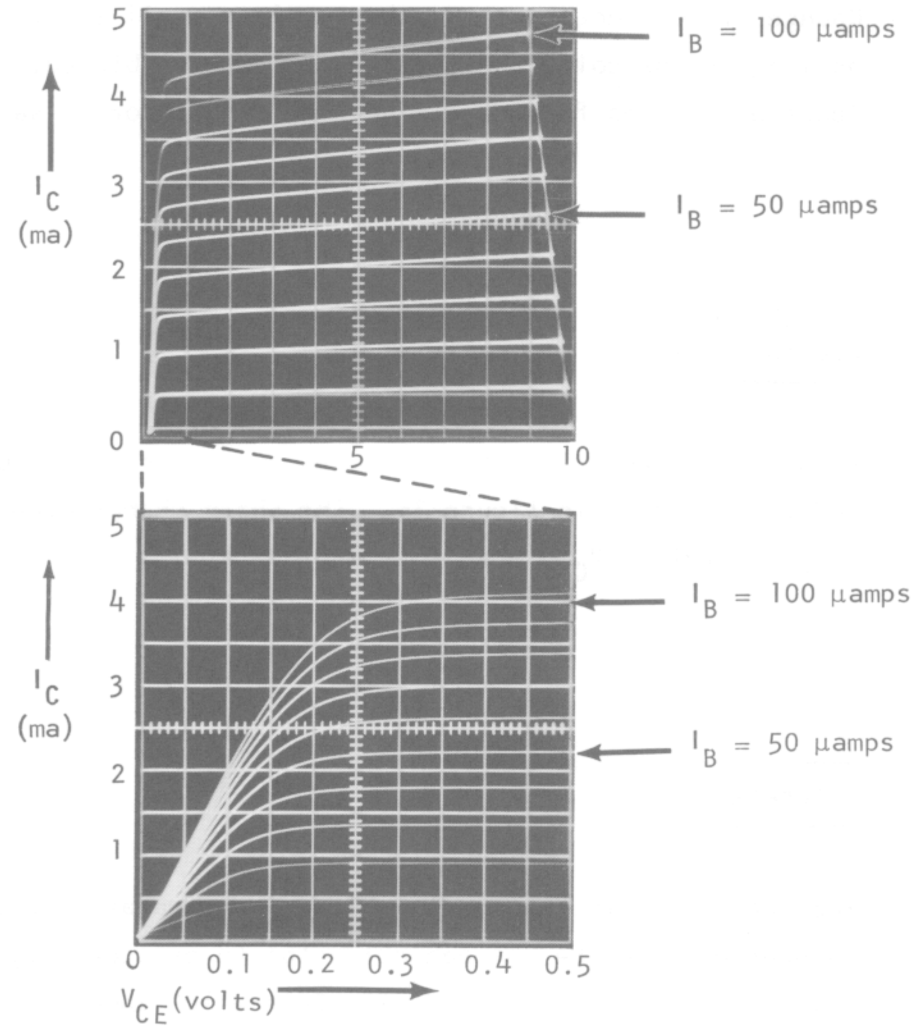
40

36.11 END OF SET

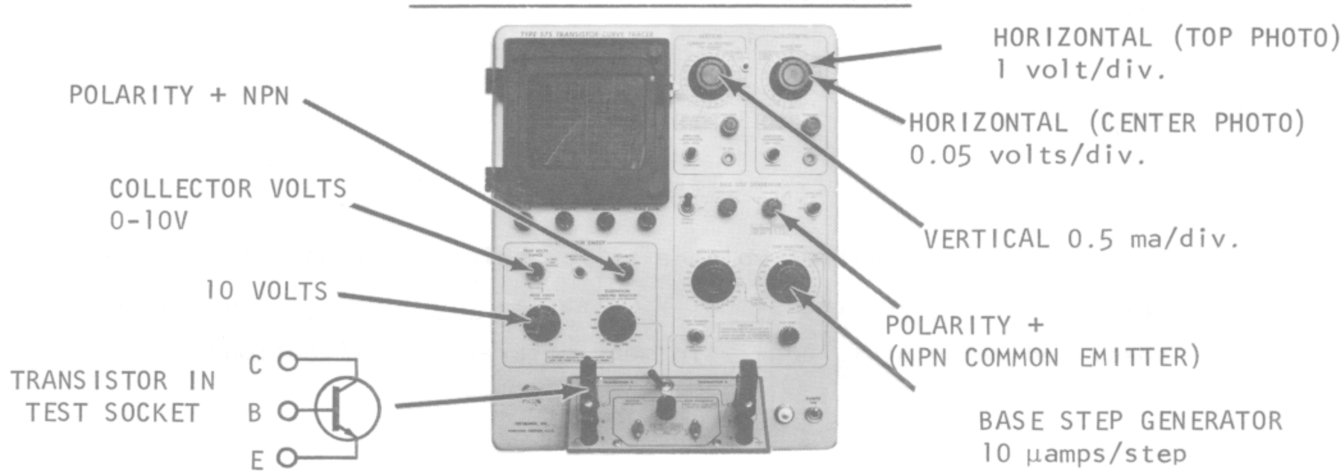
---

is not
greater

THESE PHOTOS TAKEN
WITH TYPE C-12
OSCILLOSCOPE CAMERA



COLLECTOR FAMILY OF CURVES
<u>EXPANDED AREA AROUND SATURATION</u>



<u>TEST SETUP</u>

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER

<u>Figure 36</u>

37 A transistor in saturation has both the emitter and collector junctions __________ biased. The injection of minority carriers into the base from the collector when the transistor enters saturation increases the __________ __________ in the base. This must be removed in order to turn __________ the transistor.

37.1 Carriers injected into the base recombine or diffuse to the collector. Once injected and until they recombine in the base or move into the collector circuit, they are existing as __________ carriers in the base.

forward
stored charge
off

37.2 Carriers injected into the base from the emitter represent a charge in the base during their diffusion to the collector.

minority

37.3 To turn on a transistor, the charge of minority carriers must be established in the base. To turn off a conducting transistor, this stored __________ must be removed.

no answer needed

37.4 A period of time is required to turn on a non-conducting transistor to establish the ________________ of minority carriers in the ___________ before collector current can reach its final value.

charge

37.5 Once the transistor is in full conduction, removal of the stored charge of minority carriers in the base is required to turn it off.

charge
base

37.6 It takes a period of time to remove the stored charge when turning off a conducting transistor. The greater the magnitude of stored charge, the more __________________ is required to remove it.

no answer needed

37.7 When the transistor is driven into saturation, the collector injects carriers into the base as a result of becoming forward biased. The number of minority carriers in the base is increased and the collector current is decreased.

time

37.8 Until the carriers in the base recombine or move into the collector, they are existing as a stored charge in the base. The extra injected carriers forced into the base in saturation represent an increase in the ______________ ______________ in the base.

no answer needed

37.9 A transistor driven into saturation has a larger stored charge in its base than when in an un-saturated condition. The deeper the transistor is driven into ______________________, the greater the stored charge.

stored charge

37.10 Since the stored charge represents a supply of minority carriers, the stored charge must be removed before the transistor can be turned _______________.

saturation

37.11** The collector becoming forward biased as the transistor enters saturation results in an increase in the _______________ _______________ in the base of the transistor which must be removed to turn the transistor _________________.

off

37.12 END OF SET

stored charge
off

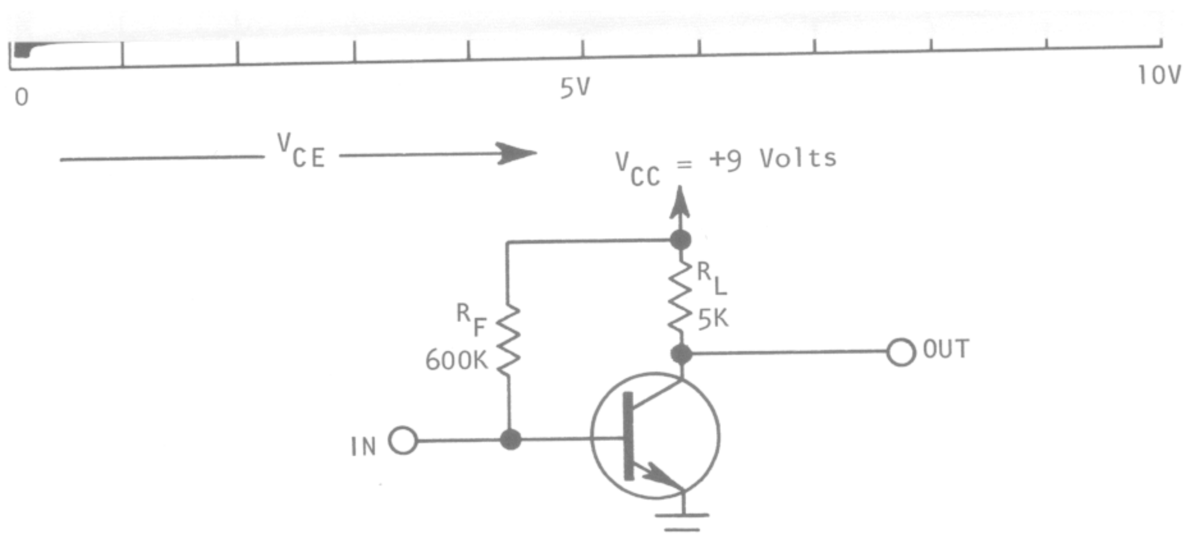


FIGURE 38

38 Construct a load line; determine the operating point base current, collector voltage and collector current for the circuit in figure 38. With an applied signal current of 10 μamps peak to peak, what signal current is flowing in the output circuit and what is circuit current gain?

38.1 One extreme of the transistor's operating range is the supply voltage. The load line will intersect the zero collector current line at __________ volts of collector voltage in figure 38.

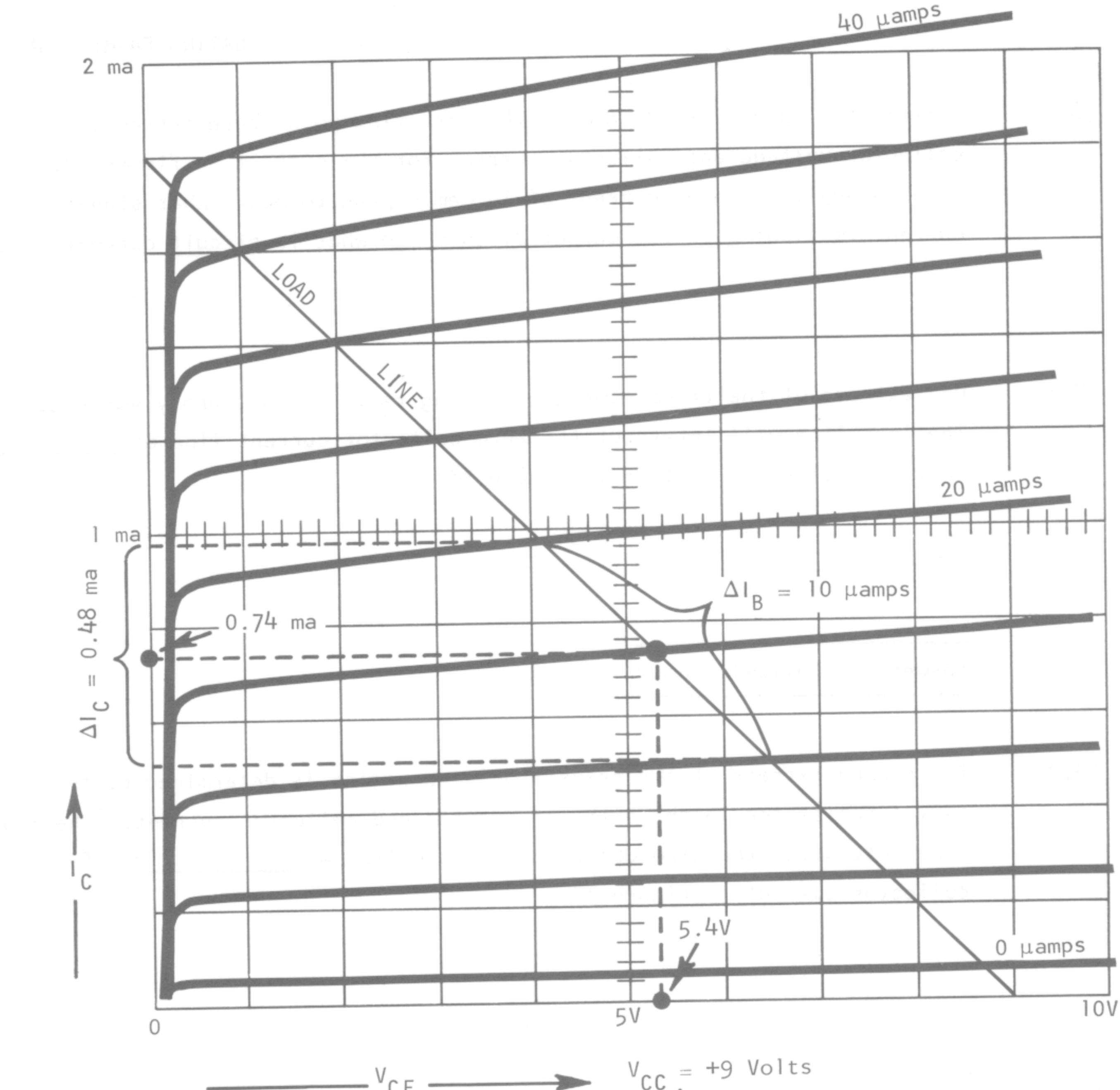
answers on following page

38.2 The second extreme of the transistor's operation is determined by the series resistance in the paths of emitter and collector current. The load line intersects the zero collector voltage line at __________ma of collector current in figure 38.

9

38.3 Operating or quiescent point base current is determined by the base biasing resistor, R_F. The operating point base current in figure 38 is ________ μamps.

1.8



A_i = CURRENT GAIN

$A_i = \frac{\Delta I_C}{\Delta I_B}$ (ALONG THE LOAD LINE)

$A_i = \frac{0.48 \text{ ma}}{10 \text{ µamps}}$

$A_i = 48$

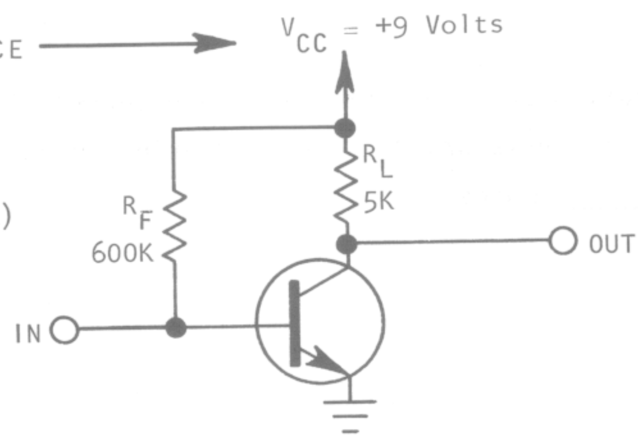


FIGURE 38-A

38.4 The operating point base current curve intersects the load line at the operating point. In figure 38-A, operating point collector current is ________ and collector voltage is ________.

$\frac{9\ \text{Volts}}{600\text{K}} = 15\ \mu\text{amps}$

38.5 h_{fe} gives the current gain of the transistor, but disregards the circuit. Making a current gain measurement along the load line gives the current gain of the ________.

0.74ma
5.4 Volts

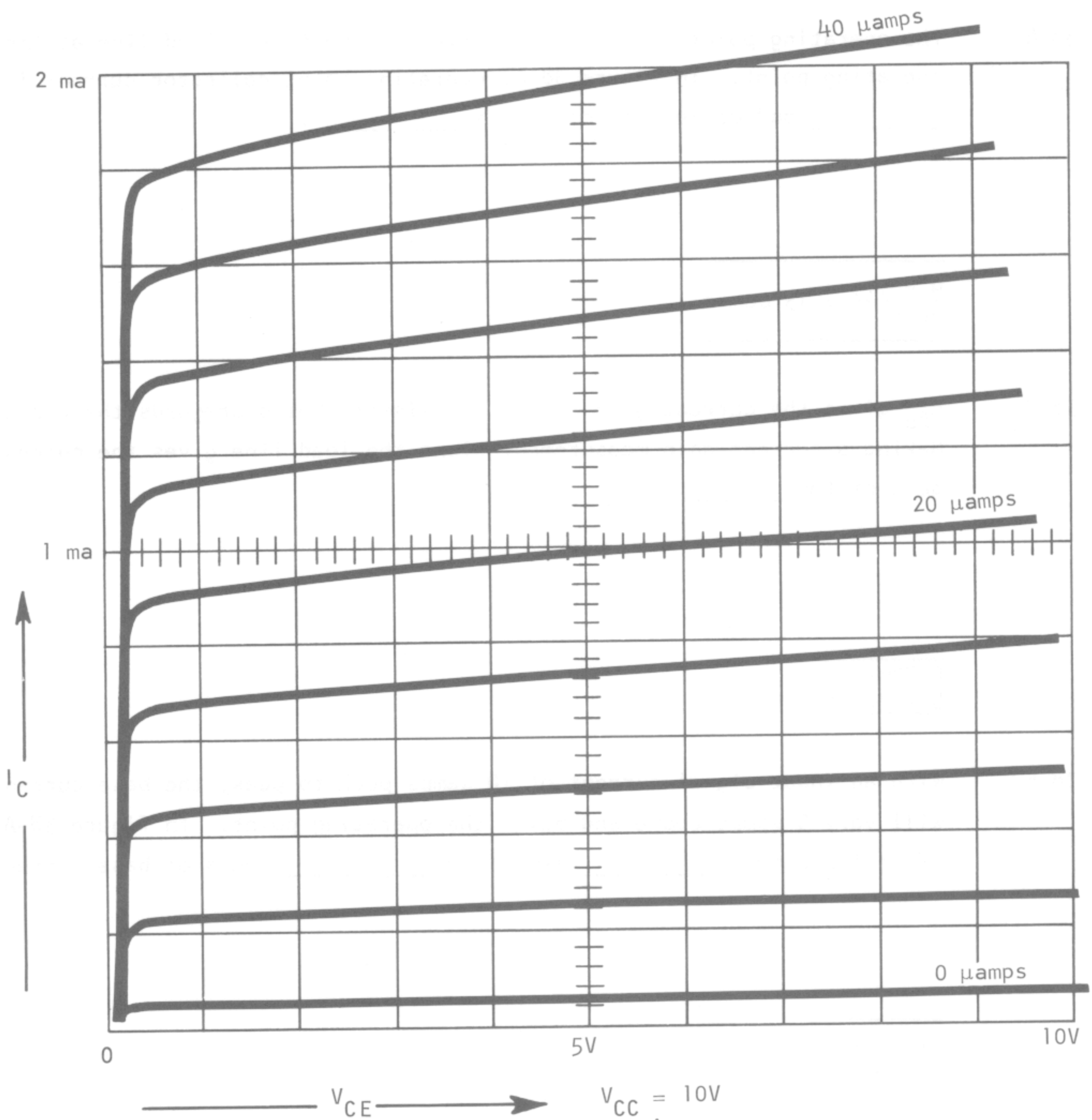
38.6 With an input signal current of 10 µamps peak to peak, the base current will vary 5 µamps above and below the operating point. In figure 38-A it varies between ________ µamps and ________ µamps of base current.

---

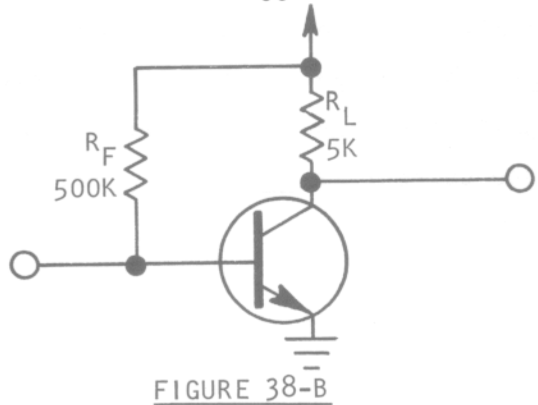
circuit

38.7 If the applied change in base current is assumed to take place <u>along the load line</u>, the change in circuit collector current can be found. In figure 38-A, the change in collector current for an input change of 10 µamps base current is ________ ma.

10
20



40 μamps
2 ma
20 μamps
1 ma
I_C
0 μamps
0
5V
10V
V_{CE}



V_{CC} = 10V
R_L
5K
R_F
500K

FIGURE 38-B

38.8 Dividing the change in collector current by the applied change in base current along the load line gives the circuit current gain . In figure 38-A, circuit current gain is ____________.

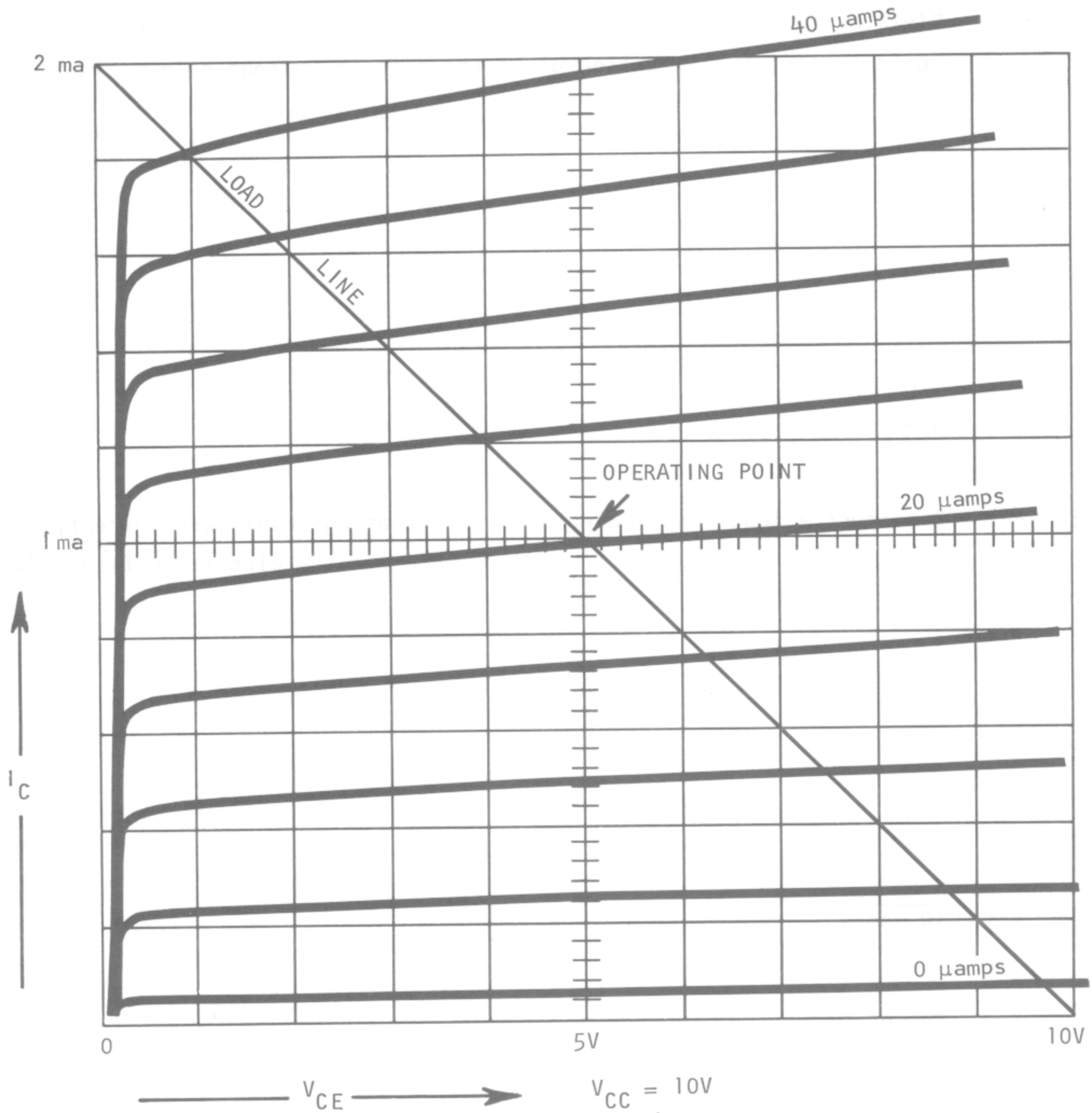
0.48 ma

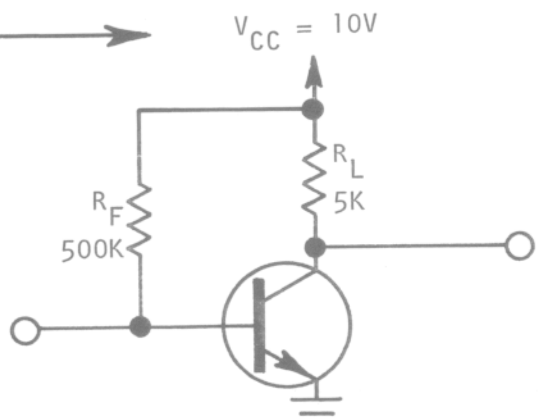
38.9** Construct a load line; determine the operating point base current, collector current, and collector voltage for the circuit in figure 38-B.

$\frac{0.48 \text{ ma}}{10\ \mu\text{amps}} = 48$

38.10 END OF SET

answer on following page





OPERATING POINT

I_B = 20 µamps

I_C = 1 ma

V_{CE} = 5 Volts

FIGURE 38-C

39 The transistors collector junction is normally reversed biased except when driven into saturation. Too large a reverse bias can result in the collector entering a condition termed ________________ ________________. This is caused by the ________________________ of carriers due to the high value of reverse bias.

39.1 At room temperature, there are minority carriers present in all parts of the transistor. ____________ bias on the collector junction results in any minority carriers that enter the transition region, crossing the junction.

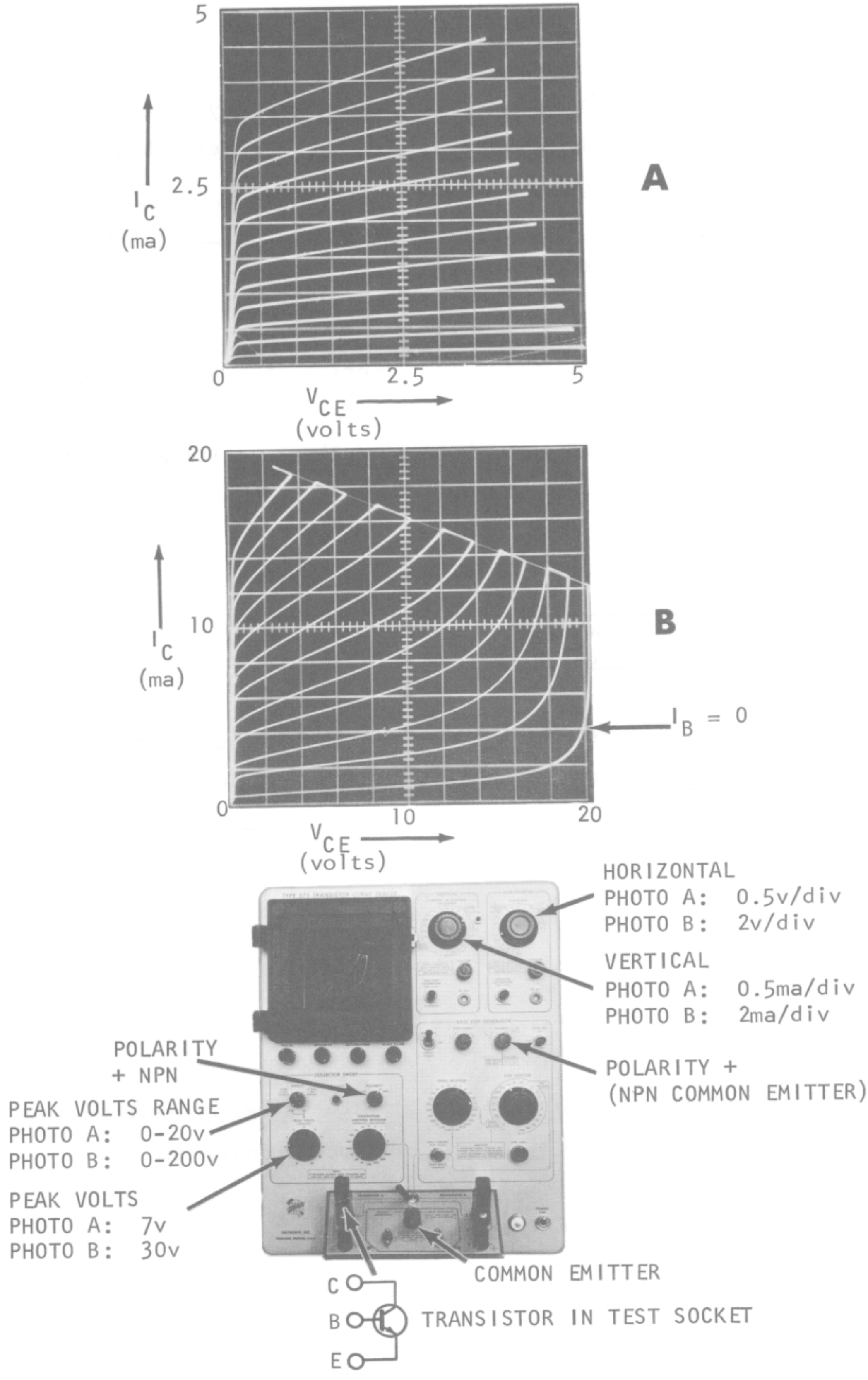
avalanche breakdown
acceleration or multiplication

39.2 A high value of reverse bias accelerates the carriers to great speeds. The accelerated carriers strike other atoms in the structure, freeing more carriers which are also ___________________ by the high reverse bias.

reverse

39.3 The multiplication of carriers at high values of reverse bias causes the collector to go into a reverse breakdown condition.

accelerated



5
2.5
I_C (ma)
0
2.5
5
V_{CE} (volts)
A
20
10
I_C (ma)
0
10
20
V_{CE} (volts)
B
I_B = 0
HORIZONTAL
PHOTO A: 0.5v/div
PHOTO B: 2v/div
VERTICAL
PHOTO A: 0.5ma/div
PHOTO B: 2ma/div
POLARITY + NPN
POLARITY +
(NPN COMMON EMITTER)
PEAK VOLTS RANGE
PHOTO A: 0-20v
PHOTO B: 0-200v
PEAK VOLTS
PHOTO A: 7v
PHOTO B: 30v
COMMON EMITTER
C
B
E
TRANSISTOR IN TEST SOCKET

FIGURE 39

39.4 The multiplication of carriers in the reverse breakdown mode is termed avalanche. Avalanche breakdown occurs at high values of collector ____________ voltage.

---

no answer needed

39.5 Figure 39 shows a collector family of curves in the top photo. The second photo is a collector family of curves for the same transistor, but includes the area around collector __________ ___________.

---

reverse

39.6 When the breakdown voltage is reached, collector current increases greatly. For zero I_B in figure 39, avalanche breakdown occurs at approximately ______________ volts of V_{CE}.

---

avalanche breakdown

39.7 When the breakdown voltage of the collector junction is exceeded, the collector enters a condition termed __________________ or reverse breakdown. This is a result of the multiplication of carriers on impact of accelerated carriers.

20

39.8 Avalanche breakdown in the collector of a transistor is the same as discussed for the basic diode. The orientation of the transistor can effect the voltage point at which breakdown occurs, however, due to the influence of transistor gains.

avalanche

39.9 A transistor in avalanche breakdown has ______________ (the same, a different) action occuring at the collector junction as the basic diode when in avalanche breakdown.

no answer needed

39.10** When the transistor enters ______________ breakdown, the current increases greatly. This is a result of the ______________ of carriers by accelerated carriers striking atoms in the structure.

the same

39.11 END OF SET

avalanche
multiplication, etc.

40 The symbol ______________ indicates breakdown voltage, collector to emitter, with the base lead open; the symbol ______________ indicates breakdown voltage, collector to base, with the emitter lead open; and the symbol ______________ indicates breakdown voltage, collector to emitter, with a specified resistance from base to emitter. They are all given at a specified temperature.

40.1 The configuration affects the voltage point at which the transistor starts to break down. The manufacturer lists several breakdown voltages for several ________________________.

BV_{CEO}
BV_{CBO}
BV_{CER}

40.2 A change in temperature will change the voltage requirements to cause breakdown. When a breakdown voltage is specified, the ________________ should also be stated.

configurations

40.3 Without injected carriers from the emitter and the reverse voltage applied directly between collector and base, the breakdown voltage is determined by the characteristics of the collector base junction (and the temperature).

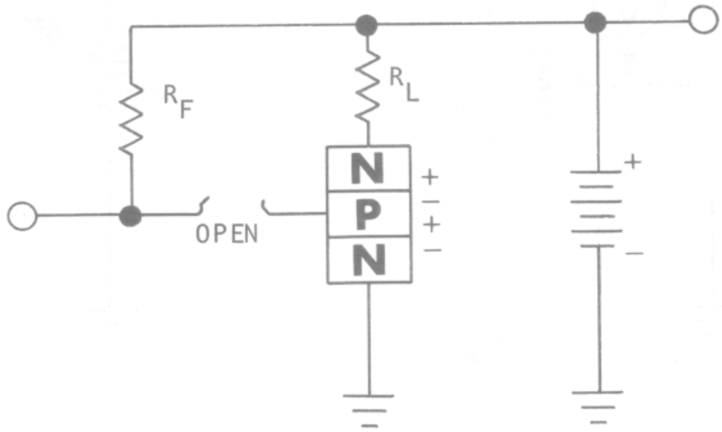
temperature

40.4 The common base configuration finds the situation in frame 40.3, if the emitter lead is open circuited. The breakdown voltage is determined by the point at which the collector diode starts to avalanche.

---

no answer needed

40.5 The common emitter configuration has the collector supply voltage applied across both junctions when the base lead is open circuited. Although this reverse biases the collector junction, it ________________ biases the emitter junction.



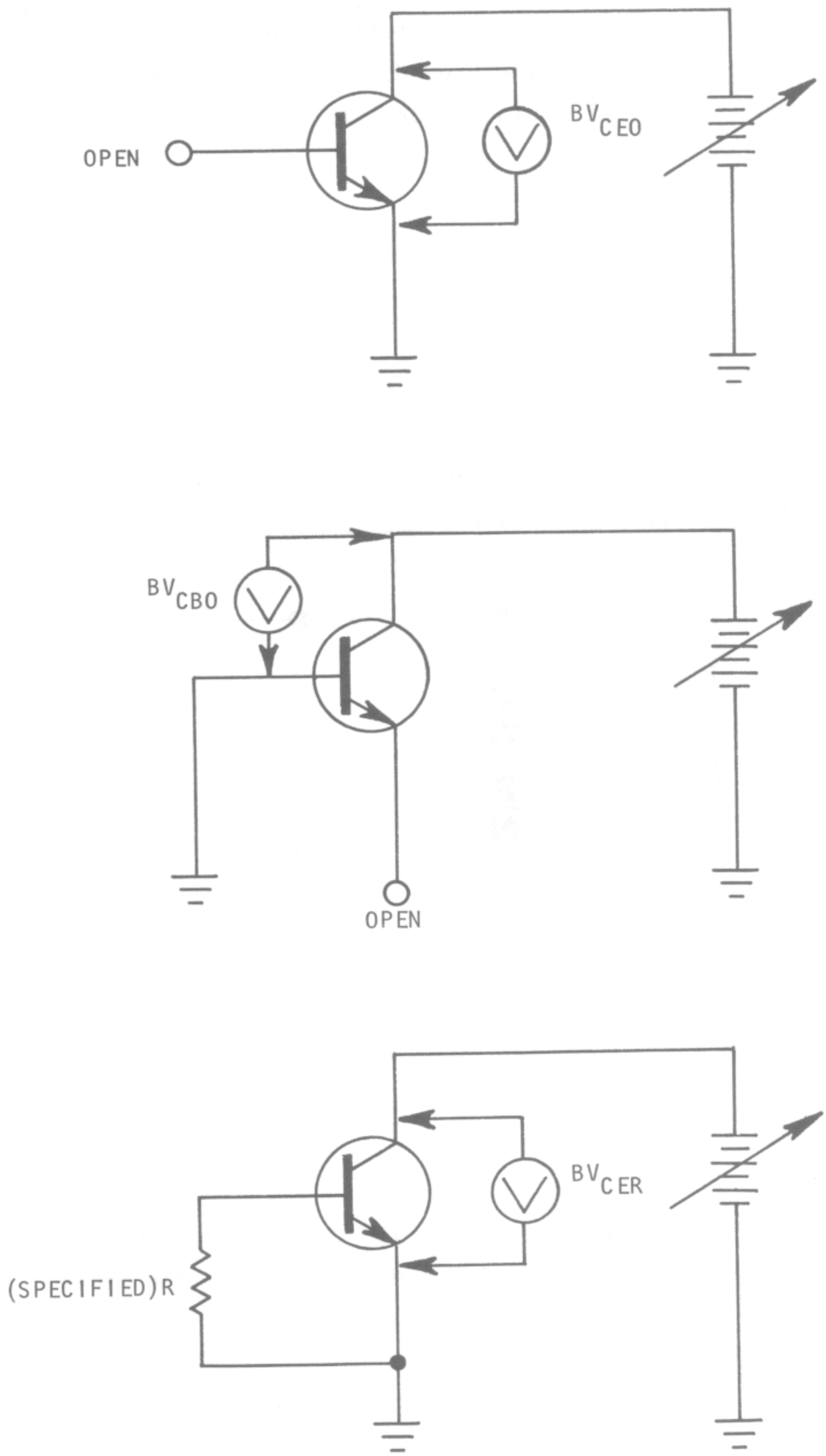
---

no answer needed

40.6 Voltage applied from collector to emitter with the base lead open circuited will reverse bias one junction and forward bias the other. This will ________________ the number of minority carriers in the base.
(increase, decrease)

---

forward



BV_{CEO}

BREAKDOWN VOLTAGE, COLLECTOR TO EMITTER, WITH THE BASE LEAD OPEN ($I_b = 0$)

BV_{CBO}

BREAKDOWN VOLTAGE, COLLECTOR TO BASE, WITH THE EMITTER LEAD OPEN ($I_e = 0$)

BV_{CER}

BREAKDOWN VOLTAGE, COLLECTOR TO EMITTER, WITH A SPECIFIED VALUE OF RESISTOR BETWEEN BASE AND EMITTER

FIGURE 40-A

40.7 The action of the emitter junction when the voltage is applied, collector to emitter rather than collector to base, reduces the voltage required to cause the transistor to enter a breakdown condition.

---

increase

40.8 A transistor in a common base configuration will break down at ____________________ (a different, the same) collector voltage as/than a transistor in a common emitter configuration.

---

no answer needed

40.9 Figure 40-A shows three possible configurations and the breakdown voltage symbols. BV_{CEO} indicates that the breakdown voltage was measured with the ________________ lead open circuited.

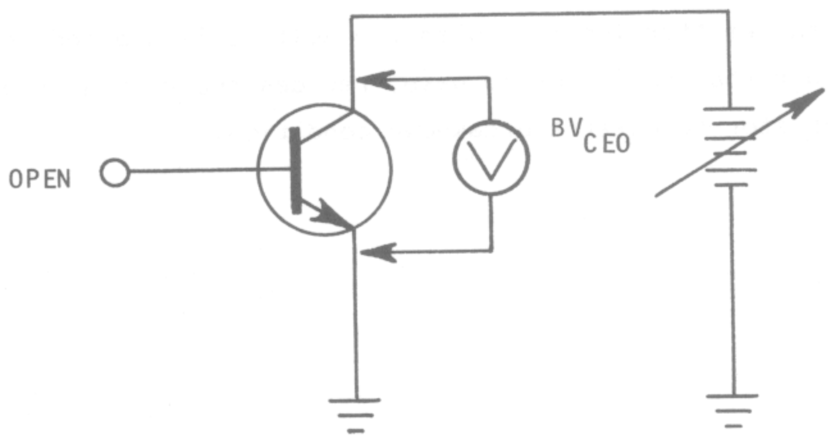
---

a different

40.10 Biasing the transistor to allow zero base lead current, allows the measurememt of the breakdown voltage whose symbol is ________________.

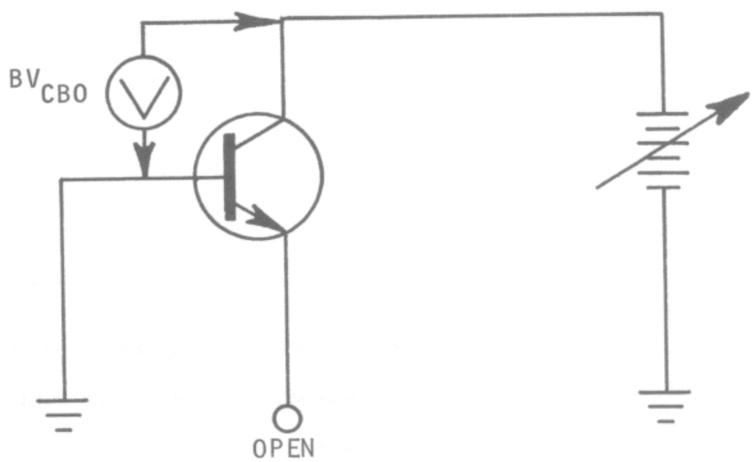
---

base



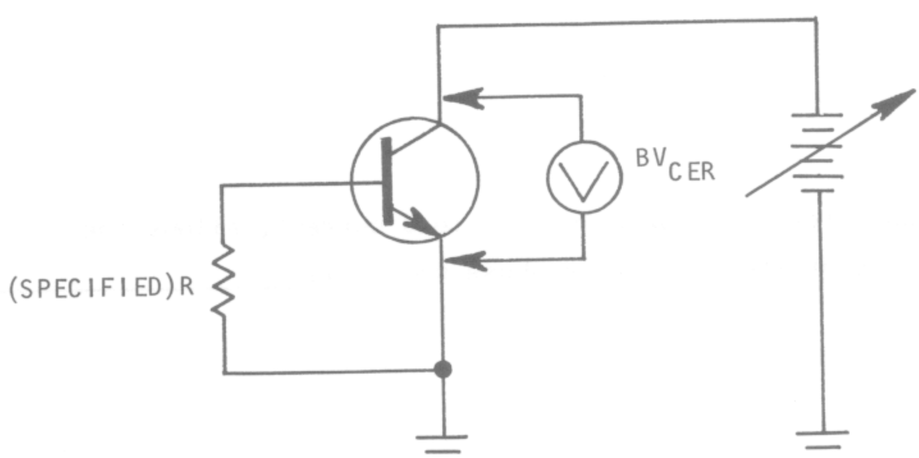
BV_{CEO}

BREAKDOWN VOLTAGE, COLLECTOR TO EMITTER, WITH THE BASE LEAD OPEN ($I_b = 0$)



BV_{CBO}

BREAKDOWN VOLTAGE, COLLECTOR TO BASE, WITH THE EMITTER LEAD OPEN ($I_e = 0$)



BV_{CER}

BREAKDOWN VOLTAGE, COLLECTOR TO EMITTER, WITH A SPECIFIED VALUE OF RESISTOR BETWEEN BASE AND EMITTER

FIGURE 40-A

40.11 BV_{CBO} is measured with the ______________ lead open. BV_{CBO} breakdown occurs between collector and ____________, as shown in figure 40-A.

BV_{CEO}

40.12 BV_{CEO} is aided by the gain of the transistor and occurs at a ____________ (lower, higher) voltage than BV_{CBO} for the same transistor.

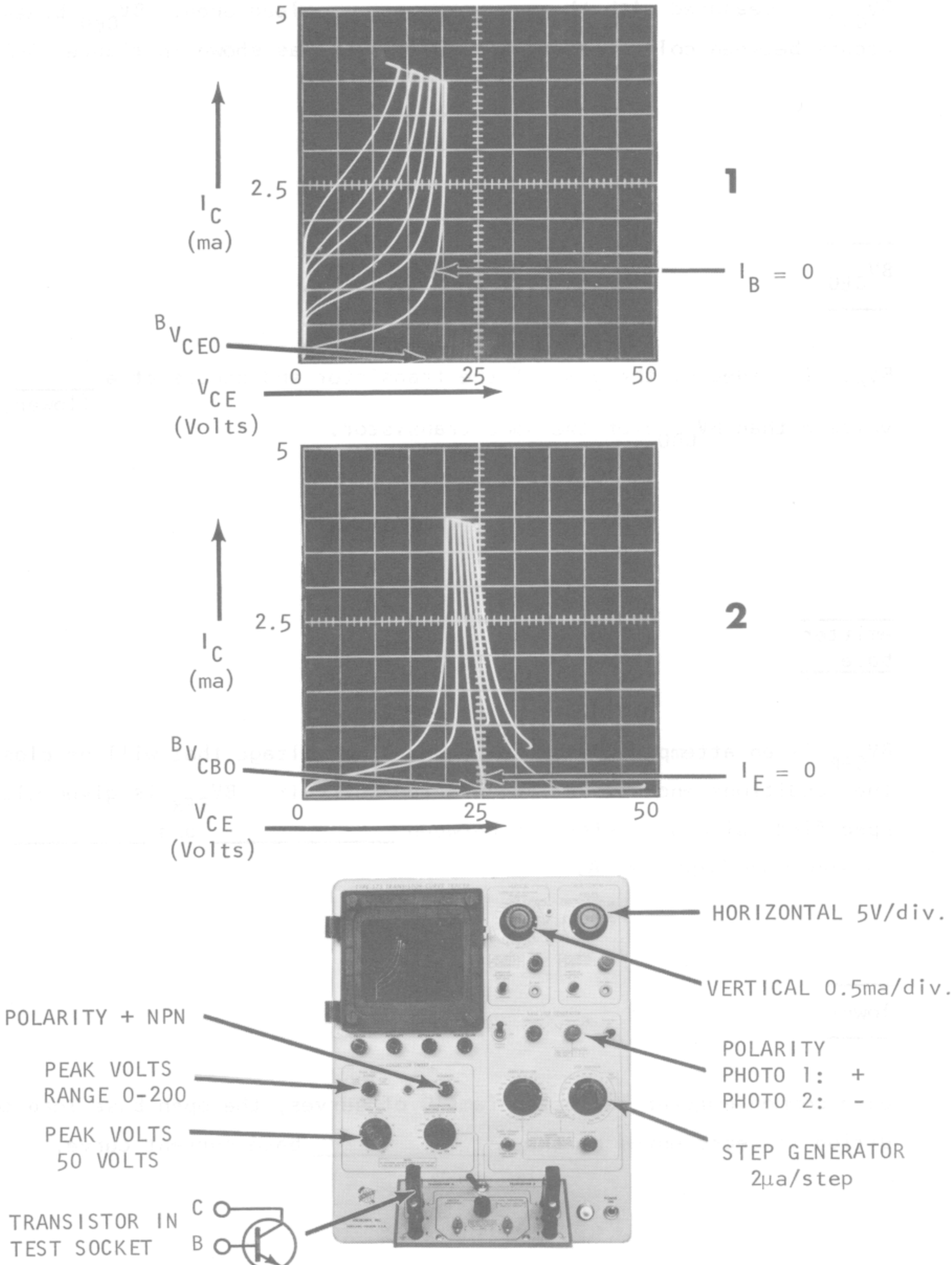
emitter
base

40.13 BV_{CER} is an attempt to specify a breakdown voltage that will be closer to the conditions encountered in an actual circuit. BV_{CER} is given with a specified value of resistance between ____________ and ______________ as shown in figure 40-A.

lower

40.14 On a common emitter collector family of curves, the open base lead condition is represented by the _____________ base current curve.

base
emitter



TEST SETUP

TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
PHOTOS 1 AND 2 TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA

FIGURE 40-B

40.15 On a common emitter collector family of curves, reverse biasing the emitter base junction sufficiently to reduce emitter current to zero is the same as opening the ______________ lead.

zero

40.16 In figure 40-B (photo 2), the line marked $I_E = 0$ indicates that sufficient reverse base current is applied to reduce the emitter current to zero. This is the same as opening the ______________ lead.

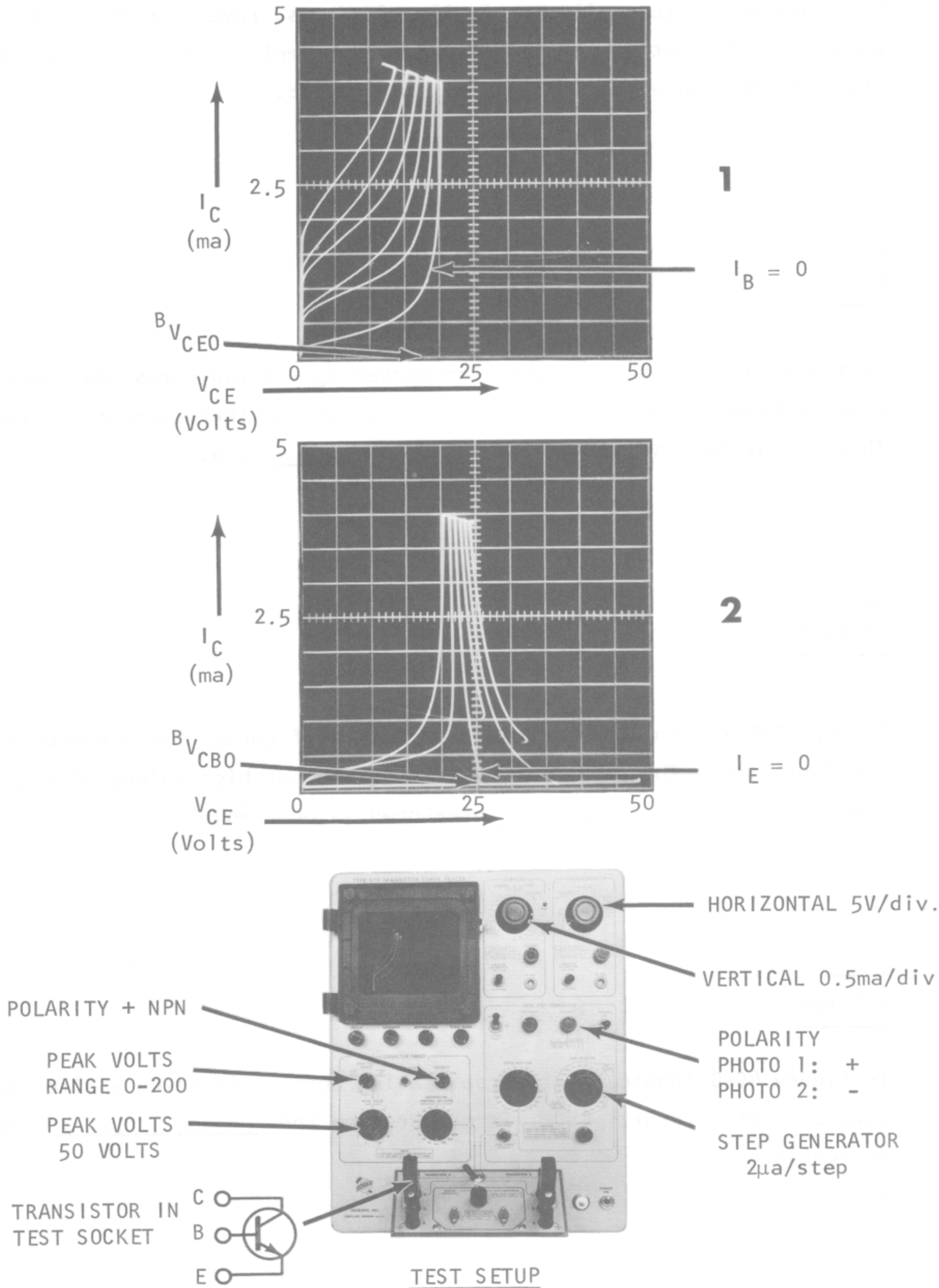
emitter

40.17 Figure 40-B (photo 1) is a collector family of curves for a common emitter configuration. The sharp increase in current at high values of V_{CE} indicates ________________ breakdown is occuring.

emitter

40.18 In figure 40-B (photo 2), reverse biasing current is being applied to reduce emitter current. BV_{CBO} is measured on the ______________ emitter current curve.

avalanche



TEKTRONIX TYPE 575 TRANSISTOR-CURVE TRACER
PHOTOS 1 AND 2 TAKEN WITH TYPE C-12 OSCILLOSCOPE CAMERA
FIGURE 40-B

40.19 In figure 40-B (photo 2), BV_{CBO} is measured on the base current curve that is marked $I_E = 0$. This curve indicates that sufficient reverse base current has been applied to oppose any minority or leakage current and simulates an open __________ circuit.

zero

40.20** The symbol BV_{CEO} indicates ______________________________;
the symbol BV_{CBO} indicates ______________________________;
the symbol BV_{CER} indicates ______________________________.
______________ should be stated when these values are given.
(Note: Define the symbols above.)

emitter

40.21 END OF SET

breakdown voltage collector to emitter with the base lead open
breakdown voltage collector to base with the emitter lead open
breakdown voltage collector to emitter with a specified resistor from base to emitter
temperature

41 Maximum power handling capabilities of the transistor are limited by the maximum temperature that the junctions can reach without harm, the surrounding air temperature and the total __________ ___________ from junction to surrounding air.

41.1 As with the basic diode, the transport of carriers results in carriers changing energy bands and giving off energy in the form of ____________ and __________________.

thermal resistance

41.2 The majority of the energy given off at the transistor's junctions is in the form of heat. The more power dissipated at the junction, the more ___________ is given off.

heat
light

41.3 The power (I x E) dissipated by a junction results in the generation of heat and raises the junction ____________ above that of its surroundings.

heat (energy)

41.4 The junction can reach an operating temperature at which it is harmed if too much power is dissipated. Moving some of the generated heat away from the junction allows ____________ power to be dissipated.
(more, less)

temperature

41.5 The collector junction dissipates the greater amount of power of the two junctions in most cases. The smaller amount of heat will be generated at the ____________________ junction.

more

41.6 The transistor is normally mounted in a case and this offers opposition to the transfer of ___________ from the junction to the surrounding air.

emitter

41.7 The greater the amount of heat that can be moved from the junction to the surrounding air, the more power can be dissipated for the same surrounding air (ambient) temperature. The lower the surrounding air (ambient) temperature, the ____________ power a given transistor can dissipate.
(more, less)

heat

41.8 The difference between the ambient (surrounding air) temperature and the maximum temperature at which the junction can operate, is the allowable rise in junction temperature due to dissipating power.

more

41.9 The opposition offered in the path of heat transfer from the junction to the surrounding air is termed "thermal resistance". The higher the thermal resistance, the ___________ heat will be transferred.
(more, less)

no answer needed

41.10 The maximum allowable junction temperature (T_{JMAX}), the ambient temperature (T_A), and the opposition offered in the path of heat transfer from the junction to surrounding air which is termed __________ __________, limits the maximum power dissipation.

less

41.11 Total thermal resistance may be the sum of several individual thermal resistances. For example, thermal resistance junction to the case and thermal resistance from the case to the surrounding air would add to give __________ thermal resistance, junction to ambient.

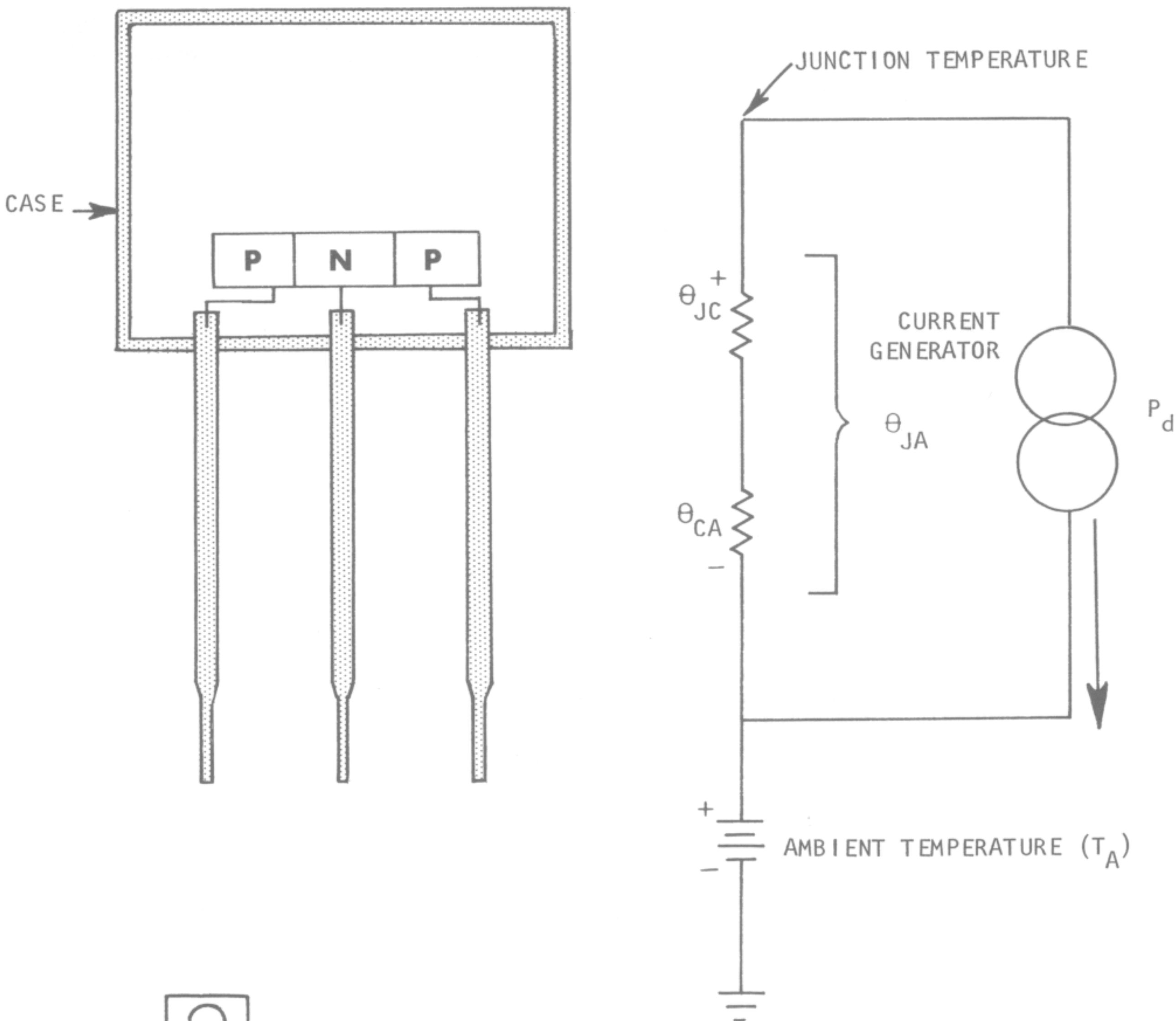
thermal resistance

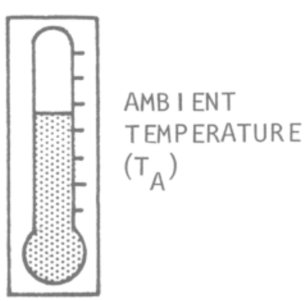
41.12** Thermal resistance, maximum ______________ ______________ (T_{JMAX}), and ________________ ____________________ (T_A) limit the amount of power the transistor can dissipate.

_____
total
_____

41.13 END OF SET

junction temperature
ambient (surrounding air) temperature





THERMAL		ELECTRICAL EQUIVALENT
AMBIENT TEMPERATURE	=	VOLTAGE
THERMAL RESISTANCE	=	RESISTANCE
POWER DISSIPATION	=	CURRENT
JUNCTION TEMPERATURE	=	VOLTAGE

THERMAL TO ELECTRICAL ANALOGY

FIGURE 42

42 The symbol for total thermal resistance, junction to ambient, is ______________. When dealing with a transistor that is not connected thermally to an external heat sink, ________________(#) thermal resistances add to give the total and their symbols are __________ and ____________. Thermal resistance is expressed in ___________.

42.1 Thermal resistance is given the symbol Θ. The subscripts indicate between what two points the opposition to heat transfer exists. Θ_{JA} indicates thermal resistance, ____________ to ambient (surrounding air).

Θ_{JA}
two
Θ_{JC}
Θ_{CA}
degrees centigrade per watt (°C/W)

42.2 When the transistor is in a case and depends on radiation of heat to the surrounding air from the case, two thermal resistances add to give total thermal resistance. Thermal resistance, junction to case (Θ_{JC}), and thermal resistance, case to ambient (Θ_{CA}), add to give _______________.

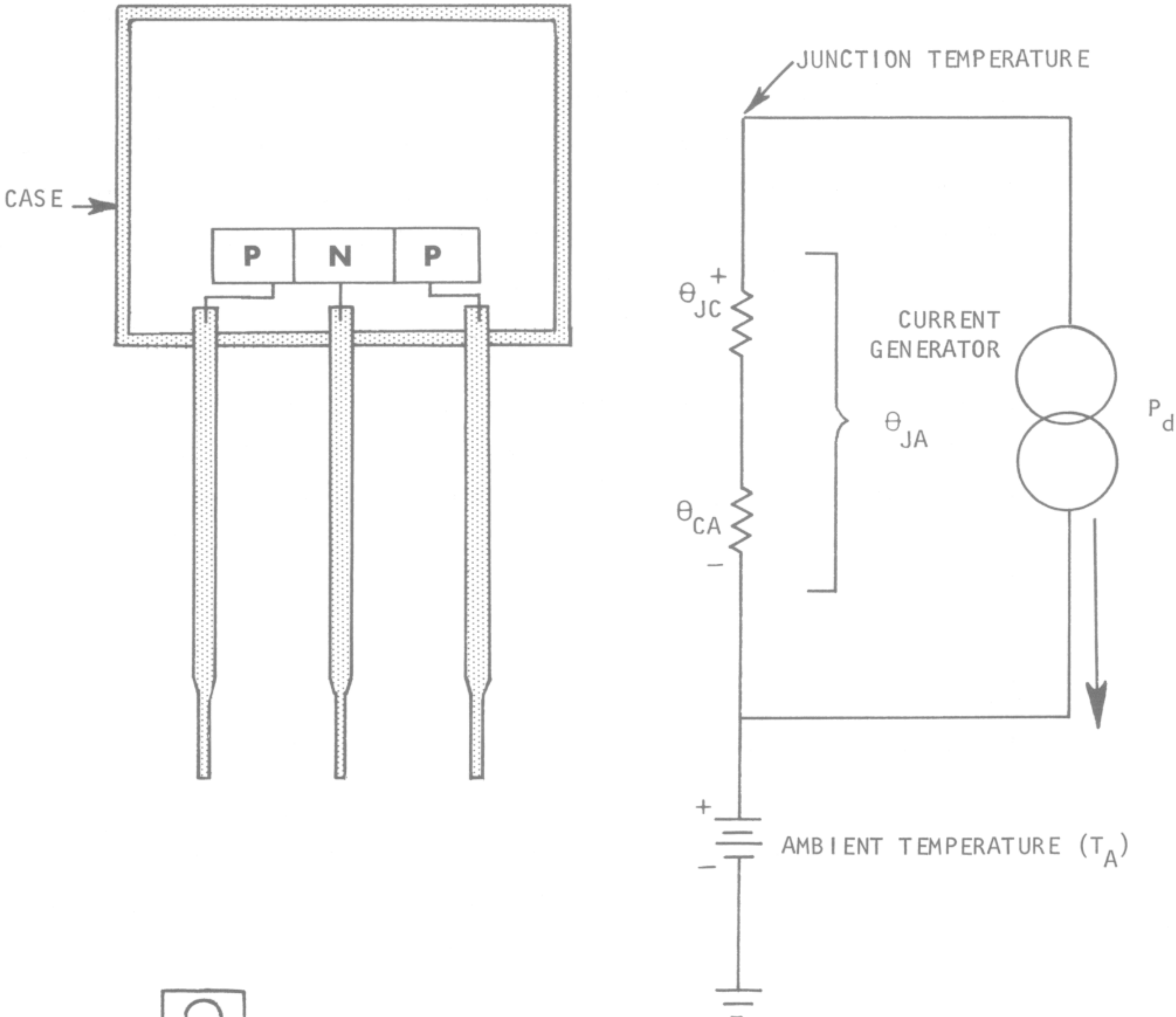
---

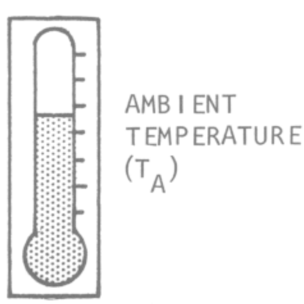
junction

42.3 Figure 42 shows the transistor and the thermal considerations in electrical terms. Thermal resistance is analogically compared with electrical resistance, power dissipation at the junction with electrical current, and ambient temperature with electrical ______________.

---

total thermal resistance (Θ_{JA})





THERMAL		ELECTRICAL EQUIVALENT
AMBIENT TEMPERATURE	=	VOLTAGE
THERMAL RESISTANCE	=	RESISTANCE
POWER DISSIPATION	=	CURRENT
JUNCTION TEMPERATURE	=	VOLTAGE

THERMAL TO ELECTRICAL ANALOGY

FIGURE 42

42.4 Θ_{JC} indicates thermal resistance, junction to ____________, and Θ_{CA} indicates thermal resistance, case to __________.

---

voltage

42.5 The product of thermal resistance total and the power dissipation will give a temperature (voltage in the analogy) that will add to ____________ temperature which is also analogically compared to a voltage and this sum gives junction temperature.

---

case
ambient

42.6 Thermal resistance is expressed in degrees centigrade per watt (°C/W). This indicates the rise in junction temperature with power dissipation at the junction in degrees centigrade per __________.

---

ambient

42.7 Connecting the transistor thermally to an external heat sink (such as the chassis) is termed "heat sinking" the transistor. Heat sinking will ____________ (raise, lower) total thermal resistance.

---

watt

42.8 Total thermal resistance (°C/W) times the power dissipation (P_d in watts) gives the rise in junction temperature (ΔT_J). The rise in junction temperature added to the ambient temperature (T_A) gives the operating temperature of the junction (T_J). $P_d \; \Theta_{JA} + T_A =$ ______________

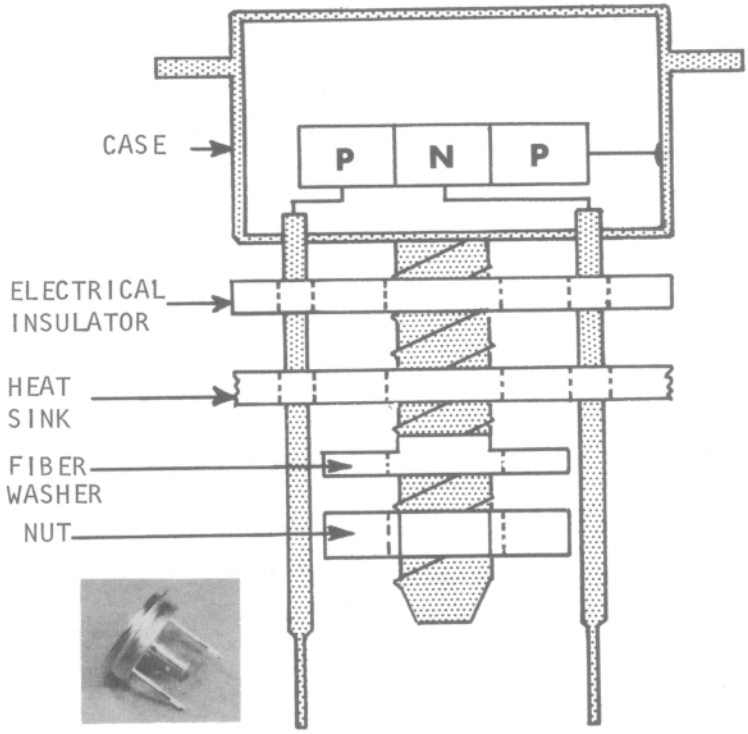
lower

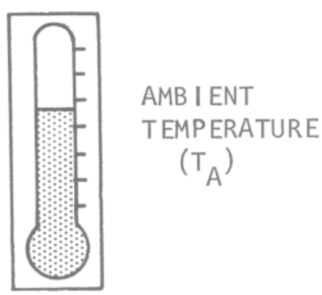
42.9** Thermal resistance __________ _________ __________ (Θ_{JC}) added to thermal resistance __________ _________ __________ (Θ_{CA}) gives thermal resistance __________ _________ __________ (Θ_{JA}) when no separate heat sink is involved. Thermal resistance is expressed in °C/________.

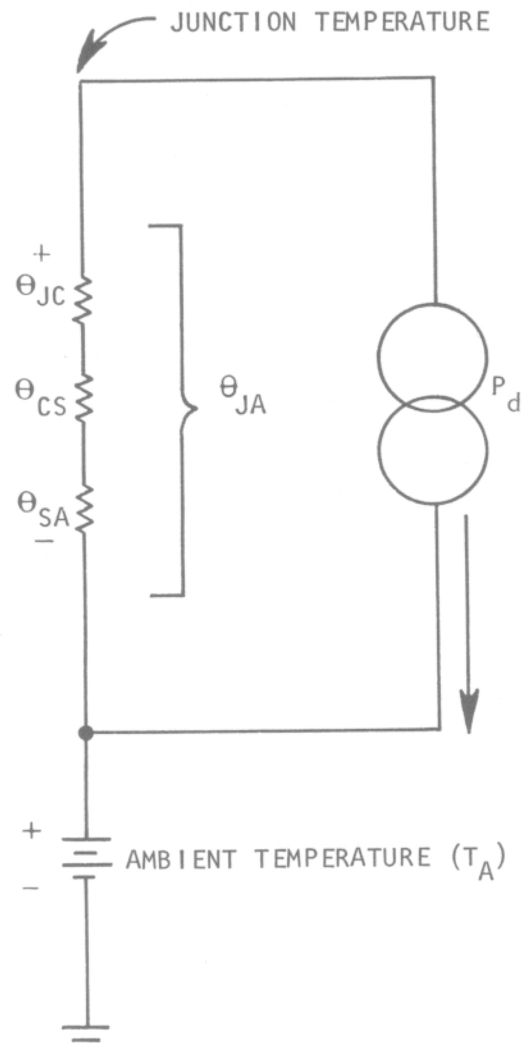
operating temperature of the junction (T_J)

42.10 END OF SET

junction to case
case to ambient
junction to ambient
watt







NOTE: When a heat sink is used, Θ_{CS} and Θ_{SA} replace Θ_{CA}. The sum of Θ_{CS} and Θ_{SA} is always much lower than Θ_{CA}.

JUNCTION POWER DISSIPATION = CURRENT
OPPOSITION TO HEAT TRANSFER = RESISTANCE
AMBIENT TEMPERATURE = VOLTAGE
JUNCTION TEMPERATURE = VOLTAGE

INSULATING WASHER	TYPICAL THERMAL RESISTANCE, (Θ_{CS}) IN °C/W	
	DRY	W/SILICON LUBRICANT
NONE	0.2	0.1
TEFLON	1.45	.8
MICA	0.8	0.4
ANODIZED ALUMINUM	0.4	0.35

THERMAL TO ELECTRICAL ANALOGY WHEN USING A SEPARATE HEAT SINK

FIGURE 43

43 When a heat sink is used to increase power dissipating capabilities, ________(#) thermal resistances add to give Θ_{JA}. Their symbols are ________, ____________, and ____________. ____________ lubricant will reduce Θ_{JA}.

43.1 Using a separate heat sink replaces the rather large thermal resistance, case to ambient (Θ_{CA}), with two thermal resistances whose sum is much less than Θ_{CA}. Θ_{CA} has a ______________ (larger, smaller) value than the thermal resistances that replace it when a heat sink is used.

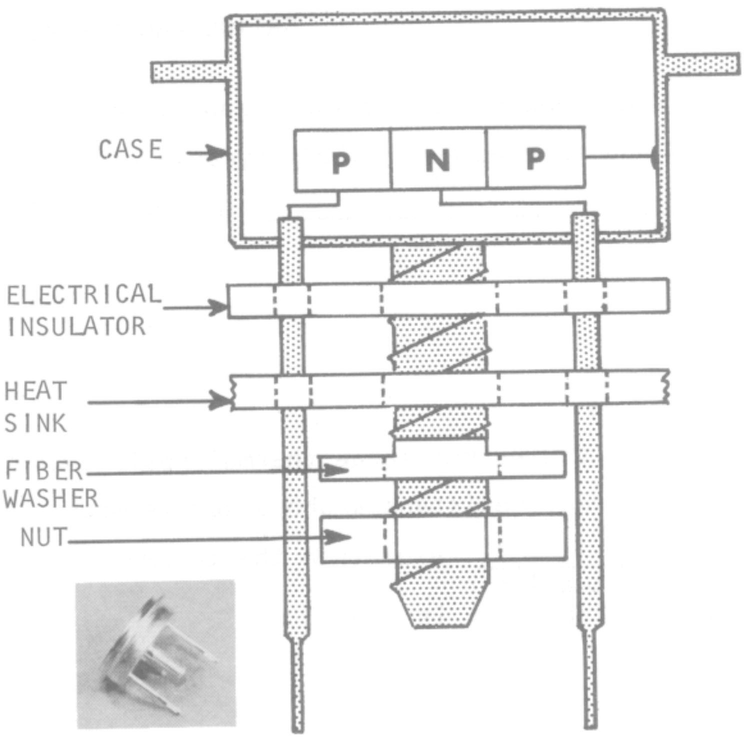
3
Θ_{JC}
Θ_{CS}
Θ_{SA}
silicone

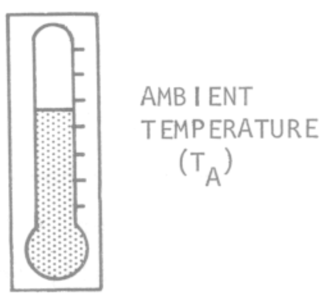
43.2 Higher power handling transistors generally have the collector connected directly to the case to aid in heat transfer. This, in most cases, requires that the case be insulated electrically from the heat sink. The electrical insulator used should have good __________ conductivity.

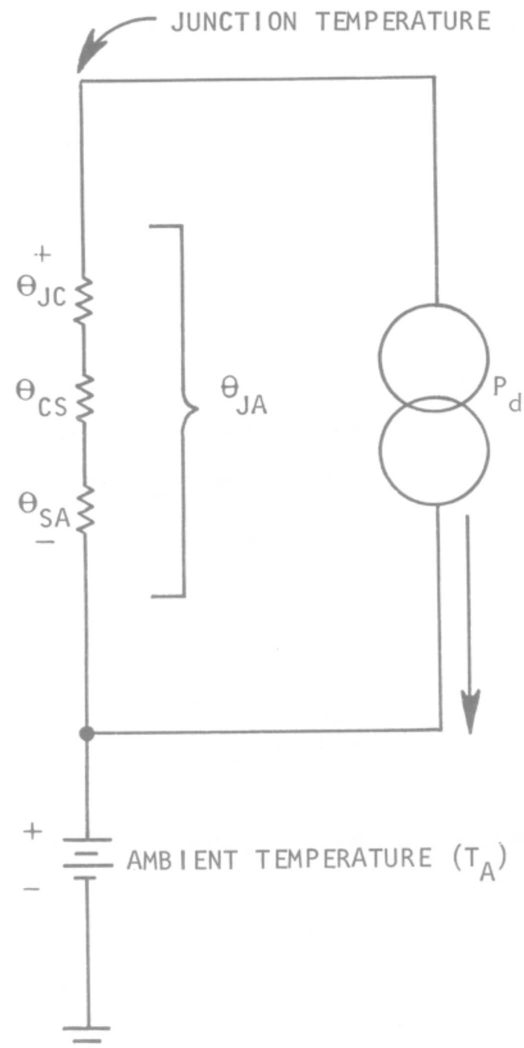
larger

43.3 Figure 43 shows a power transistor with an external heat sink and the equivalent thermal considerations in an electrical analogy. Once again power dissipation (P_d) is expressed analogically as electrical ______________.

heat (thermal)







NOTE: When a heat sink is used, Θ_{CS} and Θ_{SA} replace Θ_{CA}. The sum of Θ_{CS} and Θ_{SA} is always much lower than Θ_{CA}.

JUNCTION POWER DISSIPATION = CURRENT
OPPOSITION TO HEAT TRANSFER = RESISTANCE
AMBIENT TEMPERATURE = VOLTAGE
JUNCTION TEMPERATURE = VOLTAGE

INSULATING WASHER	TYPICAL THERMAL RESISTANCE, (Θ_{CS}) IN °C/W	
	DRY	W/SILICON LUBRICANT
NONE	0.2	0.1
TEFLON	1.45	.8
MICA	0.8	0.4
ANODIZED ALUMINUM	0.4	0.35

THERMAL TO ELECTRICAL ANALOGY WHEN USING A SEPARATE HEAT SINK

FIGURE 43

43.4 There is opposition to the transfer of heat from the case to the heat sink. This thermal resistance is given the symbol __________ as shown in figure 43.

current

43.5 Θ_{CS} is the thermal resistance, case to heat sink. Θ_{SA} is thermal resistance, __________ __________ to ambient. $\Theta_{JC} + \Theta_{CS} + \Theta_{SA} =$ ________.

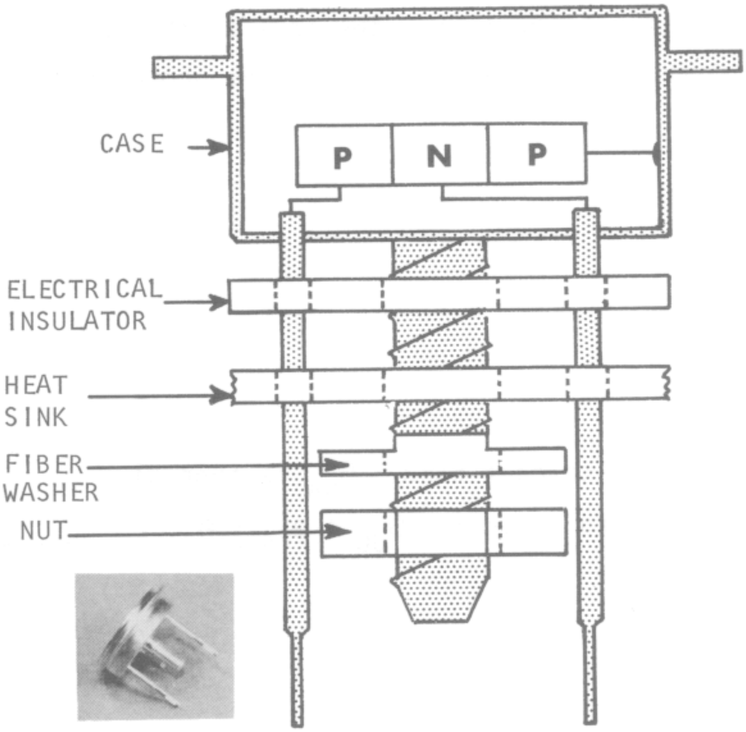
Θ_{CS}

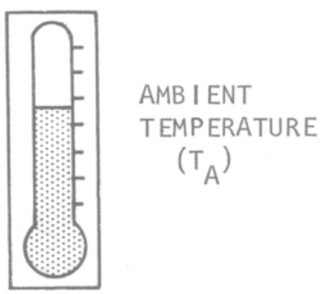
43.6 The sum of the three thermal resistances is total thermal resistance when an external heat sink is used. The product of total thermal resistance and the power dissipation gives the rise in junction temperature above __________ __________ (T_A). (Each individual thermal resistance contributing to the temperature rise)

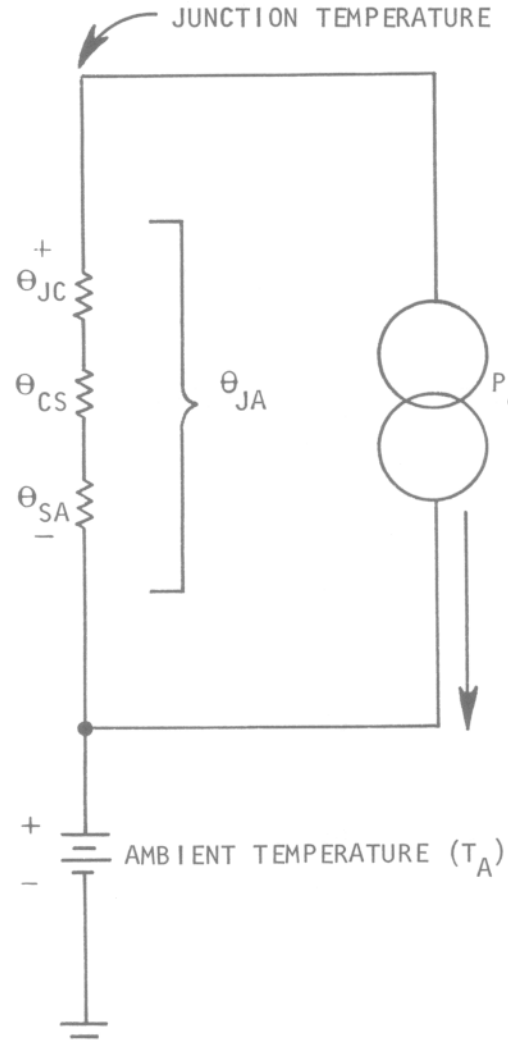
heat sink
Θ_{JA}

43.7 Θ_{CS} and Θ_{SA} replace Θ_{CA} when an external heat sink is used. Coating the insulating washer (between the case and the heat sink) with silicone lubricant will ________________ Θ_{CS} as shown in figure 43.
(increase, decrease)

ambient temperature







NOTE: When a heat sink is used, Θ_{CS} and Θ_{SA} replace Θ_{CA}. The sum of Θ_{CS} and Θ_{SA} is always much lower than Θ_{CA}.

JUNCTION POWER DISSIPATION = CURRENT
OPPOSITION TO HEAT TRANSFER = RESISTANCE
AMBIENT TEMPERATURE = VOLTAGE
JUNCTION TEMPERATURE = VOLTAGE

INSULATING WASHER	TYPICAL THERMAL RESISTANCE, (Θ_{CS}) IN °C/W	
	DRY	W/SILICON LUBRICANT
NONE	0.2	0.1
TEFLON	1.45	.8
MICA	0.8	0.4
ANODIZED ALUMINUM	0.4	0.35

THERMAL TO ELECTRICAL ANALOGY WHEN USING A SEPARATE HEAT SINK

FIGURE 43

43.8 As shown in figure 43, silicone lubricant will reduce Θ_{CS} even if no insulating washer is used. Reducing Θ_{CS} also reduces ________________.

decrease

43.9** The sum of Θ_{JC}, ____________ and ____________, is the total thermal resistance when an external heat sink is used. ____________ lubricant reduces the total thermal resistance.

Θ_{JA}

43.10 END OF SET

Θ_{CS}
Θ_{SA}
silicone

44

GIVEN:

$\Theta_{SA} = 3.2°C/watt$
$\Theta_{JC} = 1.2°C/watt$
$\Theta_{CS} = 0.6°C/watt$
$T_A = 50°C$
$T_J max = 150°C$

The maximum steady state power the transistor can dissipate is ________.

44.1 The sum of the individual thermal resistances is the total thermal resistance. $\Theta_{JC} + \Theta_{CS} + \Theta_{SA} = \Theta_{JA} =$ ____________ °C/watt with the values given in frame 44.

20 watts

44.2 Given an ambient temperature (T_A) of 50°C, and a maximum allowable junction temperature ($T_J max$) of 150°C, the allowable change in junction temperature due to power dissipation is found by subtracting T_A from $T_J max$. $T_J max - T_A =$ allowable $\Delta T_J =$ ____________°C.

5

44.3 The product of power dissipation and total thermal resistance must not exceed the maximum allowable change in junction temperature. Rearranging formula:

$$P_d max\ \Theta_{JA} = T_J max - T_A$$

$$P_d(max) = \underline{\quad ? \quad}$$

100

44.4 Since $P_d max = \frac{T_{Jmax} - T_A}{\Theta_{JA}}$

$P_d(max)$ for the problem in frame 44 $= \frac{150°C - 50°C}{5°C/watt} =$ ______?______

$\frac{T_J max - T_A}{\Theta_{JA}}$ = ____________

44.5 To find the maximum allowable power dissipation for a given ambient temperature, divide the allowable change in junction temperature by the total thermal resistance. $P_d(max) =$ ________________

---

20 watts

44.6**

$\Theta_{JC} = 2.1°C/watt$

$\Theta_{CS} = 0.8°C/watt$

$\Theta_{SA} = 5.1°C/watt$

$T_A = 70°C$

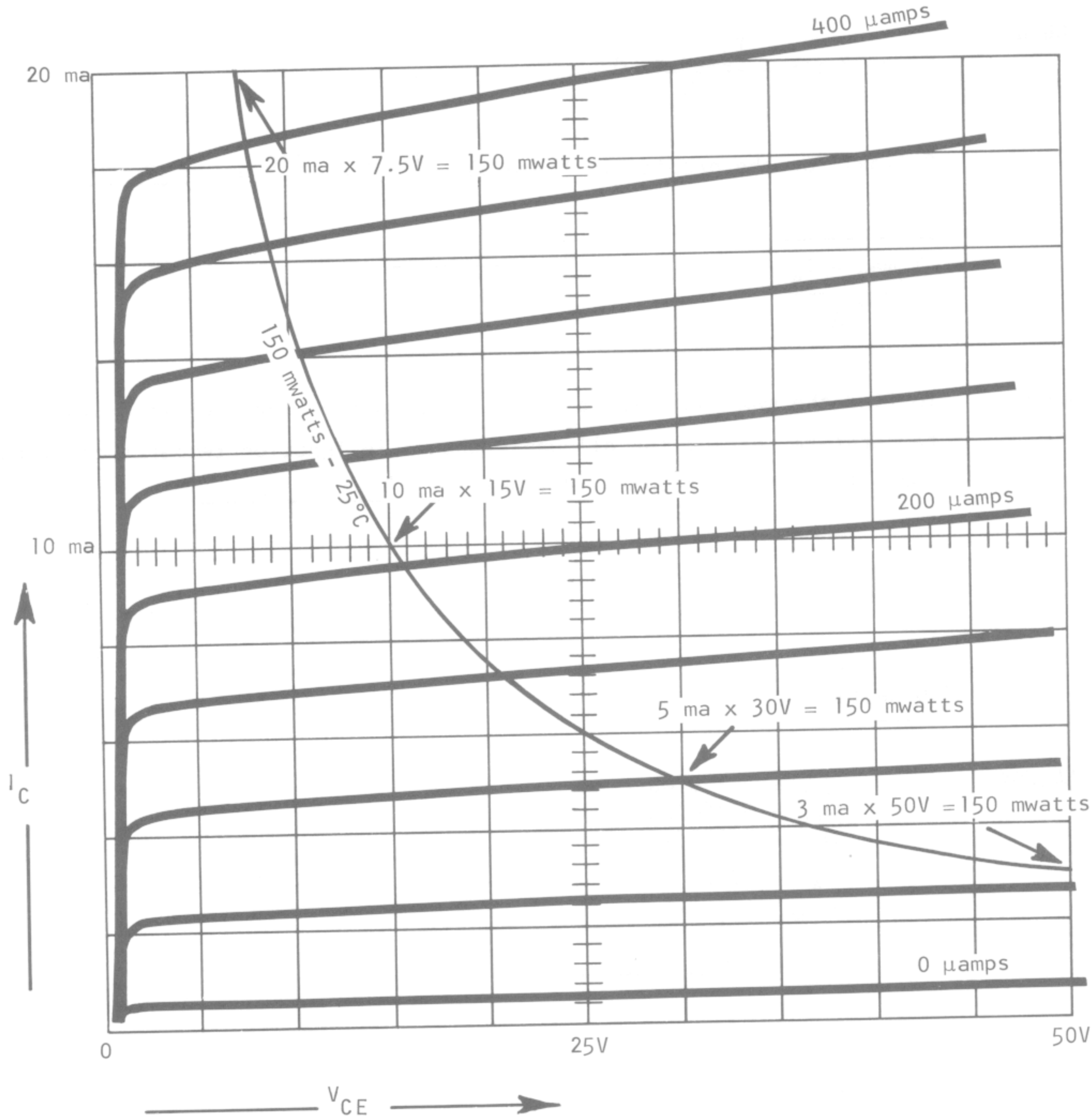
$T_J max = 150°C$

$P_d(max) =$ ______?______

$\frac{T_J max - T_A}{\Theta_{JA}}$

44.7 END OF SET

$$P_d(max) = \frac{T_J max - T_A}{\Theta_{JA}} = \frac{150°C - 70°C}{2.1°C/watt + 0.8°C/watt + 5.1°C/watt} = 10 \text{ watts}$$



COLLECTOR FAMILY OF CURVES WITH A MAXIMUM
POWER CURVE - 150 mwatts - 25°C

FIGURE 45

45 The maximum power curve is constructed by connecting all points of __________ __________ on the collector family of curves. For maximum safe output power, the load line should be __________ to the maximum power curve on the collector family of curves. For maximum current and power, the load line also intersects the maximum __________ point. __________ (T_A) must be specified.

45.1 When maximum power dissipation is given by the manufacturer or calculated using thermal resistance, it can be plotted on the collector family of curves as shown in figure 45. The curve that results connects all points of maximum power dissipation at a given __________.

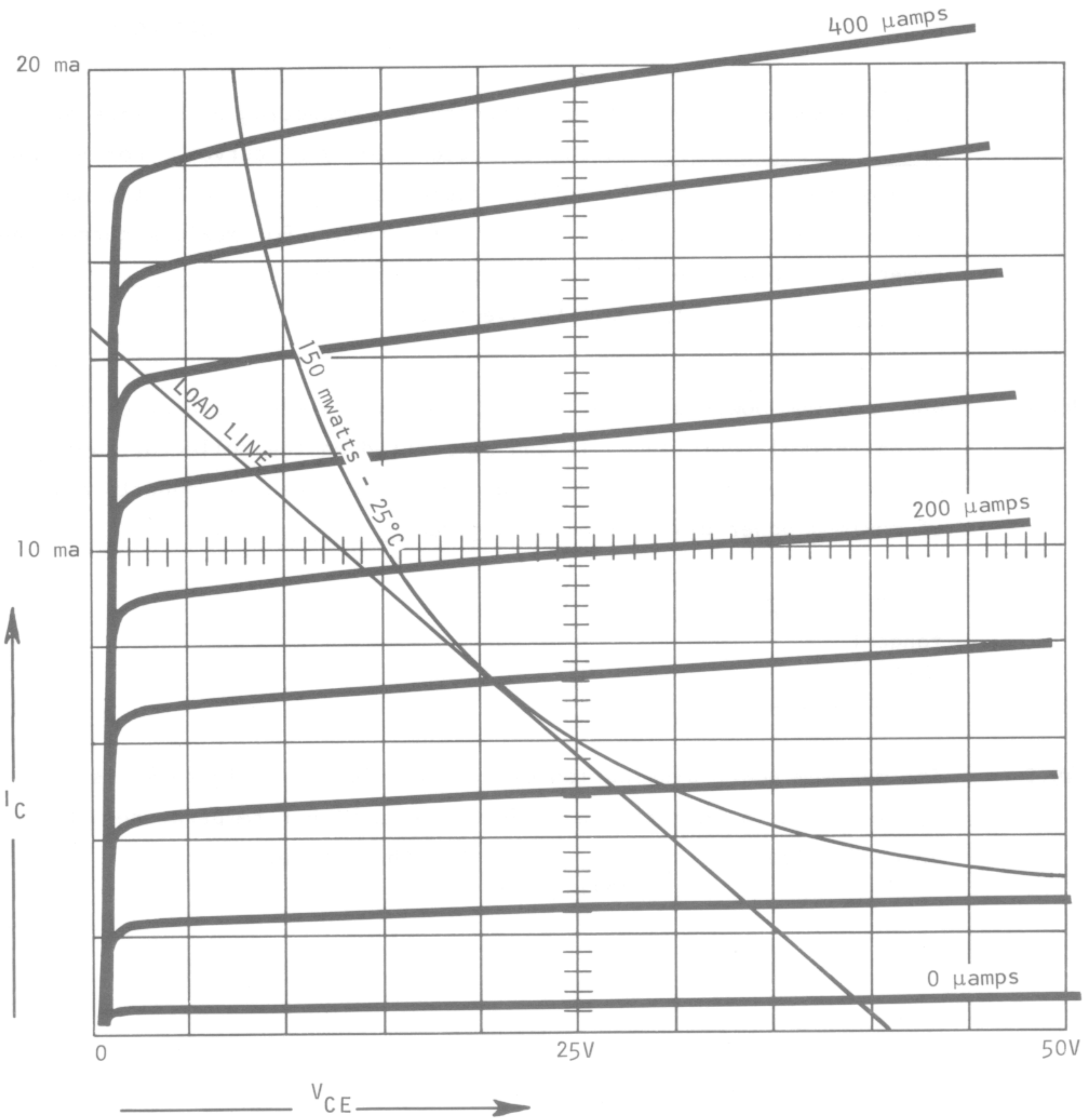
maximum power
tangent
current
temperature

45.2 The maximum power dissipation of the transistor in figure 45 is 150 mwatts at a temperature of 25°C. At a higher temperature, the maximum power dissipation is __________ (less, more) than this value.

temperature

45.3 In figure 45, the area below and to the left of the maximum power curve is the safe operating area at 25°C. The area above and to the right of the maximum power curve is the un-__________ area.

less



COLLECTOR FAMILY OF CURVES WITH MAXIMUM POWER CURVE AND LOAD LINE FOR MAXIMUM LINEAR POWER

FIGURE 45-A

45.4 A load line that is tangent to the maximum power curve and passes through the linear region of the curves will handle maximum ________________ power.

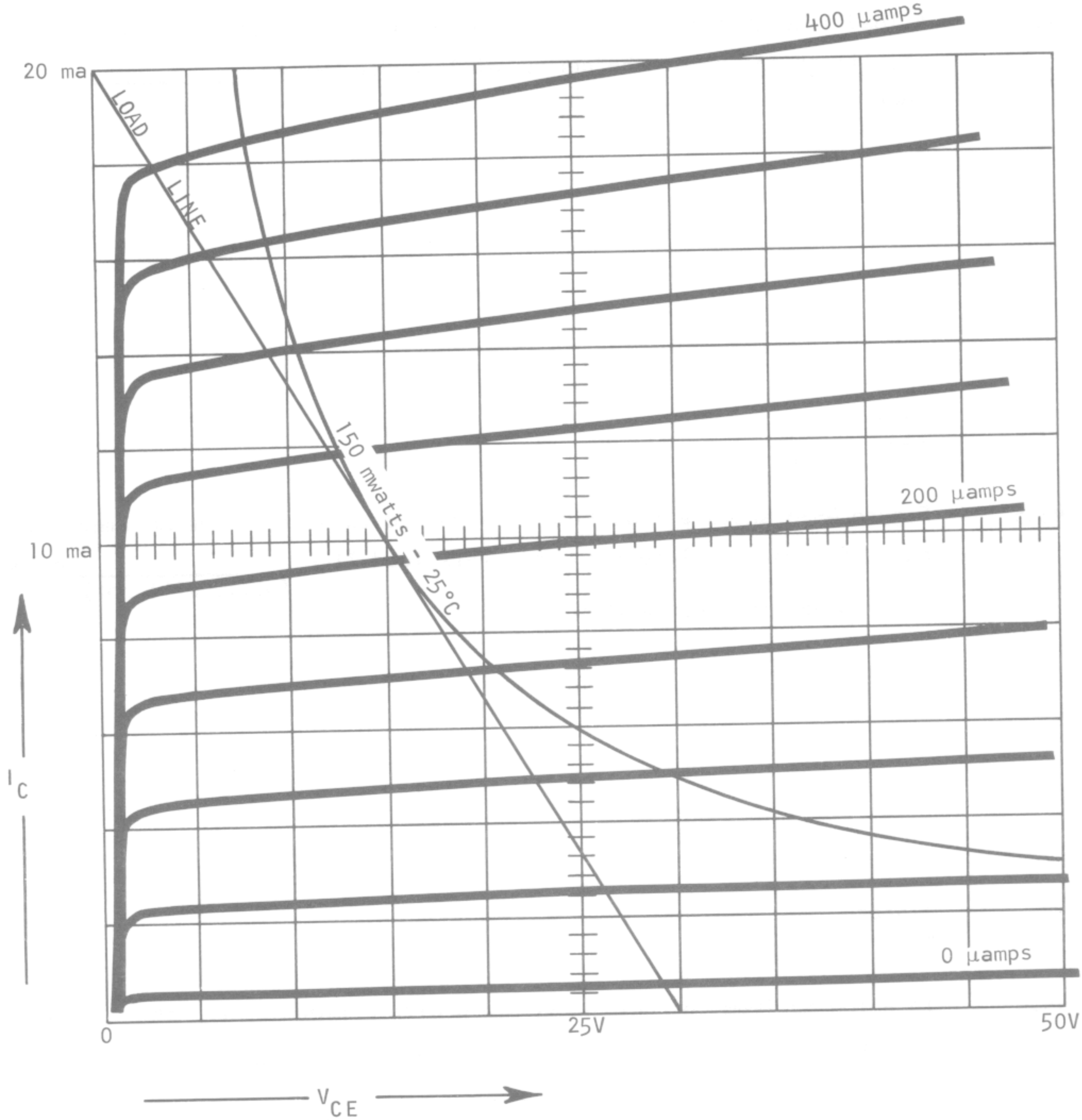
safe

45.5 Figure 45-A shows a load line constructed tangent to the maximum power curve for maximum linear power. This load line ______________ (will, will not) allow maximum possible current swing.

linear

45.6 To allow maximum current swing along with maximum power, the load line should intersect the maximum rated forward ______________ point and be tangent to the maximum ______________ curve.

will not



COLLECTOR FAMILY OF CURVES WITH MAXIMUM POWER CURVE AND LOAD LINE FOR MAXIMUM POWER WITH MAXIMUM POSSIBLE CURRENT SWING

FIGURE 45-B

45.7 Figure 45-B shows a load line tangent to the maximum power curve. The transistor in figure 45-B is rated at a maximum forward current of 20 mamps. The load line is designed to give maximum power and ____________ swing.

current
power

45.8 The load line for maximum current should be constructed from the maximum current point to a point ________________ to the maximum power curve.

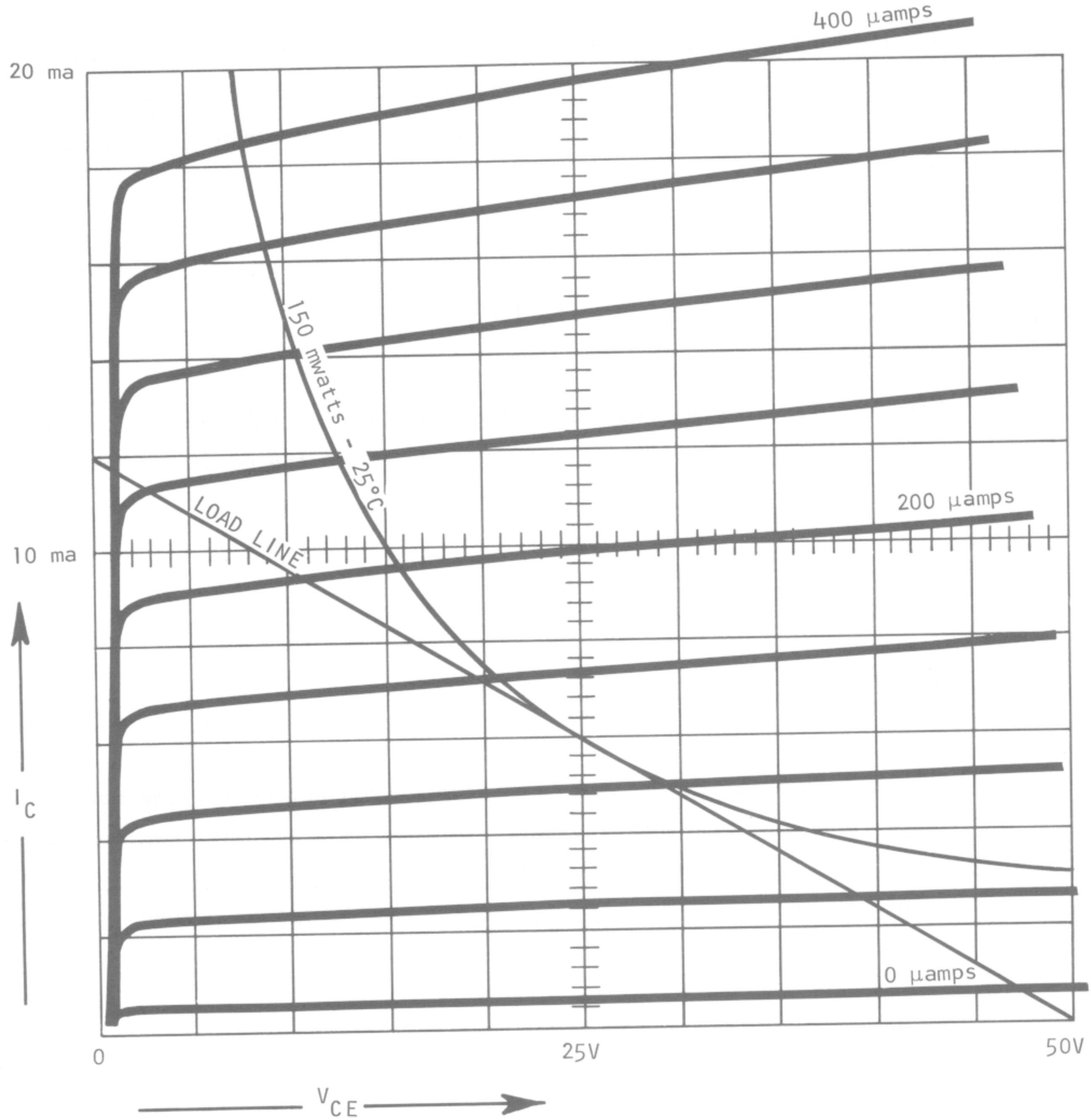
current

45.9** The maximum power curve is constructed by connecting all the maximum ________________ points together. A load line allowing maximum current swing and maximum power should intersect the _____________ ____________ point and be ________________ to the maximum power curve.

tangent

45.10 END OF SET

power
maximum current
tangent



COLLECTOR FAMILY OF CURVES WITH A MAXIMUM POWER CURVE AND A LOAD LINE FOR MAXIMUM POWER WITH MAXIMUM POSSIBLE VOLTAGE SWING

FIGURE 46

46 The load line, to insure maximum power and maximum possible voltage swing, should be ______________ to the maximum power curve and intersect the maximum ______________ point on the collector family of curves.

46.1 To insure maximum power, the load line should be tangent to the maximum power curve. To insure maximum possible voltage swing, the load line should also intersect the maximum ______________ point.

tangent
voltage

46.2 The maximum power curve is constructed by joining together all points on the collector family of curves equal to maximum power. The area to the left and below the maximum power curve is the ______________ area.

voltage

46.3 In figure 46, the load line is tangent to the maximum power curve. The maximum voltage of this transistor is 50 volts. The load line is constructed for maximum power and maximum voltage swing.

safe

46.4 The load line must not cross the maximum power dissipation curve. It is, therefore, placed ______________ to the maximum power dissipation curve.

voltage

46.5 To insure maximum possible voltage swing, the load line should also intersect the maximum ________________ point.

tangent

46.6** The load line for maximum power and voltage swing should be ___________ to the maximum power curve and intersect the maximum __________________ point.

voltage

46.7 END OF SET

tangent
voltage

47 Only a small amount of power is dissipated when the transistor is at the extremes of its operation. The extremes of the transistor's operation are termed __________ and __________. The most power is dissipated in the "____________" region between these two points (also known as the transient region).

47.1 A transistor in saturation has very little voltage across it, but a relatively large current flowing which results in a small power dissipation.

saturation
cut-off
active

47.2 At the opposite extreme of its operation, the transistor is "cut-off" and very little current is flowing. Although there may be a large voltage across the transistor at cut-off, there is very little ______________ dissipation.

no answer needed

47.3 At the two extremes of its operation, the transistor dissipates very little power. The power is dissipated between __________ and ____________.

power

47.4 The area between saturation and cut-off is termed the active region. The majority of the power is dissipated in the ________________ region.

saturation
cut-off

47.5 The active region is also termed the transient region. The transistor dissipates the greatest amount of power in the __________ or __________ region.

active

47.6** Very little power is dissipated at the extremes of the transistor's operation. The power is dissipated mainly in the ________________ or ________________ region.

active
transient

47.7 END OF SET

active
transient

48 The transistor, acting as a switch, ______________ (may, may not) have its load line cross over the maximum power curve if it has its resting states at the extremes of the transistor's operation (saturation and cut-off) and not in the active region. This will allow the switching of ____________ (less, more) power than if the transistor rests in the active region.

48.1 With the transistor operating as a switch in either the on or off condition, it may have its resting states at saturation and cut-off. Very little power is dissipated at ________________ and _________________.

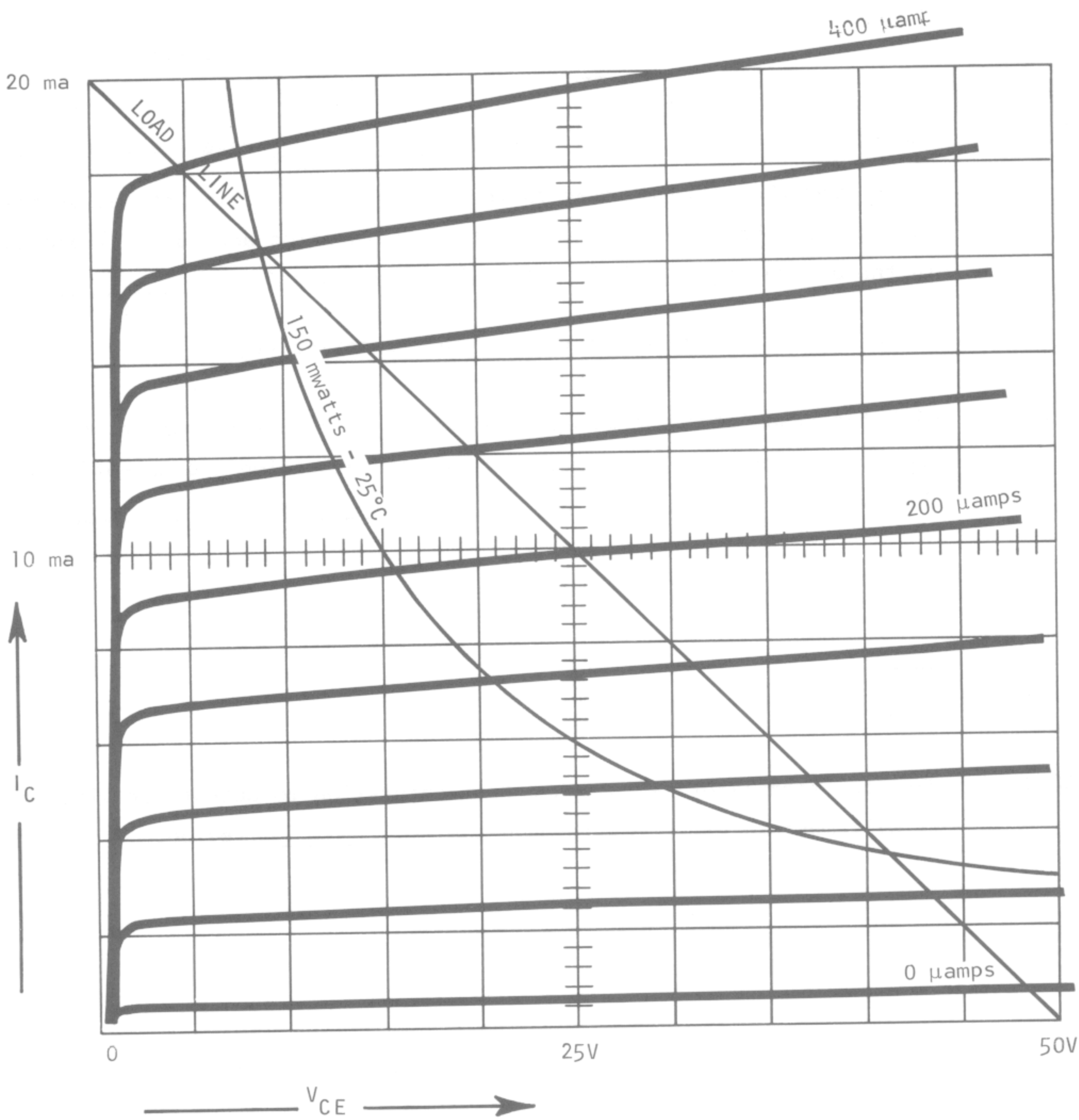
may
more

48.2 When the transistor is switched from saturation to cut-off or vice-versa, it will make an excursion through the _____________ region.

saturation
cut-off

48.3 Power will be dissipated during the excursion through the active region. The greater the amount of time spent in the active region, the ____________ (more, less) power will be dissipated.

active or transient



at 25°C $\begin{cases} B_{VCEO} = 50V \text{ (maximum voltage)} \\ I_C(max) = 20ma \text{ (maximum forward current)} \end{cases}$

TOTAL POSSIBLE POWER SWING = 1,000 mwatts

$I_C(max) \times V_{CE}(max) = 20ma \times 50V = 1{,}000$ mwatts

FIGURE 48

48.4 If the transistor does not spend too much time in the active region during its excursion and does not enter the active region too many times per second, the load line can be constructed between the maximum ___________ and ____________ points as shown in figure 48.

more

48.5 Operating the transistor as a switch between saturation and cut-off allows ______________ transistor power dissipation (during the transition)
(greater, less)
than when the transistor has a resting state in the active region.

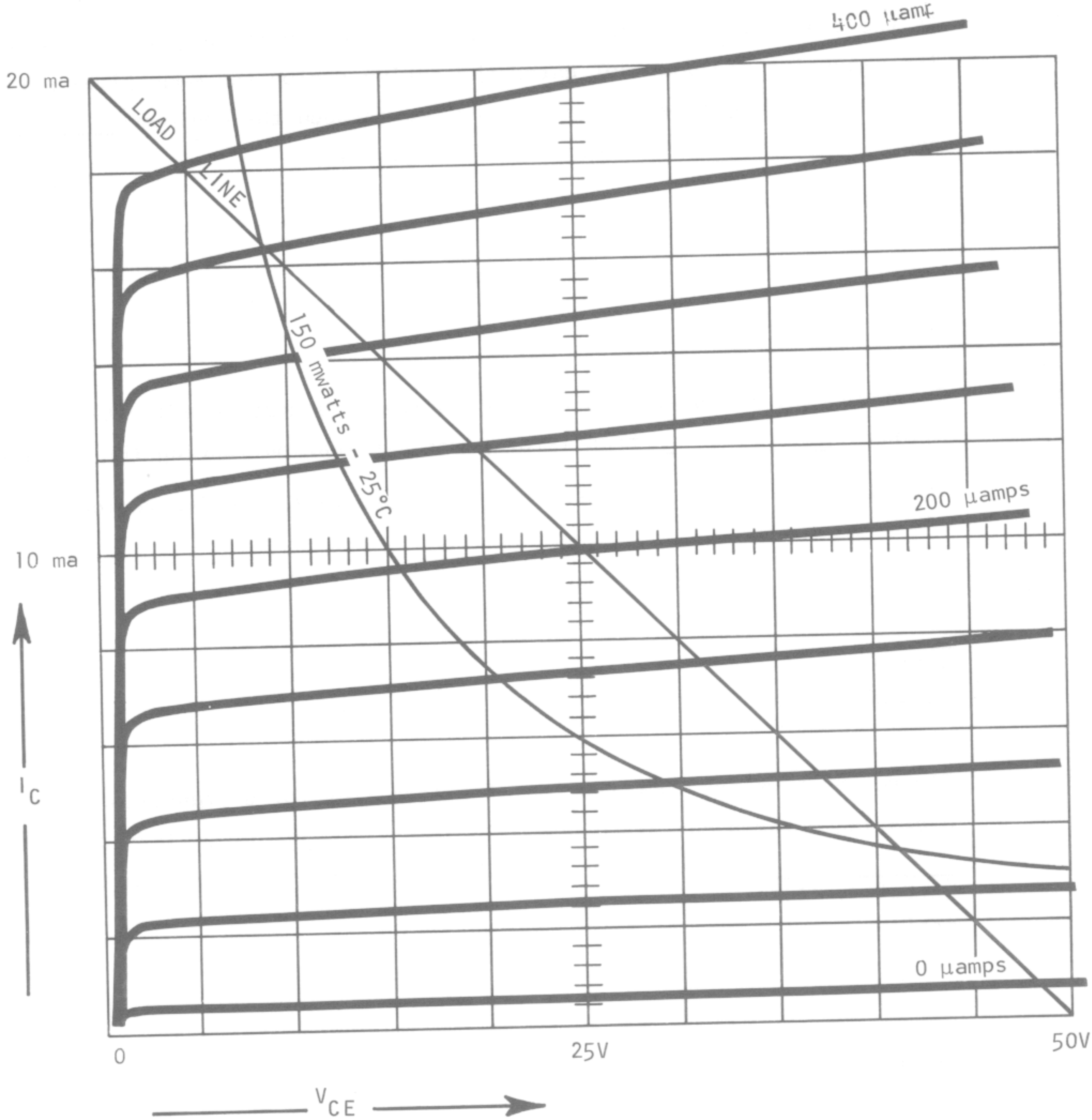
current
voltage

48.6 Figure 48 shows the construction of a load line for a transistor switch operating between cut-off and ________________________. This allows ______________ output power than when the transistor rests in the active
(greater, less)
region.

greater

48.7 The total possible power excursion in figure 48 is 1,000 mwatts since the transistor can make a transition from approximately 50V to 20ma and vice-versa. The maximum transistor power dissipation when the transistor rests in the active region is 150 mwatts.

saturation
greater



at 25°C $\begin{cases} B_{VCEO} = 50V \text{ (maximum voltage)} \\ I_C(max) = 20ma \text{ (maximum forward current)} \end{cases}$

TOTAL POSSIBLE POWER SWING = 1,000 mwatts

$I_C(max) \times V_{CE}(max) = 20ma \times 50V = 1,000$ mwatts

FIGURE 48

48.8 If the transistor in figure 48 had a resting state in the active region, the load line ________________ cross over the 150 mwatt curve.
(could, could not)

---

no answer needed

48.9 Operating in the cut-off to saturated switching mode allows greater power dissipation (and as a result, greater output power), as long as the transistor does not spend too much time in the ________________ region.

---

could not

48.10** Operating the transistor as a switch with one of its resting states in the active region ________________ allow the load line to cross the
(does, does not)
maximum steady state power curve. This allows ____________ power dissi-
(more, less)
pation and output power than the cut-off to saturated mode of operation for the same switching rate.

---

active or transient

48.11 END OF SET

---

does not
less

---

49 Operating a transistor in the cut-off to saturated switching mode has the advantage of low resting state power dissipation, but has the disadvantage of limiting ______________ rate because of the larger ______________ ______________ in the base as a result of driving the transistor into saturation.

49.1 When the transistor has its resting states at saturation and cut-off, there is little power dissipated when the transistor is at rest. When the transistor is saturated, the collector junction is ______________ biased.

repetition
stored charge

49.2 The collector becomes forward biased when the transistor enters saturation. The collector injects carriers into the base when it enters ____________ and becomes ____________ biased.

forward

49.3 The collector, becoming forward biased and injecting carriers into the base, results in an increase in the number of carriers stored in the base of the transistor. This increase in base stored charge is a result of the transistor entering ______________.

saturation
forward

49.4 On entering saturation, the stored charge in the base of the transistor is increased. The deeper the transistor is driven into saturation, the greater the __________ __________ in the base.

---

saturation

49.5 As with the basic diode, the stored charge must be removed before the transistor may be turned off. It takes a period of time to remove the __________ __________.

---

stored charge

49.6 Since it takes a period of time to remove the stored charge, the total switching time of the transistor is __________ (increased, decreased) when the transistor rests in saturation rather than the active region.

---

stored charge

49.7 An increase in total switching time of the transistor will __________ (increase, decrease) the maximum number of times the transistor can switch between its resting states per second.

---

increased

49.8 The maximum repetition rate of the transistor is the maximum number of times per second that it can switch from one resting state to the other and back again. Maximum repetition rate is reduced when the transistor is driven into ________________.

decrease

49.9 The deeper the transistor is driven into saturation, the lower the maximum __________ ___________.

saturation

49.10** The disadvantage of operating in the cut-off to saturated switching mode, is the increase in the ______________ ________________ in the base which limits maximum ___________________ ____________.

repetition rate

49.11 END OF SET

stored charge
repetition rate

50 In dealing with a transistor switch, the turn on time (t_{on}) is equal to the sum of ______ and ______ and the turn off time (t_{off}) is equal to the sum of ______ and ______. There is some current flow in the off state and some voltage across the transistor in the ______ state.

50.1 An ideal switch is one that allows zero current when open, infinite current when closed, and the ability to turn on and off in zero time. A transistor gives ______ of these qualities.
(all, none)

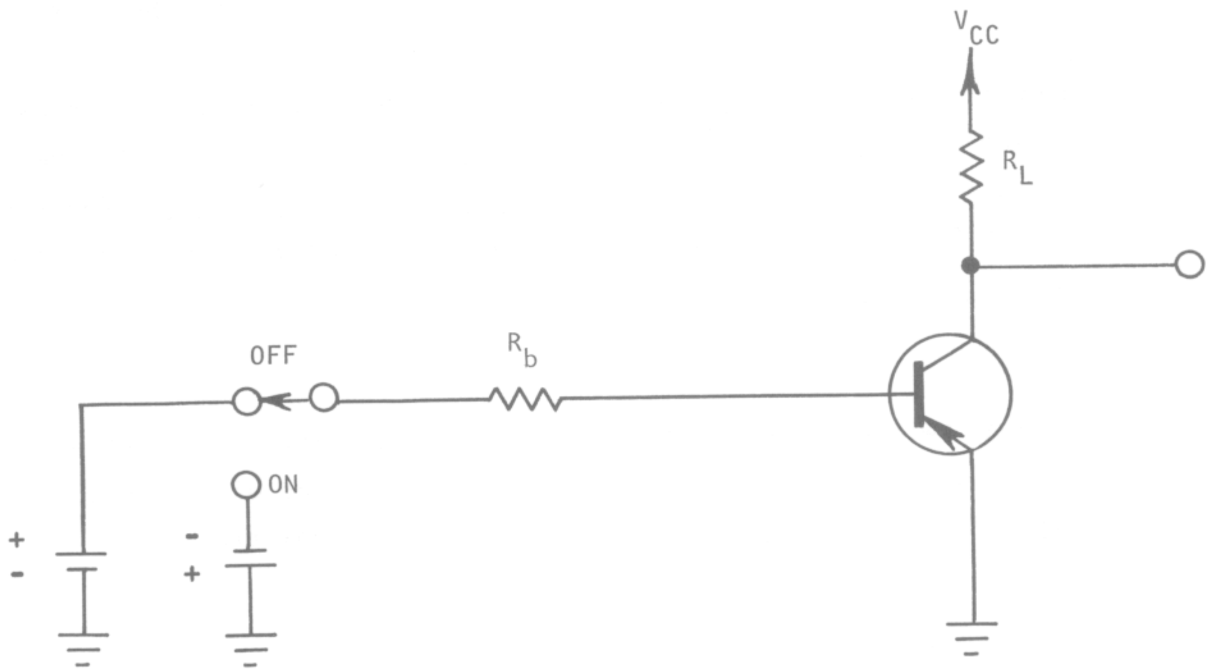
delay time (t_d)
rise time (t_r)
storage time (t_s)
fall time (t_f)
on

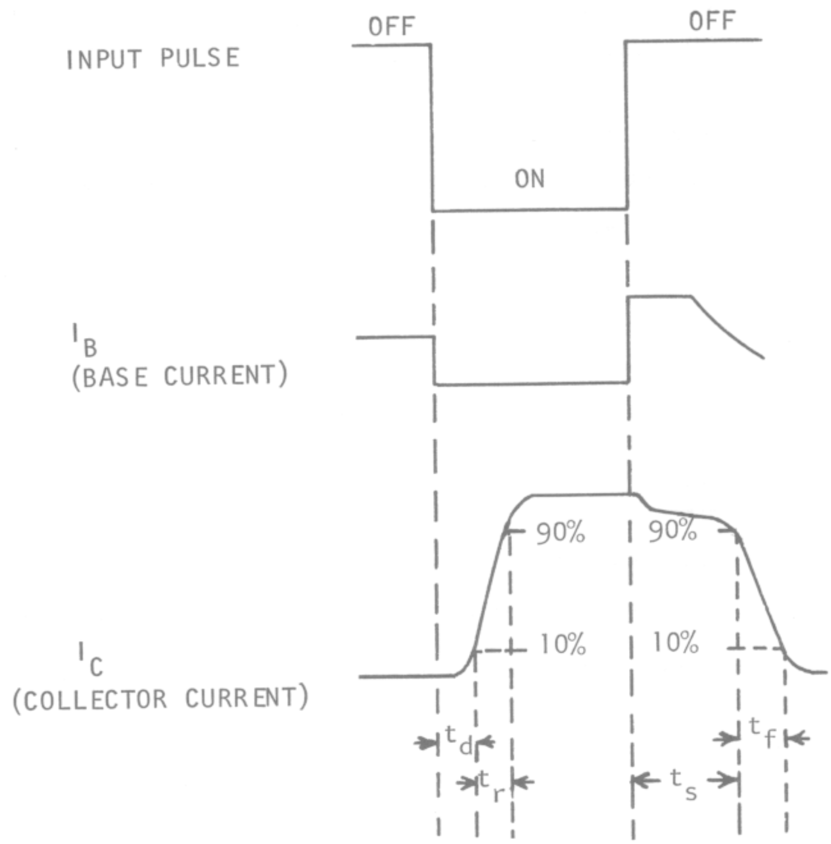
50.2 When the transistor is off, there is some current, due mostly to hole-electron pairs as formed by heat energy. The transistor in its off state will offer a high, but not a/an ______ resistance.

none

50.3 When the transistor is on and saturated, there will still be some voltage across the transistor which is given the symbol $V_{CE(sat)}$. In the on condition, the transistor will not be a/an ______ circuit.

infinite





t_d = DELAY TIME
t_r = RISE TIME
t_s = STORAGE TIME
t_f = FALL TIME

FIGURE 50

50.4 When the transistor is turned on, it will take a period of time for the stored charge to be established and for the recombination and diffusion to reach an equilibrium rate. In other words, it will take a period of time for the injected carriers to move across the base to the collector. When a change is instigated at the emitter junction, there is some ______________ before the change occurs in the collector.

zero resistance (short)

50.5 Figure 50 shows a transistor in a circuit to check its switching characteristics. The time between the instigation of the input change and the point that collector current has changed, 10% of its total excursion, is termed ______________ time (t_d).

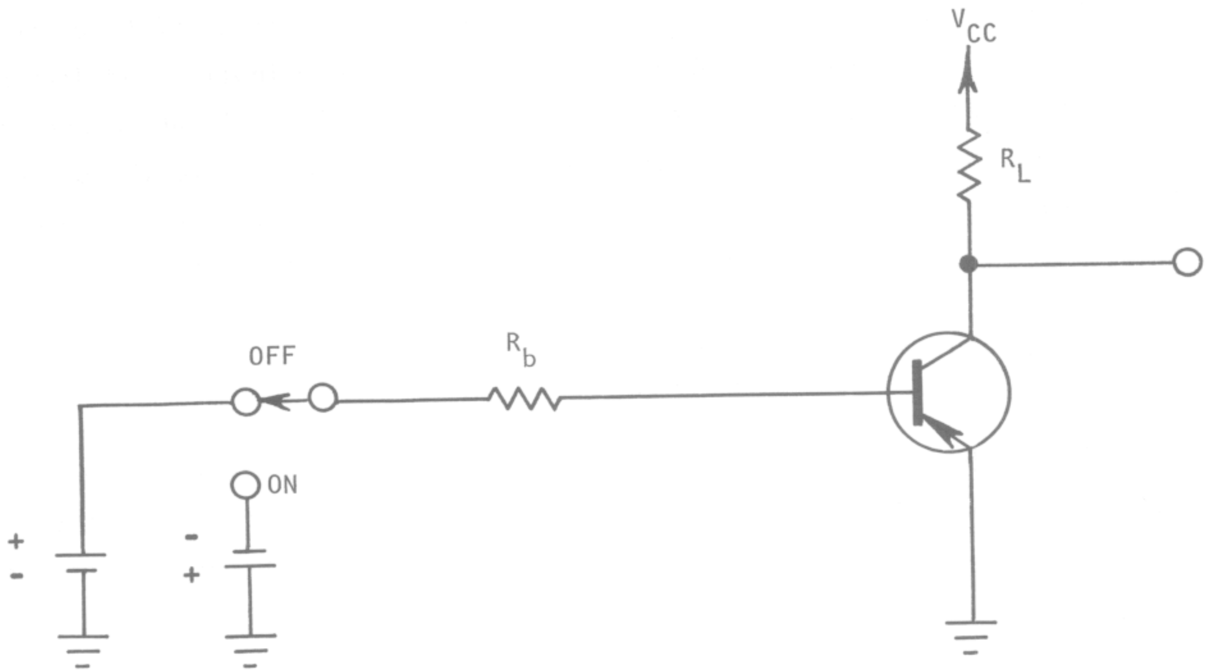
time (delay)

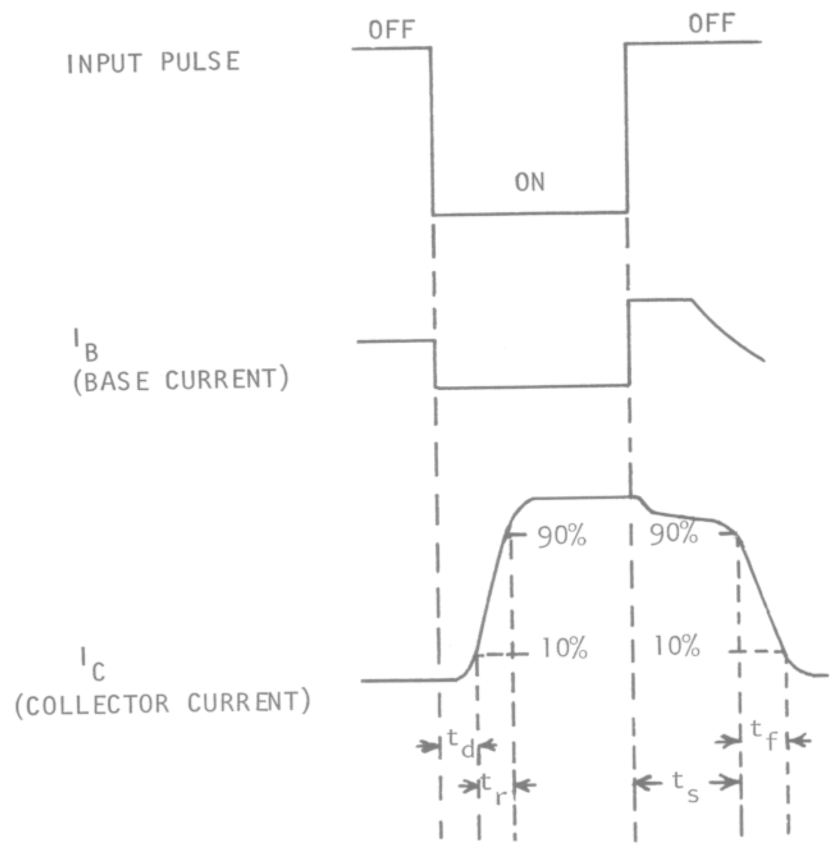
50.6 Delay time (t_d) is the time it takes to move carriers into the __________ to establish the stored charge of __________________ (minority, majority) carriers.

delay

50.7 In figure 50, the time between the points on the leading edge of the waveform where collector current has changed from 10% to 90% of its total excursion is termed ________________ time.

base
minority





t_d = DELAY TIME

t_r = RISE TIME

t_s = STORAGE TIME

t_f = FALL TIME

FIGURE 50

50.8 Rise time is determined by the charge control time constant in the base, governed by minority carrier lifetime. The sum of delay time (t_d) and rise time (t_r) is the transistor's __________ __________ time (t_{on}).

rise

50.9 In figure 50, the time between the fall of the input pulse and the point that collector current falls to 90% of its maximum value is termed __________ time (t_s).

turn on

50.10 Storage time is increased when the forward biased collector injects carriers into the base when the transistor enters __________.

storage

50.11 Holding the transistor out of saturation will reduce __________ time.

saturation

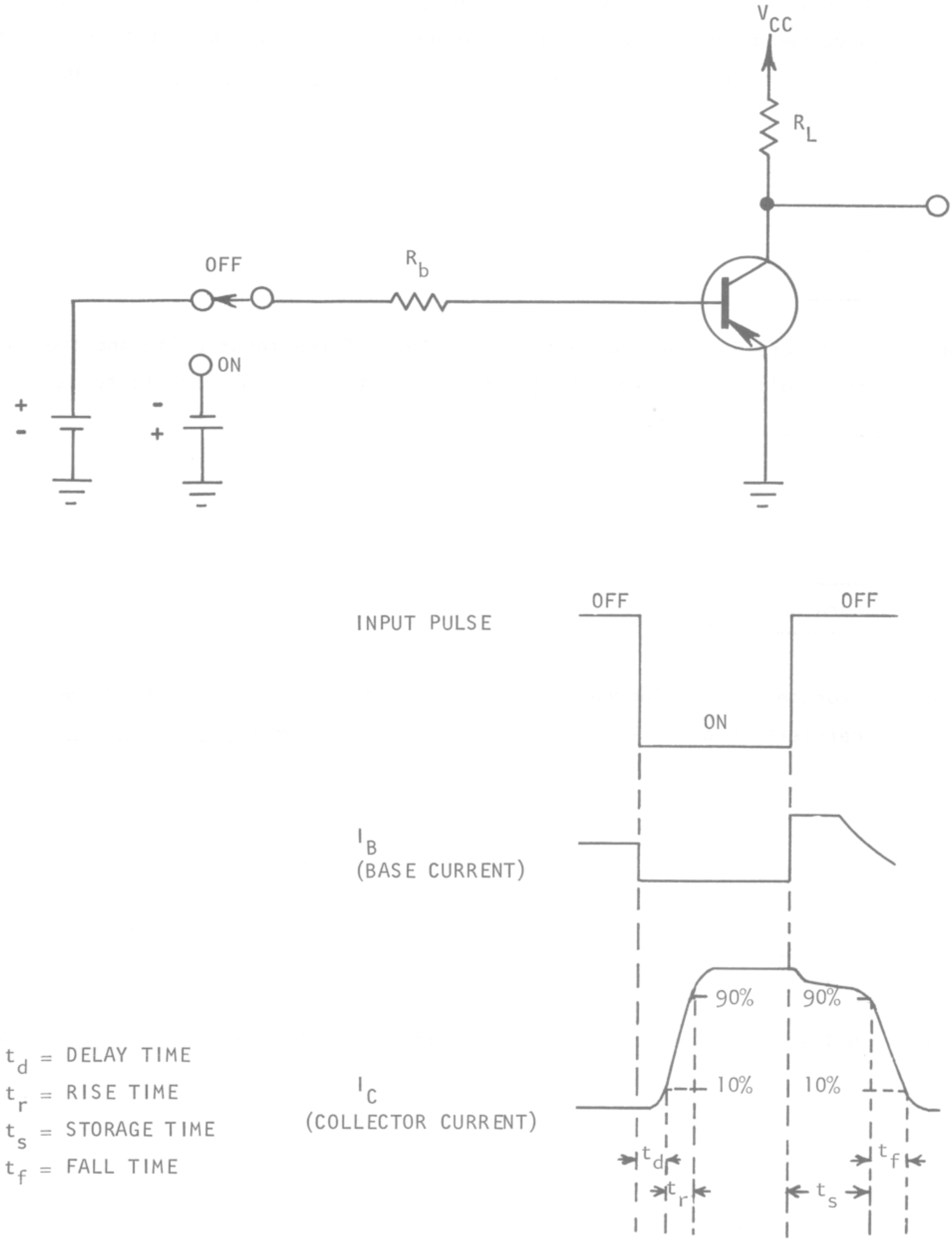

VCC
RL
Rb
OFF
ON
INPUT PULSE
OFF
ON
OFF
IB
(BASE CURRENT)
IC
(COLLECTOR CURRENT)
90%
10%
90%
10%
td
tr
ts
tf
td = DELAY TIME
tr = RISE TIME
ts = STORAGE TIME
tf = FALL TIME

FIGURE 50

50.12 The time between 90% and 10% on the falling portion of the collector current waveform in figure 50 is termed ____________ time (t_f).

---

storage (switching)

50.13 The sum of storage time (t_s) and fall time (t_f) gives the transistors ________ __________ time (t_{off}).

---

fall

50.14 Turn off time (t_{off}) = storage time (t_s) + fall time (t_f) and turn on time (t_{on}) = delay time (t_d) + rise time (t_r).

$$t_{off} - t_f = \_\_\_\_\_\_\_\_\_\_$$

---

turn off

50.15** $t_s + t_f =$ __________ and $t_d + t_r =$ ____________

The transistor is less than an ideal switch as there is some __________ in the off state and some ____________ across the transistor in the on state.

---

storage time (t_s)

50.16 END OF SET

turn off time (t_{off})
turn on time (t_{on})
current
voltage

51 The switching times of fast transistors may be checked using the Tektronix Type 290 Transistor Switching Time Tester or the Type 292 Semiconductor Tester in conjunction with a sampling system. The ____________ checks the transistor in a specific configuration while the ____________ allows the circuit to be inserted with the transistor.

51.1 The manual switch used in the previous set is not fast enough to give accurate readings of switching times. In practice, electrically driven switches are used.

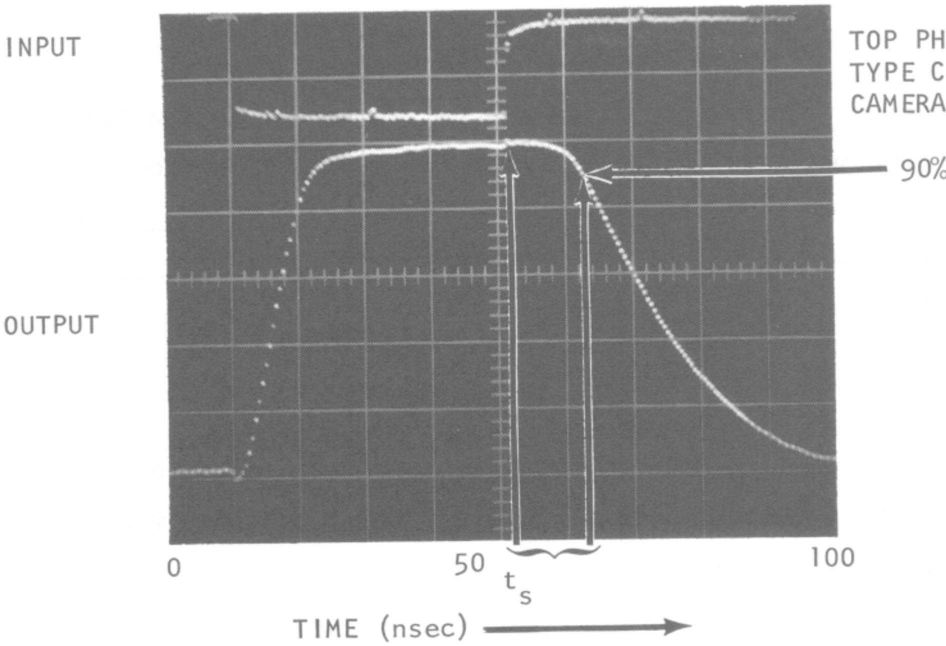
290
sampling
567

51.2 The 290 Switching Time Tester provides a circuit, bias voltages, and input and output jacks along with facilities to drive the input of the transistor. The output is monitored with a sampling oscilloscope. Both the input driving signal and the transistor's output may be monitored.

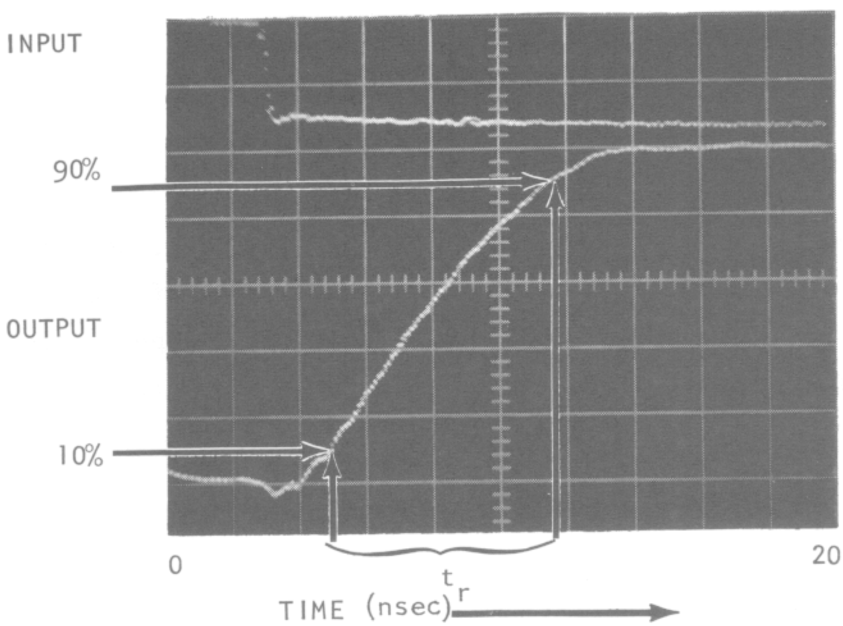
no answer needed

51.3 The input pulse and the transistor's output can be monitored and measurements taken of switching times exactly as in set 50 when the 290 and a sampling system are used. These measurements are similar to the diode switching time measurements made in volume 2 of this series.

no answer needed

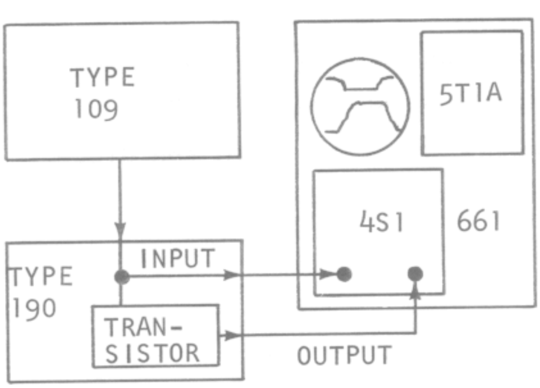


TOP PHOTOS TAKEN WITH A TYPE C-12 OSCILLOSCOPE CAMERA



TEST SET-UP

TEKTRONIX TYPE 661 SAMPLING OSCILLOSCOPE, 4S1 DUAL TRACE SAMPLING VERTICAL, 5T1A TIMING UNIT, TYPE 109 PULSE GENERATOR, AND TYPE 290 TRANSISTOR SWITCHING TIME TESTER



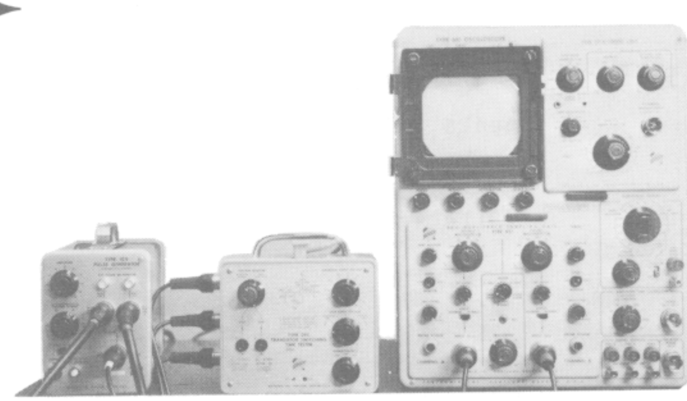


FIGURE 51

51.4 Figure 51 shows the 290 being used with the Tektronix Type 661 sampling oscilloscope. It should be remembered that the risetime considerations, when making measurements as discussed in volume 2, are valid for these measurements as well.

no answer needed

51.5 The dual trace ability allows the observance of the input and output pulse, simultaneously. The risetime measurement in figure 51 is approximately ____________ nsec.

no answer needed

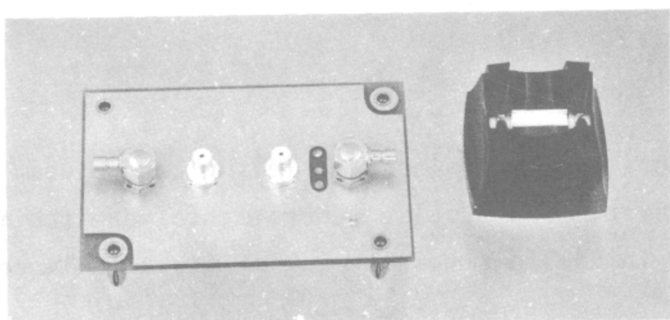
51.6 The storage time in figure 51 is approximately ____________ nsec.

7

51.7 The 290 Transistor Switching Time Tester can be used in conjunction with a sampling system and a pulse generator to make the measurements described in set 50. This allows measurement of fractional nanosecond switching times.

11

TEKTRONIX TYPE 292 SEMICONDUCTOR TESTER
AND ACCESSORIES



<u>FIGURE 51-A</u>

51.8 The Type 292 Semiconductor Tester (shown in figure 51-A) allows the circuit for the transistor to be selected and built while maintaining the transistor in an optimum measurement environment.

---

no answer needed

51.9 The Type 292 does not limit the measurements to a specified circuit, but allows the measurement circuit to be fabricated on special test fixtures provided.

---

no answer needed

51.10 The Type 292 does not limit the switching time measurements to a specified ________________.

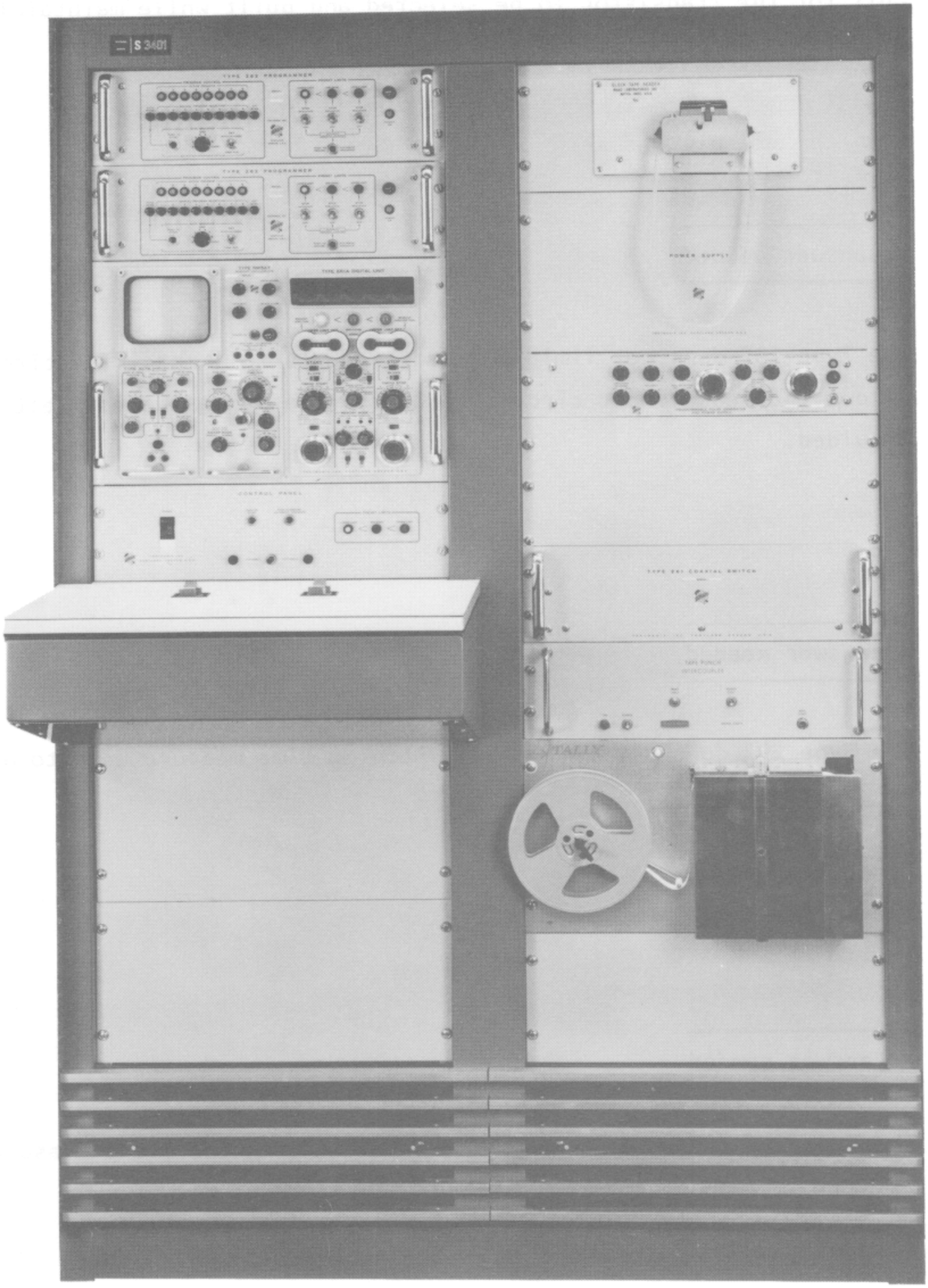
---

no answer needed

51.11 The Type 292 (shown in figure 51-A) can be used for diode measurements as well as ________________ measurements.

---

circuit



TEKTRONIX TYPE S-3401 SYSTEM

FIGURE 51-B

51.12 For transistor manufacturers, the system of measurement becomes more complex. A great number of measurements must be made in a short period of time. Figure 51-B shows a programmed measurement system for transistors (and other semiconductor devices).

---

transistor

51.13 The system in figure 51-B is the Tektronix S-3401 system. This is a programable, computer type system that can be used for rapid, sequential measurements of fast transistors. (Also, other semiconductor devices and integrated circuits.)

---

no answer needed

51.14** The Type ____________ Transistor Switching Time Tester or the Type ______ Semiconductor Tester may be used in conjunction with a pulse generator and sampling system to check fast transistor switching times.

---

no answer needed

51.15 END OF SET

52 A __________ __________ capacitor will reduce the time involved in establishing the base charge when turning on a transistor and removing the base charge when turning off a conducting transistor. The optimum value of speed-up capacitor may be found by dividing the transistor's stored charge by the value of ______________ on the speed-up capacitor.

52.1 The stored charge in the base of a transistor must be established to turn on a transistor and must be removed to turn the transistor off. Sufficient current must be supplied to establish and remove the ____________ __________________ to turn a transistor on and off.

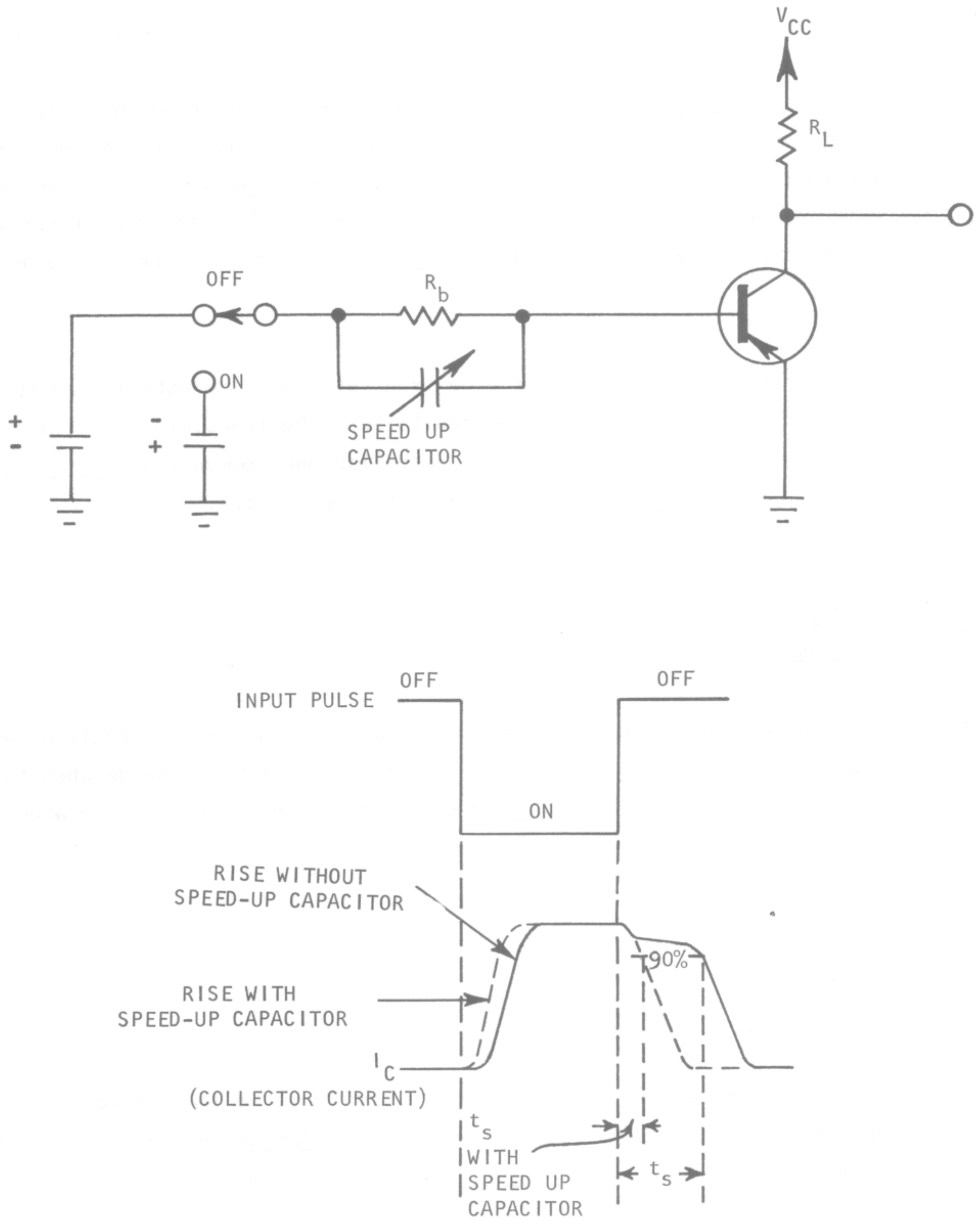
speed-up
voltage

52.2 A capacitor connected across the resistance in the input circuit of a transistor will speed up the establishment of the base charge when turning the transistor on and speed up the removal of the stored charge when turning the conducting transistor off.

stored charge
base charge

52.3 The output resistance of the driving source must be low for best effect of the added capacitor. Since the capacitor speeds up the switching time, it is referred to as a __________ __________ capacitor.

no answer needed



VCC
RL
OFF
Rb
ON
SPEED UP
CAPACITOR
OFF
OFF
INPUT PULSE
ON
RISE WITHOUT
SPEED-UP CAPACITOR
RISE WITH
SPEED-UP CAPACITOR
90%
IC
(COLLECTOR CURRENT)
ts
WITH
SPEED UP
CAPACITOR
ts

FIGURE 52

52.4 Figure 52 shows the added speed-up capacitor and its effect on the output waveform. The optimum value of speed-up capacitor to accomplish this will have a charge equal to the transistor's ________________ charge.

---

speed-up

52.5 The charge on the speed-up capacitor speeds up the establishment and removal of the stored charge when the speed-up capacitor is of optimum value. While observing the transistor's switching characteristics on the 290 Switching Time Tester or the 292 Semiconductor Tester, the speed-up capacitor can be adjusted for minimum switching ______________.

---

stored or base

52.6 Letting Q_s indicate total transistor stored charge, and Q_c indicate the charge on the speed-up capacitor, Q_c should be approximately equal to ___________ for optimum speed-up action.

---

times

52.7 $Q_c \cong Q_s$ for optimum speed-up operation.

$Q_c = CE$ where C is the capacity of the speed-up capacitor and E is the voltage across the capacitor. $Q_c = Q_s = CE$

$$\frac{Q_s}{E} = \underline{\qquad ? \qquad}$$

Q_s

52.8 The optimum value of speed-up capacitor is found by dividing the transistor's stored charge by the voltage on the speed-up capacitor. When this value of capacitor is used, the charge on the capacitor will equal the transistor's _______________ _______________.

C (value of speed-up capacitors)

52.9** A speed-up capacitor across the input driving resistance will reduce _______________ times. The optimum value of speed-up capacitor is equal to the transistor's _______________ _______________ divided by the voltage on the speed-up capacitor.

---

stored charge

52.10 END OF SET

---

switching
stored charge (Q_s)

---

53 An obvious method of reducing saturated mode storage time is to keep the transistor out of saturation. This is termed __________ ________ switching and the transistor operates between cut-off and the ___________ region. Current mode switching allows ___________ (more, less) transistor power dissipation than saturated mode switching.

53.1 Not allowing the collector to become forward biased will prevent the collector from injecting carriers into the base. The collector voltage must be held ______________ (less, greater) than $V_{CE}(sat)$ to accomplish this.

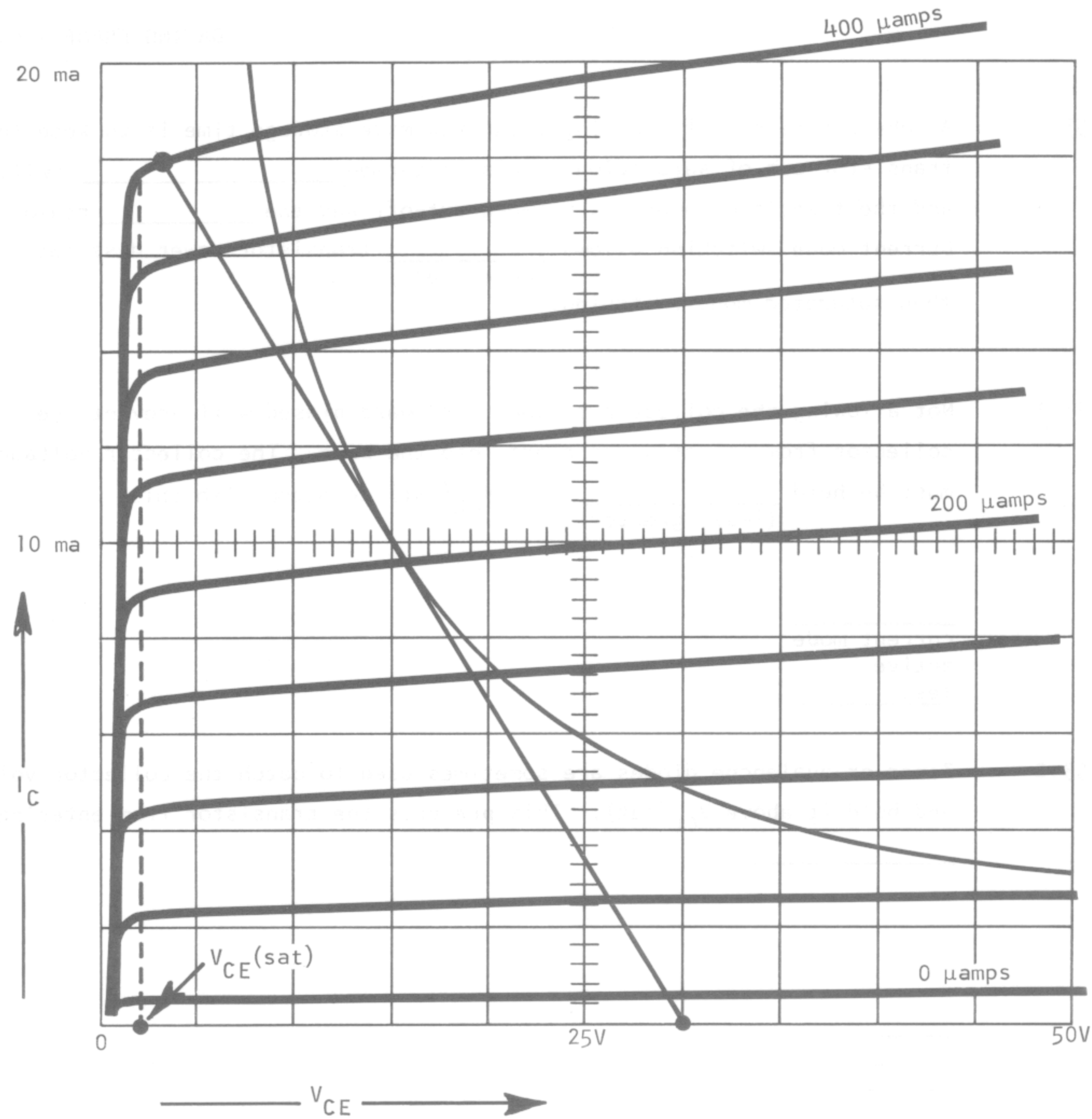
current mode
active
less

53.2 Zener or avalanche diodes are sometimes used to catch the collector voltage and hold it above $V_{CE}(sat)$. This prevents the transistor from entering _______________.

greater

53.3 When the transistor is held out of saturation, it switches from cut-off to a high current point and this is termed _____________ mode switching.

saturation



CURRENT MODE SWITCHING
CUT-OFF TO ACTIVE REGION

FIGURE 53

53.4 Current mode switching has the transistor switching between cut-off and the ____________ region. This switching mode allows ____________ (less, more) transistor power dissipation during switching than the off to saturated switching mode.

current

53.5 Figure 53 shows the load line for current mode switching. The collector voltage is caught in the active region and not allowed to go below ______________.

active
less

53.6 In figure 53, the <u>on</u> resting state is held below the maximum power curve. A disadvantage of current mode switching is the reduction in ____________ dissipation capabilities with reference to the cut-off to ______________ switching mode.

V_{CE} (sat)

53.7** Transistor storage time can be reduced by holding the transistor out of ______________. This switching mode is termed ______________ mode switching. This mode can allow the transistor to dissipate ____________ (more, less) power during switching than the saturated mode.

power
saturated

53.8 END OF SET

saturation
current
less

54 Current mode switching offers ______________ (higher, lower) speed, ______________ (higher, lower) noise, ______________ (more, less) critical transistor requirements and ______________ (more, less) complicated d-c design problems than the saturated switching mode.

54.1 Current mode switching reduces the storage time which reduces total switching time over the saturated switching mode. Current mode switching offers a ______________ (higher, lower) maximum repetition rate than the saturated mode.

high
low
less
more

54.2 When the transistor enters saturation, both the emitter and collector inject carriers into the base resulting in an increase in the noise level. The current mode switch does not enter saturation and generates ______________ (more, less) noise than the saturated mode.

higher

54.3 $V_{CE}(sat)$, $h_{FE}(sat)$, breakdown voltage from emitter to base, thermal and leakage currents are less critical with the current mode, since the transistor does not enter ______________.

less

54.4 The transistor must remain out of saturation under worst case conditions, using the current switching mode. This increases the complexity of the d-c design considerations over the ___________ mode.

---

saturation

54.5 Since the current mode switch has a resting state in the ____________ region, care must be taken that maximum power is not exceeded.

---

saturated

54.6** The advantages of current mode switching over saturated mode switching are ____________ (faster, slower) switching speed, ___________ (less, more) critical transistor parameters. The disadvantages are ____________ (higher, lower) resting state power dissipation and ___________ (less, more) complicated d-c design considerations than the off to saturated mode.

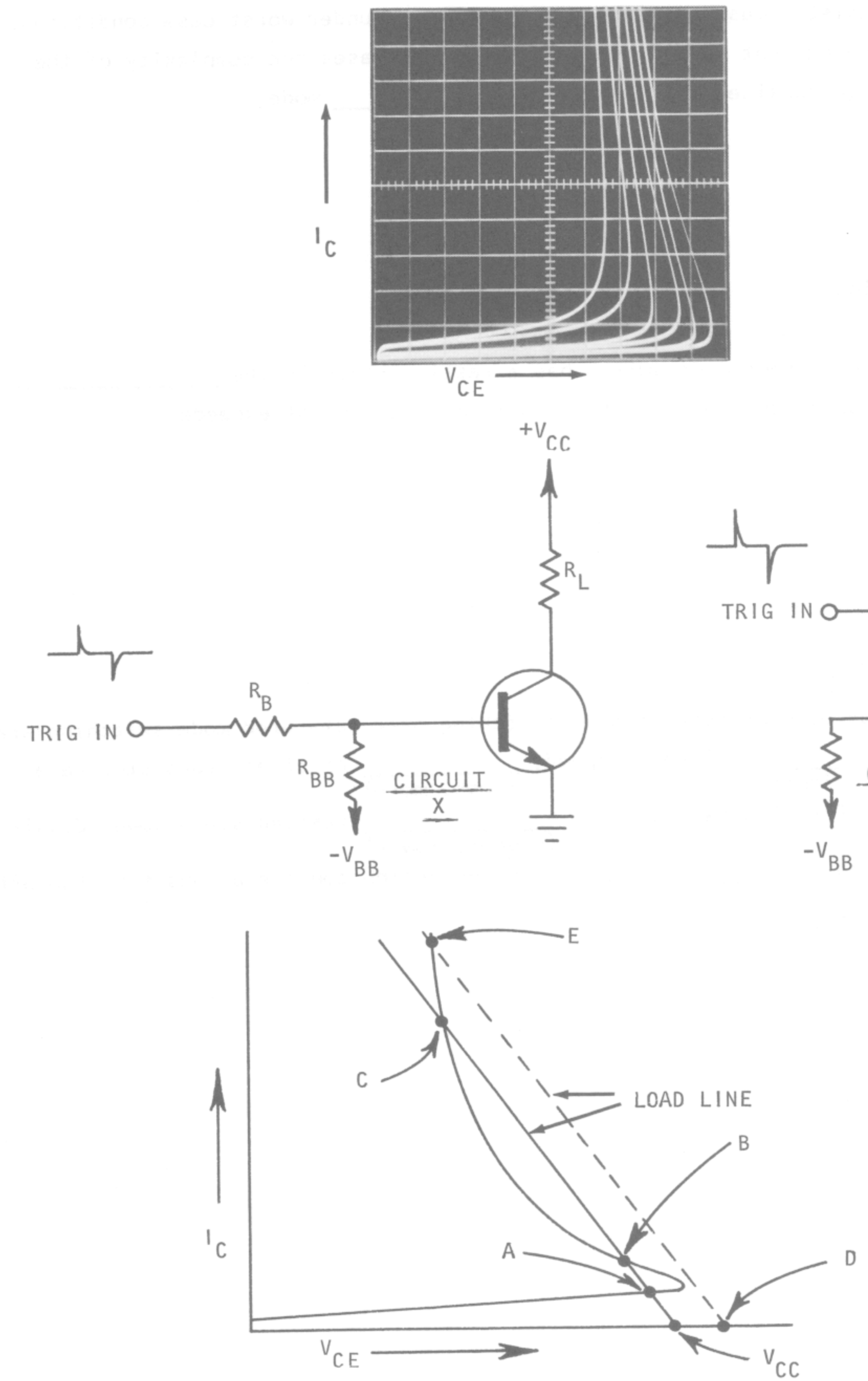
---

active

54.7 END OF SET

---

faster
less
less
higher
more



I_C
V_CE
+V_CC
R_L
TRIG IN
R_B
R_BB
CIRCUIT X
-V_BB
+V_CC
R_L
TRIG IN
C_C
CIRCUIT Y
-V_BB
E
C
LOAD LINE
B
A
D
I_C
V_CE
V_CC

FIGURE 55

55 The avalanche switching mode has the transistor switching between cut-off and a point in the _________ ___________ region. The switching time can be on the order of fractional ___________ seconds. Avalanche switching can be triggered in the base or ____________ circuit.

55.1 One resting state of an avalanche switching transistor is just out of avalanche breakdown and the other is in the _________________ breakdown region.

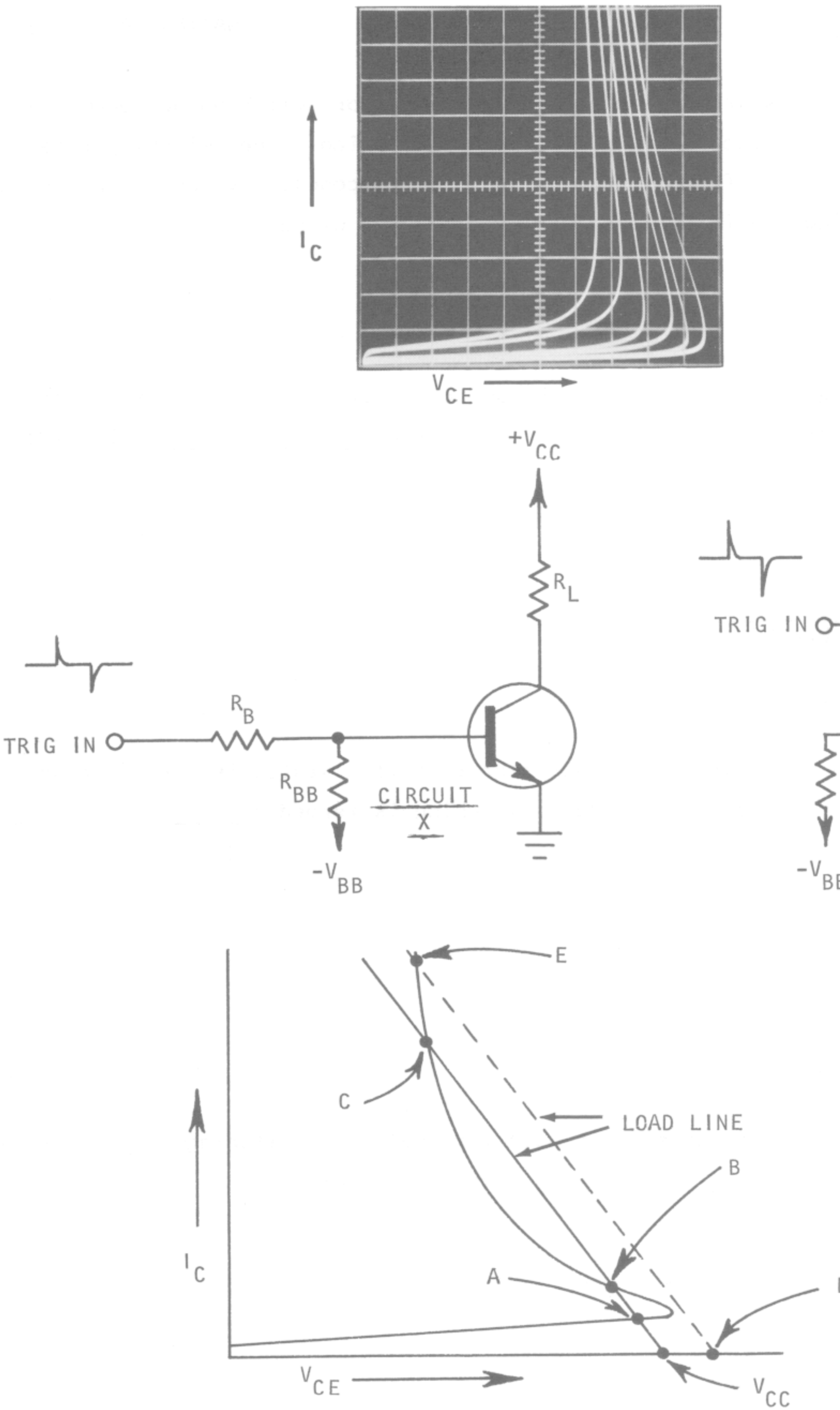
avalanche breakdown
nano
collector

55.2 The action of causing the transistor to switch states is termed triggering and the applied energy to cause switching is termed a _______________.

avalanche

55.3 Figure 55 shows transistors biased for avalanche switching. V_{CC} is very near the __________ ____________ voltage point.

trigger



I_C
V_{CE}
$+V_{CC}$
R_L
TRIG IN
R_B
R_{BB}
CIRCUIT X
$-V_{BB}$
$+V_{CC}$
R_L
TRIG IN
C_C
CIRCUIT Y
$-V_{BB}$
E
C
LOAD LINE
B
I_C
A
D
V_{CE}
V_{CC}

FIGURE 55

55.4 The transistors in figure 55 must operate on the load line. The transistor can operate only at points A, B and C with the load line and value of ____________ shown.

avalanche breakdown

55.5 Consider the transistor in circuit X in figure 55 as operating at point A on the curve. Forcing more current with V_{CC} constant will cause the operating point to shift to B and then to ______________.

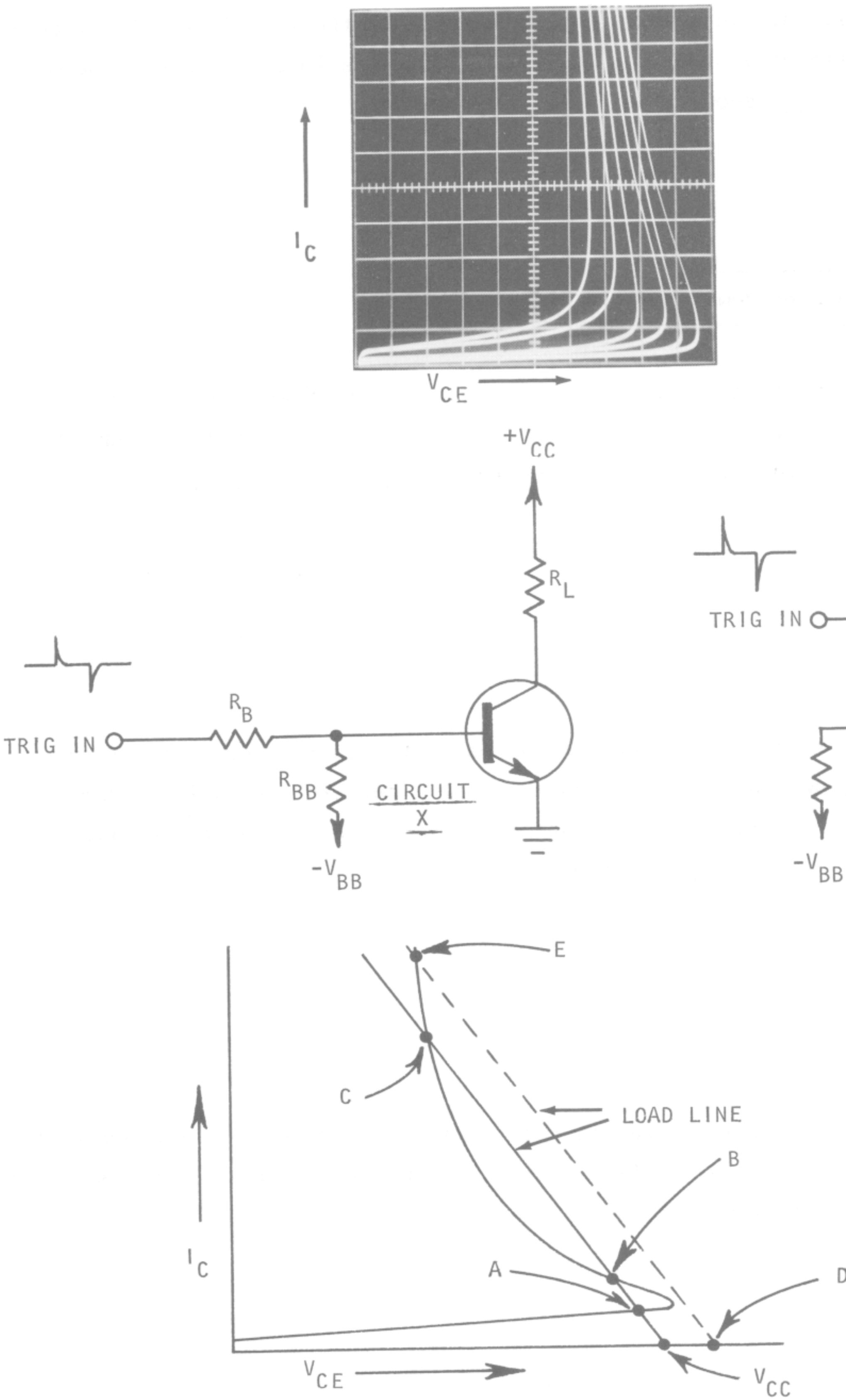
V_{CC}

55.6 The input trigger in circuit X increases the current causing the transistor to switch to point C on the load line. This transition can take place in a fraction of a nanosecond. Avalanche switching can give a very _____________ switching time.

C

55.7 A trigger is needed to return the transistor to point A. The avalanche switching mode shown in figure 55 is bi-stable, meaning the transistor has _________(#) stable states.

fast



I_C
V_CE
+V_CC
R_L
TRIG IN
R_B
R_BB
CIRCUIT X
-V_BB
+V_CC
R_L
TRIG IN
C_C
CIRCUIT Y
-V_BB
E
C
LOAD LINE
B
A
D
I_C
V_CE
V_CC

FIGURE 55

55.8 The circuit Y in figure 55 has the trigger applied to the collector. The trigger will increase or decrease the collector voltage depending on its polarity.

two

55.9 With circuit Y operating at point A in figure 55, a positive going trigger will increase the applied collector voltage and the load line will move to point D. At that instant, the only point on the load line that the transistor can exist is at point ________.

no answer needed

55.10 Once triggered to point E in figure 55, the transistor in circuit Y will rest at point ______________ when the trigger is no longer present.

E

55.11 In order to move back to point A from point C, the collector must be triggered in the opposite polarity. Circuit Y in figure 55 is _________-stable and switches between resting points __________ and __________.

C

55.12 Avalanche mode switching can be accomplished in fractional nanoseconds, allowing very fast rising outputs. The collector supply voltage is near the __________ ____________ voltage.

bi
A
C

55.13** The two resting states of an avalanche switching transistor are just below the __________________ _______________ point and in the __________ _________________ region. Fractional __________second risetimes are possible with this switching mode.

avalanche breakdown

55.14 END OF SET

avalanche breakdown
avalanche breakdown
nano

56 The main high frequency limiting factors in the transistor are collector and emitter junction ____________, base ____________ time, and the spreading out of the carriers in the ____________.

56.1 Carriers injected from the emitter into the base are existing as minority carriers in the base. They must diffuse the entire ________ thickness to reach the collector.

capacitance
transit
base

56.2 As the applied frequency is increased, a frequency will be reached where the time involved in the transit of the carriers across the base causes phase shift and loss of gain. The greater the transit time, the ____________ (lower, higher) the frequency at which phase shift and loss of gain occur.

base

56.3 There is capacitance across the collector and emitter junctions. This capacitance will change with the amount of current and the voltage across the junction. This capacitance shunts the junction and, as frequency is increased, will have ____________ (a greater, less) effect.

lower

56.4 The collector junction is reverse biased and the emitter junction is forward biased in amplifier configurations. The ____________ junction will have the highest resistance.

a greater

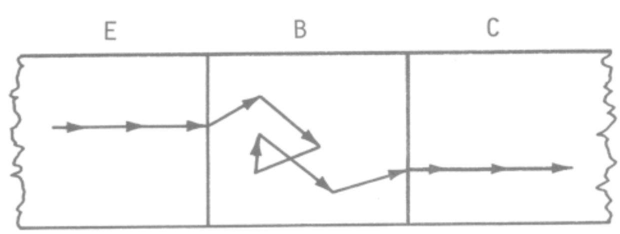
56.5 The effects of collector junction capacitance will occur at a lower frequency than the effects of emitter junction capacitance as collector junction capacitance is shunting a ______________ resistance.
(higher, lower)

collector

56.6 The carriers, on entering the base, spread out or diffuse in the base. They strike atoms in the structure and bound off, taking an erratic path in the base. Carriers do not travel in a direct route from emitter to ____________ through the ____________.

higher

56.7 The diagram shows a typical path a current carrier might take in its transit through the base. Several carriers entering the base at the same time could well arrive at the collector at ________________ times.



collector
base

56.8 The wider the base, the ____________ opportunity the carriers will have
(more, less)
to spread out and arrive at the collector at ______________ times.

different

56.9** High frequency operation in transistors is limited mainly by the ____________ at the collector and emitter junctions, the time of ______________ in the base, and the _______________ out of the carriers in the base.

more
different

56.10 END OF SET

capacity
transit
spreading

57 ______________ is the symbol for the cut-off frequency of the transistor in a common base configuration. This indicates the frequency at which ______________ has fallen to 0.707 of its low frequency value.

57.1 h_{fb} is the small signal, a.c. current gain of the transistor in a common base configuration. Due to factors already discussed, h_{fb} will decrease with an increase in frequency.

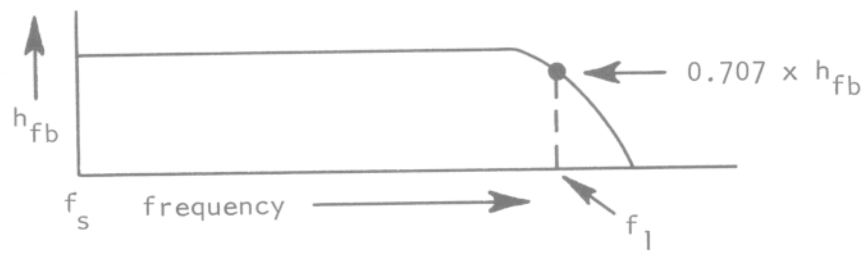
f_{hfb} or f_{α_b}

h_{fb}(alpha)

57.2 A frequency will be reached at which h_{fb} has decreased to 0.707 of its low frequency value. The <u>frequency</u> at which this occurs is given the symbol f_{hfb} or f_{α_b}. This is usable with the common ____________________ configuration.

decrease

57.3 In the diagram, h_{fb} is plotted vertically and frequency is plotted ______________ on the base line. f_1 is given the symbol ______________ and indicates the common base cut-off frequency of the transistor.



base

(NOTE: f_s = standard frequency, usually 1kc)

57.4** f_{hfb} or f_{α_b} indicates the ______________ at which h_{fb} falls to __________ of its low frequency value. This is the cut-off frequency of the transistor in a common ____________ configuration.

horizontally
f_{hfb} or f_{α_b}

57.5 END OF SET

frequency
0.707
base

58 ______________ is the symbol for the cut-off frequency of the transistor in a common emitter configuration. This indicates the frequency at which ______________ has diminished to 0.707 of its low frequency value. For a given transistor, this frequency will be much ______________ (higher, lower) than f_{hfb}.

58.1 h_{fe}, the small signal, a-c current gain of the transistor in a common emitter configuration will decrease at the higher frequencies. The cut-off point is considered to be the point at which h_{fe} has decreased to ______________ of its low frequency value.

f_{hfe} or f_{α_e}

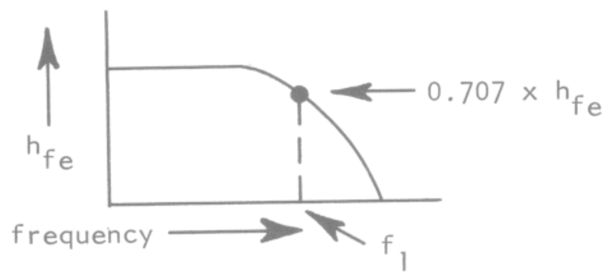
h_{fe}

lower

58.2 The frequency at which h_{fe} has decreased to 0.707 of its low frequency value is given the symbol f_{hfe} or f_{α_e}. This frequency is usable with the common ______________ configuration.

0.707

58.3 In the diagram, h_{fe} is plotted vertically and frequency is plotted horizontally. f_1 is given the symbol ______________ and indicates the common emitter cut-off frequency of the transistor.



emitter

(NOTE: f_s = frequency standard, usually 1kc)

58.4 The relationship of f_{hfe} and f_{hfb} is expressed as $f_{hfe} = f_{hfb}(1 + h_{fb})$. Consider a transistor with an $h_{fb} = -0.98$ and an h_{fe} of 49. If the transistor has an f_{hfb} of 10 megacycles, h_{fe} will fall to 0.707 of its low frequency value at ______________ cycles.

$$f_{hfe} = f_{hfb}\ (1 + hfb)$$

(NOTE: hfb is always a negative quantity)

f_{hfe} or $f\alpha_e$

58.5 f_{hfe} will occur at a much lower frequency than f_{hfb}. For a given transistor, the common emitter configuration will have its gain reduced to 0.707 of its low frequency value at a ______________ (higher, lower) frequency than the common base configuration.

$f_{hfe} = f_{hfb}\ (1 + h_{fb}) = 10^7\ 1 + (-0.98) = 10^7 \times 0.02 = 200K$

58.6 Consider a transistor with an h_{fb} = -0.96 and an f_{hfe} = 500K cycles.

f_{hfb} = ____________________

(NOTE: h_{fb} is <u>always</u> a negative quantity)

---

lower

58.7** f_{hfe} is the symbol for the transistor's cut-off frequency in a common ____________________ configuration. This is the frequency at which ______________ has fallen to ______________ of its low frequency value. For given transistor, f_{hfb} will be a ________________ (higher, lower) frequency than f_{hfe}.

$$f_{hfb} = \frac{f_{hfe}}{1+h_{fb}} = \frac{500 \times 10^3}{0.04} = 12.5 \text{ megacycles}$$

58.8 END OF SET

---

emitter
h_{fe}
0.707
higher

---

59 C_{ob} is the symbol given the output capacitance of a transistor in a common ________________ orientation and C_{oe} is the symbol given the output capacitance of a transistor in a common ________________ orientation. They are related as shown by the formula C_{ob} = ________________.

59.1 In the symbol C_{ob}, the C indicates capacitance, the o indicates output, and the ________________ indicates common base.

base
emitter
$C_{oe}\ (1+h_{fb})$

59.2 In the symbol C_{oe}, the C indicates capacitance, the o indicates output, and the e indicates common ________________.

b

59.3 The relationship between C_{ob} and C_{oe} is expressed by the formula $C_{ob} = C_{oe}(1+h_{fb})$. If $h_{fb} = -0.98$ and $C_{oe} = 200$ picofarads,

C_{ob} = ________________.

(Note: h_{fb} is always a <u>negative</u> quantity.)

---

emitter

59.4 C_{oe} will be much larger than C_{ob} for a given transistor and set of conditions. It has already been shown that the common ________________ configuration current gain will fall off to 0.707 of its low frequency value at a lower frequency than the common ________________ configuration.

$C_{ob} = 200pf\ (1-0.98) = 200pf \times 0.02 = 4pf$

59.5 $C_{ob} = C_{oe}(1+h_{fb})$

$C_{ob} = 9pf$

(Note: h_{fb} is always a <u>negative</u> quantity.)

$h_{fb} = -0.97$

C_{oe} = ________________

---

emitter
base

59.6** The output capacitance of the common emitter configuration has the symbol ________________ and, the output capacitance of the common base configuration has the symbol ____________. Their relationship is expressed by the formula C_{ob} = ________________.

$$C_{oe} = \frac{C_{ob}}{1+h_{fb}} = \frac{9pf}{0.03} = 300pf$$

59.7 END OF SET

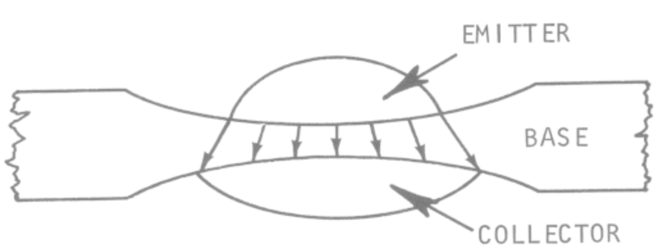
C_{oe}
C_{ob}
$C_{oe}\ (1+h_{fb})$

60 High frequency construction calls for a __________ but uniform base width. The narrower the base, the less the ____________ time and the less time the carriers have to ______________ out in the base.

60.1 The narrower the base thickness between the emitter and the collector, the less the transit time for a given minority carrier lifetime. Making the base very narrow increases the frequency at which __________ shift becomes a problem.

narrow
transit
spread

60.2 The thin base should also have a uniform thickness. The transistor in the diagram has high frequency problems built in, since it takes some of the carriers longer than others to move through the base.



phase

60.3 Making the base narrow reduces the time the carriers spend in the base. The carriers will spread out less in a ___________ base with a short transit time.

no answer needed

60.4 Transit time and spreading out of the carriers are reduced with a narrow base. A uniform, narrow width further improves the high ______________ characteristics.

narrow, thin, etc.

60.5 High frequency transistors will have a different structure than low frequency or general purpose types. The desired characteristics will govern the _____________ of the transistor.

frequency

60.6** High frequency operation dictates a narrow _____________ with uniform width. This reduces ___________ time and the spreading out of the carriers in the _____________.

structure, construction, etc.

60.7 END OF SET

base
transit
base

62 A narrow, uniform width base is the aim in construction of high frequency transistors. The rate grown transistor has limited high frequency characteristics. The alloy type transistor gives a/an ________________ (increase, decrease) in f_{hfb} over the rate grown. Typical f_{hfb} for the alloy transistor is ________ ________ ________ megacycles.

62.1 The rate grown transistor is manufactured by pulling a seed crystal from a container of molten materials. The crystal is said to be __________ in the process.

increase
1 to 10

62.2 Changing the rate at which the crystal is grown is one method of forming the N and P type regions. Different amounts of dopent impurities enter the crystal when the growing ________________ is changed.

grown

62.3 The rate grown crystal is cut up and makes a number of transistors. Changing the _________ of growing forms the N and P regions as shown in the cross section in figure 62.

rate

62.4 The base could be made thinner in the rate grown process, but the problem is both in getting a uniform width and attaching a wire to the base. The base should be thinner than the ___________ that must be attached.

rate

62.5 The alloy transistor is constructed by alloying two dots of material to the sides of a very thin crystal wafer. The dots should give an impurity concentration ____________________ the thin wafer.
(opposite of, same as)

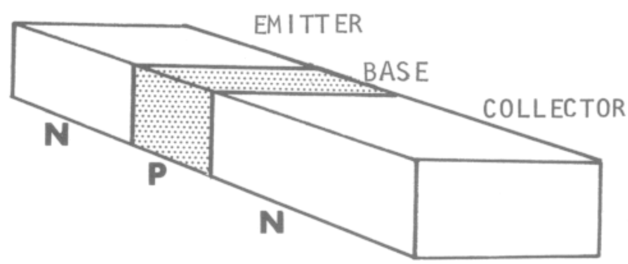
wire, lead, etc.

62.6 Figure 62 shows a cross section of the alloy transistor. The dots become the emitter and collector contacts and the crystal wafer becomes the ____________.

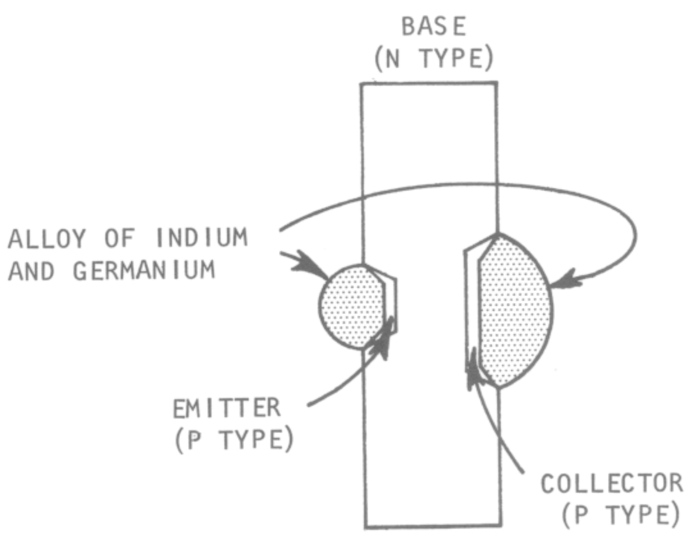
opposite of

62.7 The alloying process makes possible a much thinner base between the emitter and collector with the ability to connect a wire to the crystal wafer for an electrical connection to the ___________________.

base



RATE GROWN



ALLOY

FIGURE 62

62.8 It is difficult to gain uniformity if the base is made too thin in the alloy transistor. Typical f_{hfb} for the alloy transistor is from 1 to 10 megacycles. This is an increase in f_{hfb} over the ________ ________ transistor.

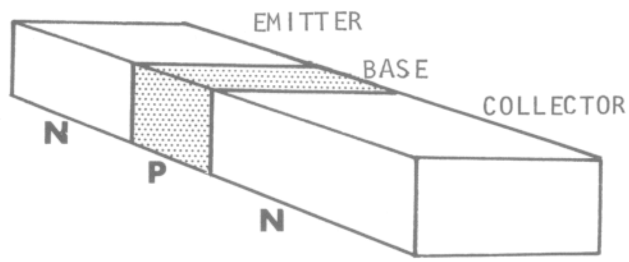
base

62.9** The rate grown transistor is rugged and useful at the ________ (lower, higher) frequencies. The alloy type gives a/an ________ (increase, decrease) in f_{hfb} with respect to the rate grown type. Typical f_{hfb} for the alloy type is ________ to ________ megacycles.

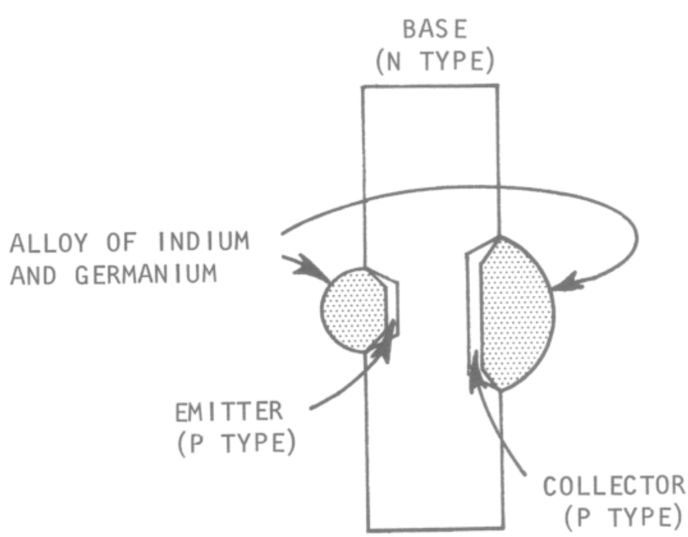
rate grown

62.10 END OF SET

lower
increase
1
10



RATE GROWN



ALLOY

FIGURE 62

63 The micro-alloy is a variation of the ____________ type transistor. To obtain a very thin, uniform base, the center of the wafer is etched very thin before the dots are applied and ___________. This gives the characteristics of a/an __________ transistor with a thinner base. An increase of f_{hfb} to ____________ megacycles is typical. A further improvement in f_{hfb} to ____________ megacycles can be obtained with the micro-alloy diffused. This transistor gives the effect of a built-in electric ____________ in the base. The micro-alloy diffused is also called a drift ____________ transistor.

63.1 In order to get a thinner base and yet not make the device too fragile, the center of the wafer is etched very thin. Etching is the process of concentrating a stream of acid on the two sides and removing some of the material. The outer edges, not being etched, gives the device ___________.

alloy
alloyed
alloy
40
200
field
field

63.2 The dots are applied to the thin portion of the wafer and when alloyed, give a very thin base. The dots should give an impurity concentration ____________________ as/to the etched wafer as shown in figure 63.
(the same, opposite)

strength, rigidity, etc.

63.3 The micro-alloy gives the characteristics of an alloy transistor with a much thinner ___________. An increase in f_{hfb} to 40 megacycles is typical. This is _____________ (higher, lower) than the alloy transistor.

opposite

63.4 A further variation of the alloy is the micro-alloy diffused or drift field transistor. In this type, the dopents are diffused into the wafer. Diffusion doping is the process of heating the wafer while surrounding it with the impurities in the form of a gas. The impurities _____________ into the wafer during the process.

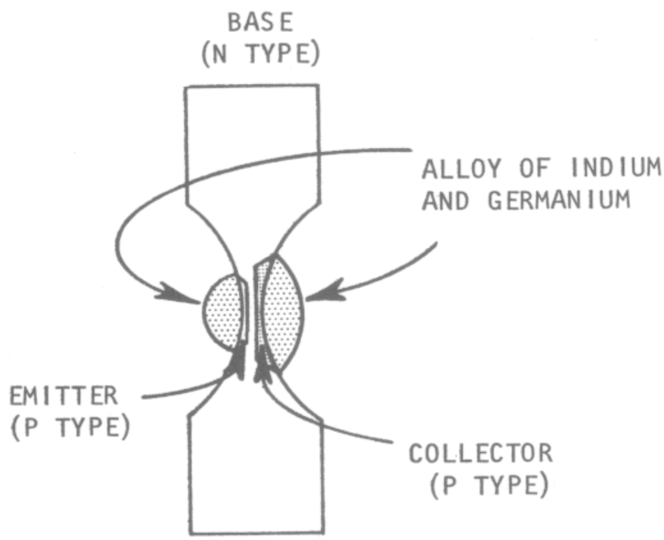
base
higher

63.5 The diffused wafer is then etched, predominately on the collector side. This places the heavier doped portion of the base nearest the emitter when the dots are applied and alloyed. The doping will appear to be graduated heavy to light from _________ to ____________.

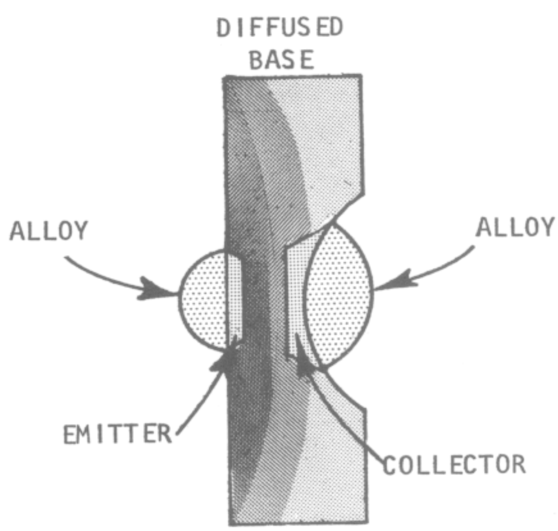
diffuse, spread, etc.

63.6 The graduated doping in the base gives the effect of an electric accelerating field in the base. The diffusing carriers will be accelerated reducing both __________ time and the amount that the carriers _________ out in the base.

emitter
collector



MICRO-ALLOY



MICRO-ALLOY DIFFUSED

FIGURE 63

63.7 The effective electric field in the micro-alloy diffused base increases the frequency limits. An extension of f_{hfb} to 200 megacycles can be obtained with this construction. Another name commonly used for the micro-alloy diffused is "drift field" transistor.

transit
spread

63.8 The micro-alloy diffused or ________ ________ transistor has an effective accelerating electric ____________ built into the base.

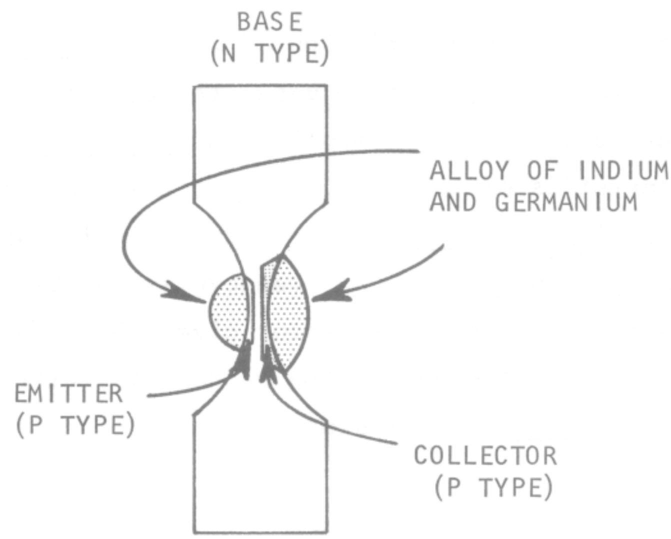
no answer needed

63.9 Figure 63 shows the cross section of the drift field transistor. Base doping is heaviest near the __________.

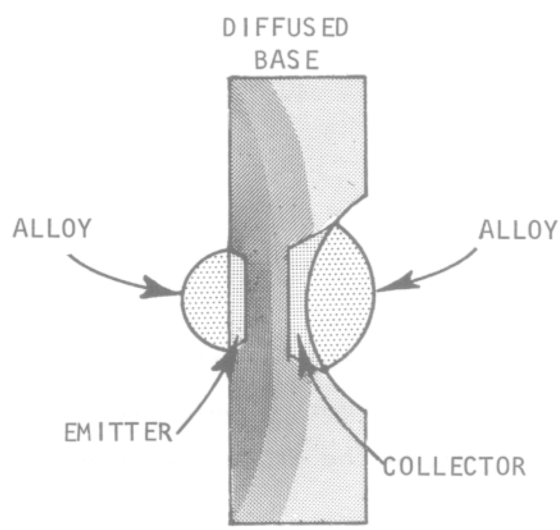
drift field
field

63.10** The wafer is etched very thin before the dots are placed and alloyed to form a ________ ________ transistor. This gives the characteristics of an alloy transistor with an extension of f_{hfb} to _____ megacycles. The micro-alloy diffused gives an extension of f_{hfb} to _____ megacycles by graduated doping in the base. It is also called a ________ ________ transistor.

emitter



MICRO-ALLOY

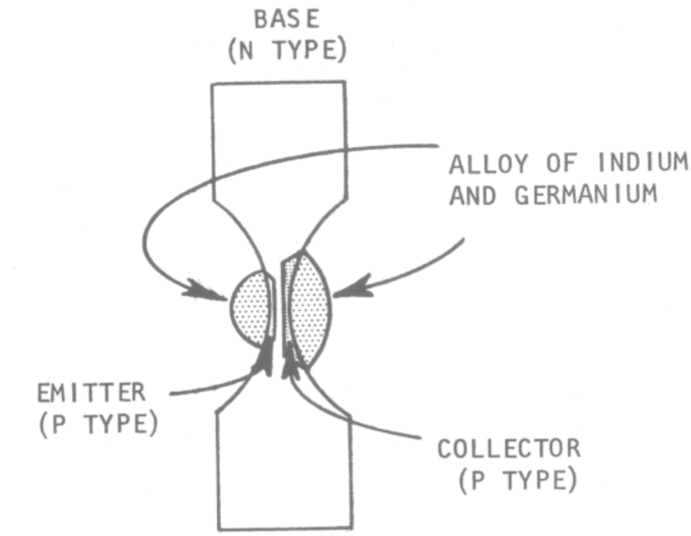


MICRO-ALLOY DIFFUSED

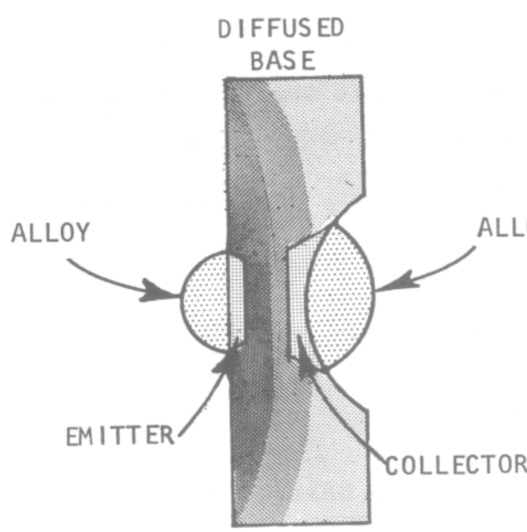
FIGURE 63

63.11 END OF SET

micro-alloy
40
200
drift field



MICRO-ALLOY



MICRO-ALLOY DIFFUSED

FIGURE 63

64 The aim in construction of the mesa transistor is a very narrow base, low collector junction ______________, while maintaining the collector large to dissipate ______________. The epitaxial mesa has an epitaxial layer that makes up the flat topped peak. The epitaxial layer allows high ______________, while the collector is a low resistance material for a low ______________.

64.1 The mesa construction starts with a thin layer of dopent being diffused into a basic wafer. The diffusing dopent is opposite to the dopent in the basic wafer. The thin diffused layer and the basic wafer will form a ______________.

capacitance
heat, (power)
B_{VCBO}
$V_{CE}(sat)$

64.2 The thin diffused layer becomes the base. A non-rectifying contact is connected to the layer for electrical connection. The basic pellet should be doped ______________ than the diffused layer.
(heavier, lighter)

junction

64.3 The emitter is alloyed into the base (or an aluminum stripe is used) to form the emitter. The alloyed emitter (or the aluminum stripe) and the diffused layer will form the second ______________.

heavier

64.4 The top of the wafer is etched away except that portion containing the base lead and the emitter. This leaves a flat topped peak or ___________ as shown in figure 64.

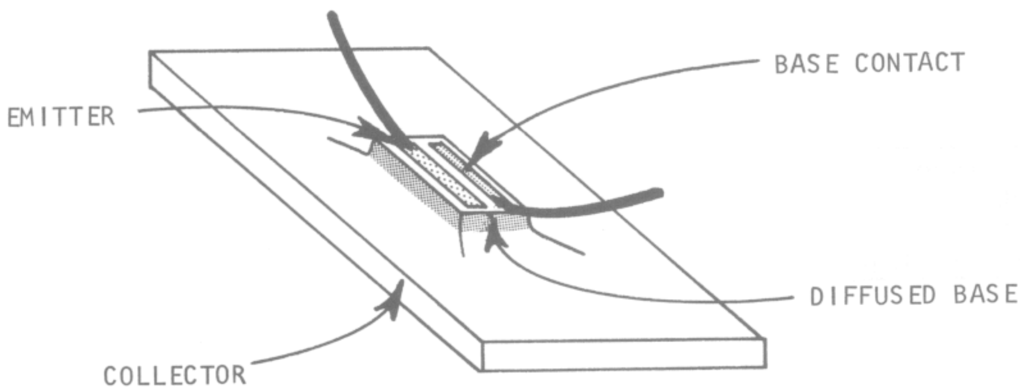
junction

64.5 The area around the collector junction is etched away to reduce collector junction capacitance, while leaving the rest of the wafer to dissipate the _____________ generated by power dissipation. Etching away part of the junction effectively reduces the area of the plates of the _____________ at the junctions.

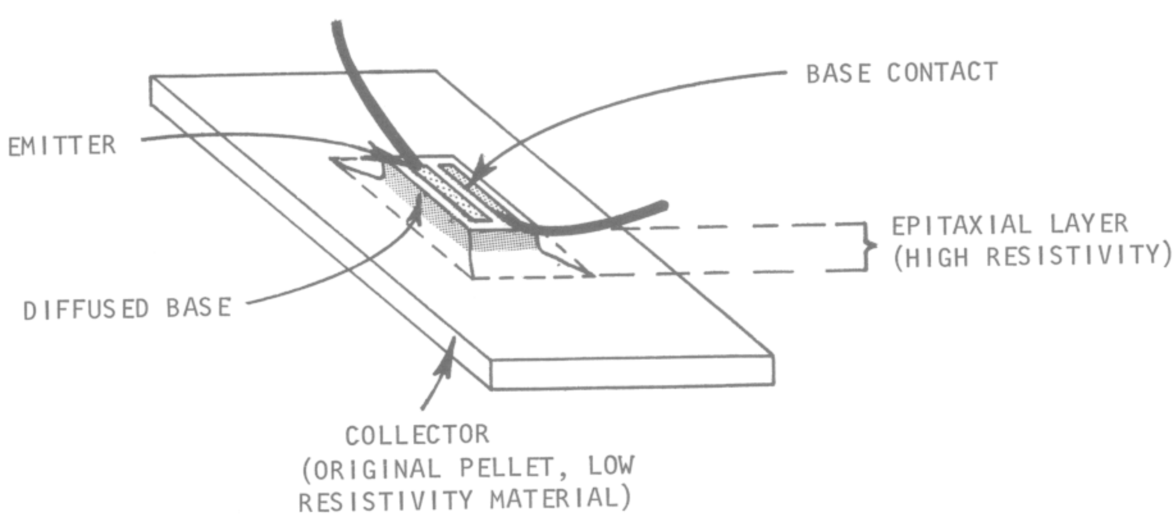
mesa

64.6 The mesa has an increase in f_{hfb} into the hundreds of megacycles. The low resistance of the collector allows a low value of V_{CE}(sat). The low resistance collector results in a low value of collector to base breakdown voltage, ___________(symbol).

capacitance



MESA



EPITAXIAL MESA

FIGURE 64

64.7 An epitaxial layer refers to the process of passing a gas over a structure until the gas has deposited a layer of solidified material on top of the original structure. The epitaxial mesa utilizes an ________________ layer.

BV_{CBO}

64.8 The epitaxial mesa has the same characteristics as the mesa with the added advantage of a higher value of BV_{CBO}. The ________________ layer makes possible the higher breakdown voltage capability.

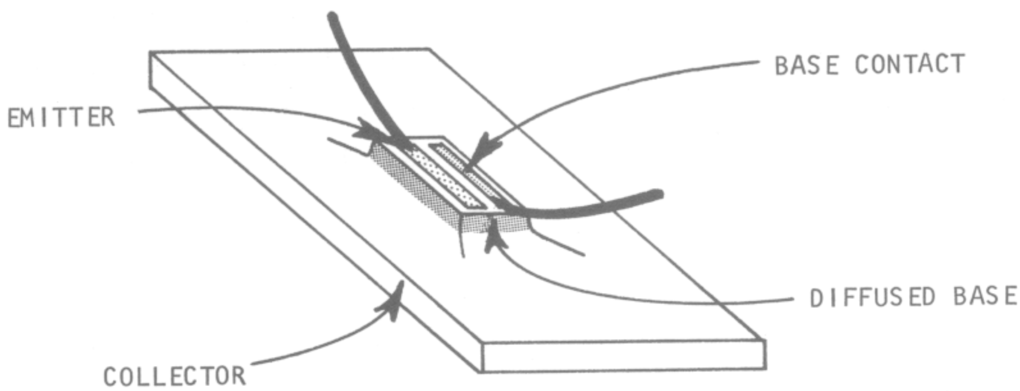
epitaxial

64.9 The epitaxial mesa is constructed by first depositing a high resistivity epitaxial layer on a basic low resistant crystal pellet. The base is diffused into the epitaxial layer and the rest of the construction is the same as the ________________.

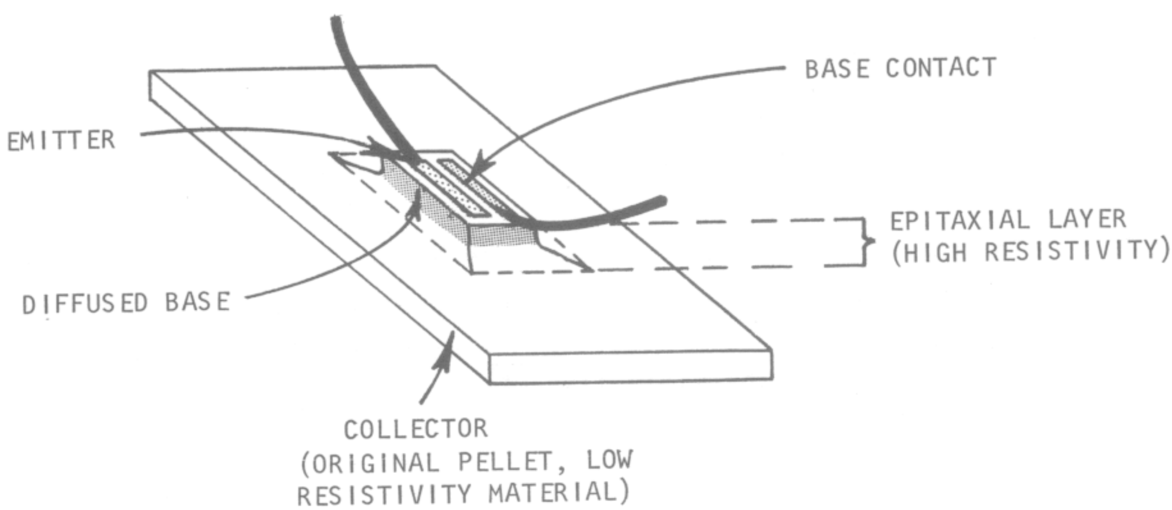
epitaxial

64.10 The diffused base and the remainder of the epitaxial layer form the collector junction. The rest of the pellet or wafer serves to dissipate heat. The high resistance epitaxial layer at the collection junction allows a higher value of collector breakdown voltage.

mesa



MESA



EPITAXIAL MESA

FIGURE 64

65 The planar transistor does not need the flat topped peak of the mesa, as _________ ___________ is used to mask the basic pellet and allow controlled diffusion. Selected portions for the emitter and base are cut through the protection to allow ______________. The junctions are protected immediately on being formed and are said to be surface ___________________.

65.1 The planar transistor is made by diffusing both the emitter and base into the basic crystal wafer. The planar is a double ____________ transistor.

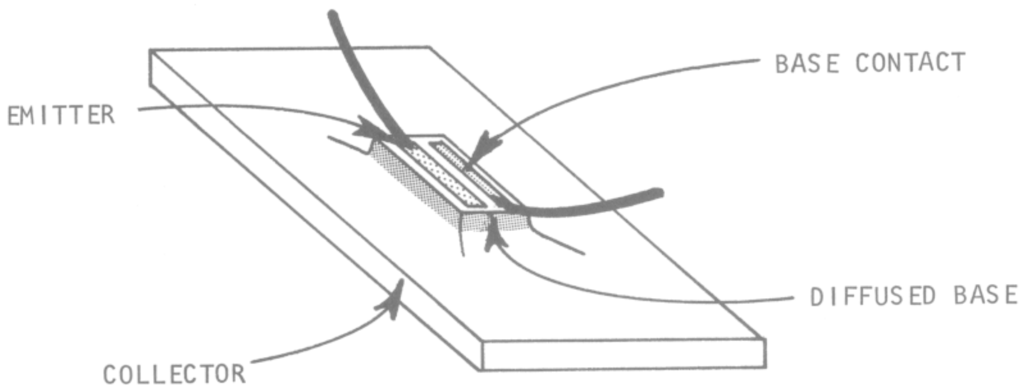
silicon dioxide
diffusion
passivated

65.2 A layer of silicon dioxide is grown on the surface of the basic crystal wafer. Diffusion cannot occur through the _____________ ______________.

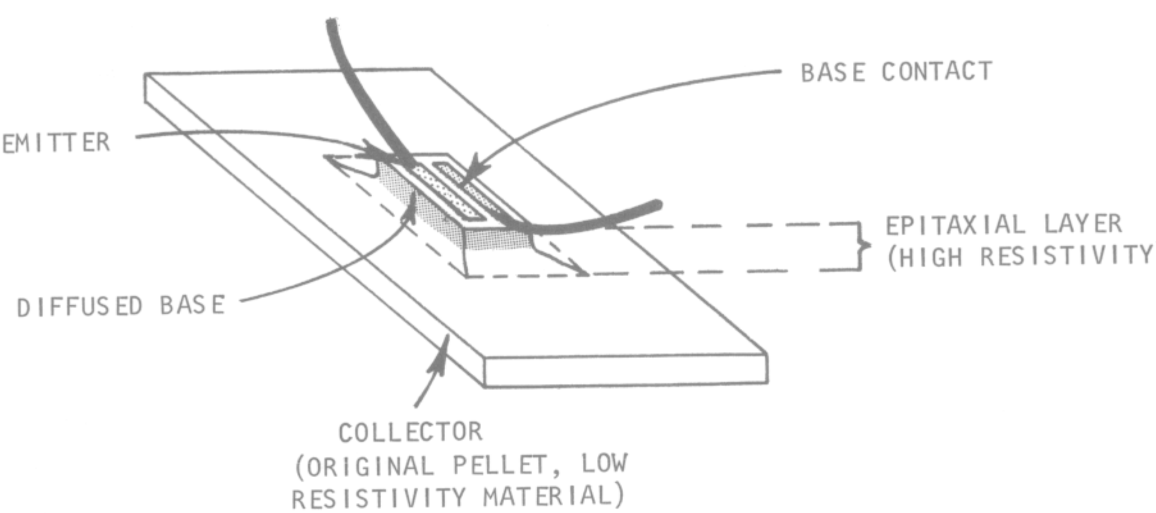
diffused

65.3 Holes can be cut through the silicon dioxide and allow well controlled diffusion of the emitter and base as shown in figure 65. The original pellet becomes the ______________.

silicon dioxide



MESA



EPITAXIAL MESA

FIGURE 64

65.4 The silicon dioxide masks the remainder of the collector area and keeps the junction confined to the selected area. This maintains low junction capacitance and the mesa is not necessary. The ____________ ______________ mask does much the same job as etching the mesa.

collector

65.5 Since the silicon dioxide is replaced immediately over the junction after it is formed, the junction is protected from the surrounding environment and is said to be surface passivated. The _________________ transistor is double-diffused and surface ____________________.

silicon dioxide

65.6 The emitter and base contacts in figure 65 are termed ohmic contacts. This indicates that they are passive or non-rectifying contacts. The junctions are active internally, but are surface ____________________.

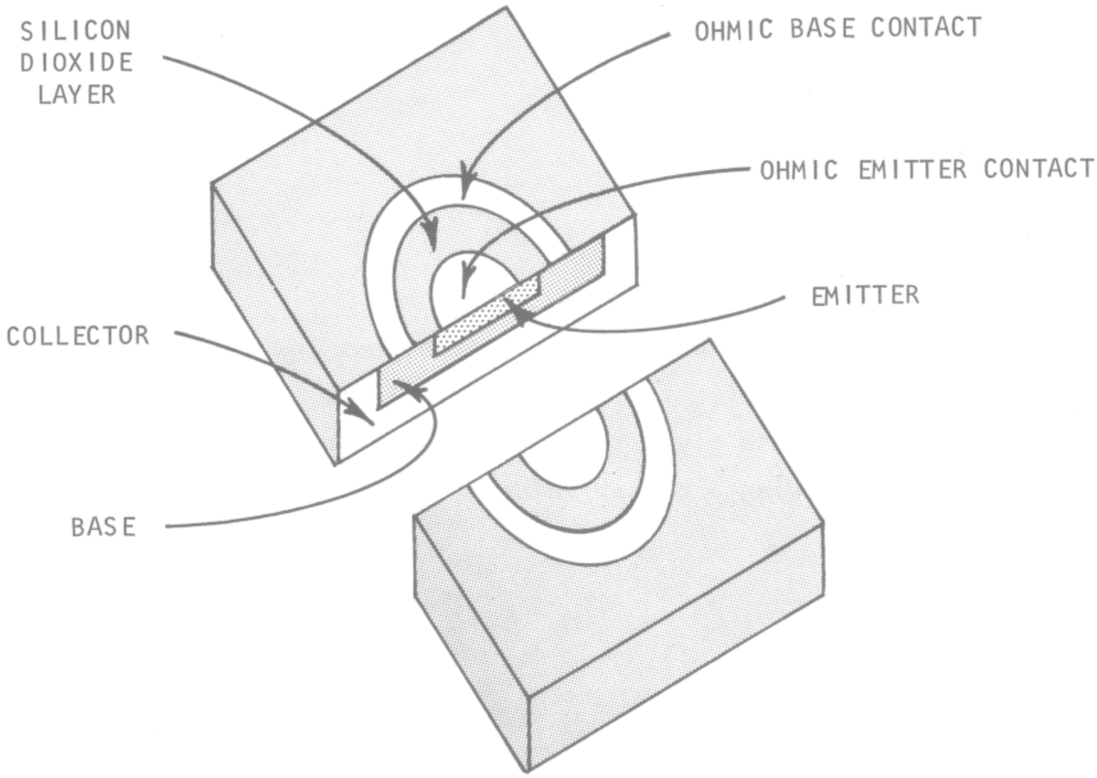
planar
passivated

65.7** The mesa or flat topped peak is not needed in the planar because _________________ _________________ is used to mask the device and allow controlled diffusion. Holes are cut through the surface protection for selected ________________ of a given area for the emitter and base. The junctions are surface _________________.

passivated

65.8 END OF SET

silicon dioxide
diffusion
passivated



PLANAR

FIGURE 65

SELF TEST

Read each question carefully, studying any diagrams provided and select the most correct answer.

1. Forward biasing a PN junction results in majority carriers crossing the junction and becoming minority carriers. The average time the carriers exist after crossing the junction and before recombining is termed ____________________.
   a. half life of the material
   b. minority carrier lifetime
   c. transit time
   d. recombination time

2. Applying forward bias to a PN junction with one side dopes much lighter than the other, results in some carriers failing to recombine and diffusing through the lightly doped side as ______________ carriers.
   a. heat
   b. bias
   c. majority
   d. minority

3. Doping one side of a PN junction much lighter and making it very narrow results in much of the forward bias current in the external circuit being the result of ________________ current in the diode.
   a. diffusion
   b. majority carrier
   c. photon
   d. phonon

4. Forward bias current transported by diffusion of carriers results when the ____________ side of the junction is doped much lighter than the opposite side.
   a. N
   b. P
   c. either N or P
   d. none of the above

5. When two junctions are formed in a single piece of semiconductor, recombination occurs at both junctions until a state of ________________ exists at both junctions and carrier movement across the junctions _______________.
   a. pandimonium, starts
   b. balance, stops
   c. equilibrium, starts
   d. reverse bias, reverses

6. Junction transistors are constructed by doping two junctions in a single piece of semiconductor with the two ends ____________ doped and the center ________ doped.

a. lightly, heavily
b. heavily, heavily
c. heavily, lightly
d. lightly, lightly

7. The center portion of a junction transistor is made narrow to enhance the transport of carriers by ______________ in the center portion.

a. photon
b. majority carrier
c. only electron
d. diffusion

8. The center portion in the diagram is termed the _____________ and the right hand portion the _______________.

a. base, collector
b. collector, base
c. gate, collector
d. gate, anode

9. Injection of carriers from the emitter into the base is accomplished by application of __________ __________ to the emitter-base junction.

a. thermal energy
b. reverse bias
c. forward bias
d. series resistance

10. The collector junction is normally ____________ biased and depends on ________ carriers in the base for current.

a. reverse, minority
b. forward, majority
c. forward, minority
d. reverse, majority

11. The emitter current is the sum of ____________ and ___________ current in the ________________.

a. recombination, diffusion, base
b. collector, diffusion, base
c. base, collector, transistor
d. either a or c
e. base, recombination, collector
f. either b or e

12. h_{FB} is the symbol for ______________ current gain from the ___________ to the ______________ of the transistor.

a. small signal, emitter. collector
b. d-c, base, collector
c. small signal, base, collector
d. d-c, emitter, collector

13. The product of d-c current gain, __________(symbol), and the d-c base current will give the value of _____________ current.

a. h_{FE}, collector
b. h_{FB}, collector
c. h_{FE}, emitter
d. h_{FB}, emitter

14. A variation in base or emitter current will be accompanied by a change in collector current. For a given change in base or emitter current, a change in ____________ current will result in the greatest change in collector current.

a. base
b. emitter

15. I_{CBO} indicates current between ___________ and ___________, with the _________ open circuited.

a. emitter, collector, base
b. collector, emitter, base
c. collector, base, emitter
d. emitter, base, collector

16. I_{CBO} is made up of carriers present as a result of ____________ and will vary with a change in _____________.

a. thermal energy, forward bias
b. reverse bias, thermal resistance
c. forward bias, temperature
d. thermal energy, temperature
e. reverse bias, capacitance

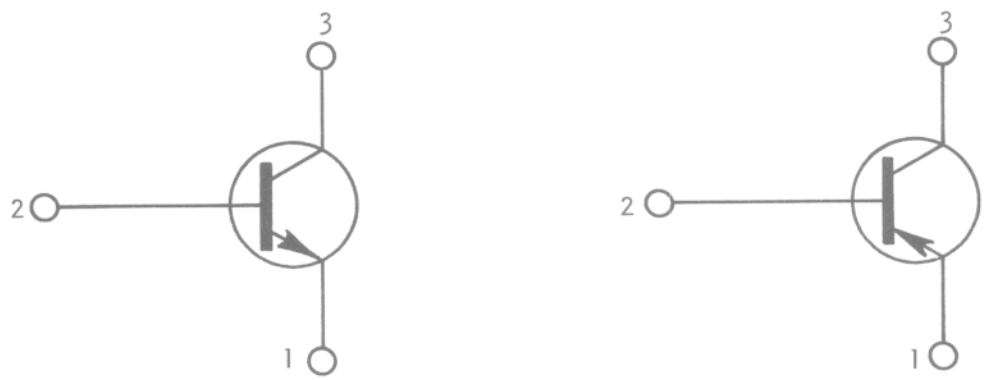
17. I_{CEO} is the current between ____________ and ___________ with the __________ open circuited.

a. collector, emitter, base
b. collector, base, emitter
c. emitter, base, collector
d. collector, emitter, emitter

18. $I_{CEO} \approx$ ______________ $\times I_{CBO}$.

a. h_{FB}
b. h_{FE}
c. ambient temperature
d. thermal resistance

19.



SYMBOL A SYMBOL B

Symbol B is a/an _____________ transistor and point 2 indicates the __________ lead.

a. NPN, base
b. PNP, base
c. PNP, emitter
d. NPN, emitter

20. A transistor in a common emitter configuration has a greater possible current gain than ____________.

a. a transistor in a common base configuration
b. a transistor in a common collector configuration
c. unity
d. any of the above
e. either a or c

21. A transistor in a common __________ configuration can yield the highest possible power gain of the three configurations.

   a. emitter
   b. base
   c. collector

22. A transistor in a common __________ configuration cannot offer a current gain greater than unity.

   a. collector
   b. emitter
   c. base

23. A transistor in a common __________ configuration cannot offer a voltage gain greater than unity.

   a. collector
   b. emitter
   c. base

24. h_{fe} is the ____________, a-c current gain of the transistor in a common ______________ configuration.

   a. direct current, base
   b. small signal, emitter
   c. direct current, emitter
   d. small signal, base

25. The small signal, a-c, current gain of the transistor in a common base configuration is given the symbol ________ and _________ include circuit effects.

   a. h_{fb}, does not
   b. h_{fc}, does not
   c. h_{fb}, does
   d. h_{fe}, does
   e. h_{fc}, does not

26. Power gain is possible with the common base configuration, although _____________ gain is less than unity, since ___________ gain greater than unity is possible.

   a. voltage, current
   b. current, voltage

27. Power gain is possible with the common collector configuration, although ____________ gain is less than unity, since ____________ gain greater than unity is possible.

a. current, voltage
b. voltage, current

28. Emitter follower is another name given a transistor in a common ______________ configuration.

a. emitter
b. collector
c. base

29. h_{fc} is the small signal, low frequency current gain of the transistor in a common _____________ configuration and is approximately equal to _____________.

a. base, $h_{fb} + 1$
b. emitter, $h_{fe} + 1$
c. collector, $h_{fb} + 1$
d. collector, $h_{fe} + 1$

30. The emitter follower offers a ____________ input resistance and a _____________ output resistance.

a. low, low
b. high, high
c. high, low
d. low, high

31. A transistor in a common ______________ configuration has a very low output resistance is able to supply large output _______________.

a. collector, currents
b. emitter, voltages
c. base, voltages
d. base, currents

32. The slope of a d-c load line constructed on a collector family of curves is determined by the ___________ in ____________ the transistor.

a. reactance, series with
b. resistance, series with
c. current, the base of
d. current, the collector of

33. The d-c load line is constructed between the maximum ____________ point and the maximum ___________ point on the collector family of curves set by the series resistance and the total supply _______________.

a. voltage, current, current
b. voltage, current, voltage
c. voltage, current, resistance
d. resistance, current, voltage

34. The transistor is termed in saturation when the collector becomes ___________ __________. The collector voltage at this point is given the symbol ________.

a. cut-off, V_{CC}
b. forward biased, BV_{CBO}
c. reversed biased, $V_{CE(sat)}$
d. forward biased, $V_{CE(sat)}$
e. fully saturated, $BV_{CBO(sat)}$

35. Saturation in a transistor results in an increase in the __________ __________ in the base as a result of the collector junction becoming ___________ biased.

a. stored charge, reverse
b. depletion region, forward
c. depletion region, reverse
d. stored charge, forward

36. Avalanche breakdown occurs at high _____________ collector voltages due to the __________ of carriers at the collector junction.

a. forward, acceleration
b. reverse, recombination
c. reverse, multiplication
d. forward, multiplication

37. Changing the transistor's configuration will change the collector voltage point at which avalanche breakdown occurs. BV_{CBO} indicates the breakdown voltage, _______________ to _____________ with the __________ d-c open circuited.

a, collector, base, emitter
b. collector, emitter base
c. emitter base, collector
d. collector, ground, emitter

38. BV_{CEO} indicates the breakdown voltage, __________ to __________ with the __________ d-c open circuited.

a. base, emitter, collector
b. collector, emitter, base
c. collector, base, emitter
d. collector, ground, emitter

39. BV_{CER} is the breakdown voltage, __________ to __________ with a specified value of resistance between __________ and __________.

a. collector, emitter, collector, base
b. collector, base, base, emitter
c. collector, emitter, base, emitter
d. collector, emitter, collector, emitter

40. Maximum steady state power dissipation in a transistor is limited by the maximum allowable junction __________, surrounding air __________, and the total __________ __________, junction to ambient.

a. temperature, temperature, thermal resistance
b. current, temperature, temperature gradient
c. voltage, temperature, thermal resistance
d. temperature, temperature, temperature gradient

41. Θ_{JA} is the symbol for thermal resistance, __________ to __________ and is measured in __________.

a. jacket, ambient, °C/watt
b. junction, area, watts/°C
c. junction, ambient, watts/°C
d. junction, ambient, °C/watt

42. $\Theta_{JC} + \Theta_{CS} +$ __________ $= \Theta_{JA}$ when a separate __________ sink is used with a transistor.

a. Θ_{SC}, heat
b. Θ_{CA}, conductance
c. Θ_{CA}, heat
d. Θ_{SA}, heat

43. __________ lubricant reduces thermal resistance, case to __________ and as a result, reduces total thermal resistance.

a. Germanium, heat sink
b. Silicone, heat sink
c. Gallium, heat sink
d. Gallium, ambient

44. Θ_{JC} = 1.8°C/watt
Θ_{SA} = 3.6°C/watt
Θ_{CS} = 0.6°C/watt
T_A = 60°C
T_{Jmax} = 150°C

$$P_{max} = \frac{T_{J(max)} - T_A}{\Theta_{JA}}$$

The maximum steady state power the transistor can dissipate with the thermal characteristics listed above is ____________.

a. 1.5 watts
b. 30 watts
c. 15 watts
d. 3 watts

45. For maximum linear power operating in the active region, the load line should be placed ____.

a. tangent to the maximum power curve in the most linear region of curves.
b. from BV_{CBO} to a point tangent to the maximum power curve
c. from $I_C(max)$ to a point tangent to the maximum power curve
d. $I_C(max)$ to $V_{CE}(max)$

46. Answer d in question 45 will allow ______________ for a given transistor.

a. maximum linear power
b. maximum power with maximum current swing in the linear region
c. maximum power for low repetition rate switching
d. maximum power for high repetition rate switching

47. Little power is dissipated at cut-off and ___________ while most of the power is dissipated in the ________________ region of the transistor's characteristics.

a. transient, active
b. depletion, transient
c. saturation, active
d. saturation, depletion

48. ________________ power can be dissipated during switching with the transistor is operated as a cut-off to saturated, low rep-rate switch and the load line can ___________________ the maximum power curve on a collector family of curves.

a. less, not cross over
b. more, be tangent to
c. more, be in the safe area below
d. more, cross over

49. The off to saturated switching mode offers ____________ resting state power, but limited repetition rate due to increased ___________.

a. low, storage time
b. high, storage time
c. maximum, transit time
d. low, transit time

50. A transistor switch turn on time (t_{on}) is equal to the sum of ______________ and ______________, and the transistors turn off time is equal to the sum of ___________ and _____________ when using the switching parameters.

a. rise time, transit time — fall time, response time
b. rise time, transit time — storage time, fall time
c. rise time, delay time — storage time, fall time
d. rise time, interface time — storage time, recovery time

51. A capacitor used to reduce switching time in a transistor switching configuration, by aiding in the establishment and removal of the stored charge is referred to as a ____________ ___________ capacitor.

a. switching filter
b. speed up
c. charge chopper
d. time chopper

52. The charge on the capacitor mentioned in question 51 should be ____________ the transistors stored charge for an effective increase in switching time.

a. equal to
b. less than
c. ten times
d. one tenth of

53. __________ __________ switching offers faster switching times than the saturated mode, but sacrifices ______________.

a. cut-off, flexibility
b. current mode, less critical transistor specification
c. voltage mode, power
d. current mode, power capabilities

54. A/an ____________ switching transistor has the transistor switching in the collector breakdown region and can offer rise times in the fractional ________ second region.

a. avalanche, nano
b. avalanche, micro
c. current mode, nano
d. current mode, micro
e. avalanche, milli

55. The three main high frequency limiting factors in transistors are __________, __________, and __________.

a. doping ratio, junction capacity, storage time
b. junction capacity, base transit time, thermal resistance
c. base transit time, spreading of carriers in the base, junction capacity
d. emitter transit time, spreading of carriers in the base, junction capacity

56. __________ is the symbol for the cut-off frequency of a transistor in a common base configuration and indicates the frequency at which __________ falls to 0.707 of its low frequency value.

a. f_{hfe}, h_{fe}

b. f_t, h_{fb}

c. f_{hfb}, h_{fb}

d. f_{α_b}, h_{fe}

57. C_{ob} is the symbol for the output capacitance of a transistor in a common __________ orientation. C_{oe} is the symbol for the output capacitance of a transistor in a common __________ orientation.

a. base, emitter
b. emitter, base

58. A __________ base and __________ junction capacity is the aim in high frequency transistors.

a. heavily doped, low
b. lightly doped, diffused
c. narrow, low
d. narrow, variable

59. f_t is the symbol for the frequency at which __________ falls to __________.

a. h_{fe}, unity

b. h_{fb}, 0.707 of low frequency value

c. h_{fe}, 0.707 of low frequency value

d. h_{fb}, unity

60. f_{hfe} indicates the cut-off (__________) of the transistor in a common _______________ configuration.

a. h_{fe} = unity, emitter

b. low frequency h_{fe} x 0.707, base

c. h_{fe} = unity, base

d. low frequency h_{fe} x 0.707, emitter

29. d
30. c

59. a
60. d

ANSWERS TO SELF TEST

1. b
2. d
3. a
4. d
5. b
6. c
7. d
8. a
9. c
10. a
11. d
12. d
13. a
14. a
15. c
16. d
17. a
18. b
19. b
20. e
21. a
22. c
23. a
24. b
25. a
26. b
27. b
28. b
29. d
30. c
31. a
32. b
33. b
34. d
35. d
36. c
37. a
38. b
39. c
40. a
41. d
42. d
43. b
44. c
45. a
46. c
47. c
48. d
49. a
50. c
51. b
52. a
53. d
54. a
55. c
56. c
57. a
58. c
59. a
60. d