ثانوية التكنولوجيا التطبيقية
Applied Technology High School

المدرسة الثانوية الفنية
Secondary Technical School

Term 3 (Part 2) – Instructional Guide
Grade 12/ASP & ES – Physics
PHY70A/71

Textbook: https://drive.google.com/file/d/1BjMgyOZGaPiHlE6UdLIGwXx-etoOvkM3/view?usp=sharing
(Physics for Scientists and Engineers)

Learning Outcome	Number of Periods	Suggested Exercises /Assignments
Topic 10– Band Theory of Solids Subtopic 10.1– Energy Bands Subtopic 10.2– Doping of a Semiconductor (KPIs 10.1.1 – 10.2.4)	6 + 4	Chapter 43

• Practice Questions (Addition to Specified Example Questions)

Multiple choice questions

1. In an insulating material, ______.

√ A. the valence band is filled and the conduction band is empty

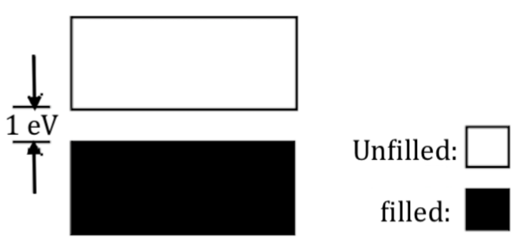
B. the valence band is empty and the conduction band is filled

C. both the valence band and conduction band are empty

D. both the valence band and conduction band are filled

E. both the valence band and conduction band are partially filled

2. The energy level diagram shown applies to ___.



A. A conductor

B. An insulator

√ C. A semiconductor

D. An isolated molecule

E. An isolated atom

3. A material with a relatively large gap between its valance band and conduction band would be expected to be _____.

A. a good conductor

B. easily melted

√ C. a poor conductor

D. in the liquid state

E. crystalline material

4. According to the band theory of solids, why is lead a good conductor?

A. There is a wide energy gap between the valance band and conduction band of lead

B. The valance band of lead is empty and the conduction band is filled

C. The valance band and the conduction band of lead is half filled.

D. A great deal of energy is needed to move valence electrons of lead to the conduction band

√ E. The conduction band of lead overlaps the valance band

5. What is the approximate energy gap between the valance band and conduction band of a semiconductor?

A. 0 eV
√ B. 1 eV
C. 5 eV
D. 10 eV
E. 100 eV

6. Which of the following is not a semiconductor?

A. Silicon
B. Gallium
C. Germanium
√ D. Aluminum
E. Antimony

7. If a material contains overlapping conduction and valence bands, both of which are partially filled, then ___.

A. no potential difference is required to induce a current in the material
B. the acceleration of electrons will require a relatively large input of radiation
C. the conductance of the material will be directly related to its temperature
√ D. a small electric field will make electrons move from one atom to another
E. the acceleration of electrons will require doping of the material

8. A material that conducts electricity well tends to have _____.

A. no valance electrons
√ B. partially filled bands
C. completely filled bands
D. conduction and valance bands that are far apart
E. a full valence band and an empty conduction band

9. _______ is an insulator.

A. Copper
B. Silicon
C. Gold
√ D. Table salt
E. Germanium

10. Dopants increase the conductivity of semiconductors by ____.

A. increasing the forbidden gap
B. turning them into insulators
C. adding net charge to the semiconductor
√ D. making extra electrons or holes available
E. turning them into intrinsic semiconductors

11. A hole refers to _____.

A. a proton
B. a positively charged electron
C. a microscopic defect in a solid
D. an electron which has somehow lost its charge
√ E. the absence of an electron in an otherwise filled band

12. Which of the following is/are true for an intrinsic semiconductor?

I. Pure semiconductor
II. Have low conductivity
III. Conducts due to thermally freed electrons

A. I only
B. II only
C. III only
D. I and III only
√ E. I, II and III

13. Which of the following elements has the correct number of valance electrons to be used as a dopant for an n −type semiconductor?

A. Beryllium ($Z = 4$)
B. Boron ($Z = 5$)
√ C. Nitrogen ($Z = 7$)
D. Aluminum ($Z = 13$)
E. None of the above

14. A semiconductor can amplify a weak electrical signal through electron movement in a ____.

A. gas
B. liquid
C. vacuum
D. band gap
√ E. crystalline material

15. How do dopants increase the conductivity of semiconductors?

A. They add net charge to the semiconductor
B. They increase the forbidden gap
√ C. They make extra electrons or holes available
D. They turn them into intrinsic semiconductors
E. They always decrease the number of charge carriers

16. Dopants are used to ____ semiconductors.

A. increase the conductivity of extrinsic
B. increase the heat generated by
√ C. increase the conductivity of intrinsic
D. decrease the heat generated by
E. increase the heat generated by

17. Conduction is increased in an n −type semiconductor by ____.

A. increased applied electrical field
B. decreased applied electrical field
C. the availability of extra holes
√ D. the availability of donor electrons
E. the availability of extra holes and donor electrons

18. If a fixed potential difference applied across a material creates a current that increases as the material heats up, the material is most likely

√ A. Silicon
B. Rubber
C. Copper
D. Glass
E. Aluminum

19. The forbidden gap in a semiconductor is ___ the forbidden gap in an insulator.

A. half
B. much larger than
C. slightly larger than
D. the same size as
√ E. smaller than

20. Dopant atoms that increase conductivity are added to a semiconductor to produce ___.

A. a conductor
B. an insulator
C. a pure semiconductor
D. an intrinsic semiconductor
√ E. an extrinsic semiconductor

21. When dopants are added to a semiconductor, the net charge of the material ___.

√ A. remains zero
B. becomes zero
C. becomes positive
D. becomes negative
E. becomes positive or negative depending on the dopant added

22. When an electric field is applied to a length of wire, there ___.

A. is random motion, but no overall drifting in one direction
√ B. is overall drifting in one direction, but no random motion
C. are both random motion and overall drifting in one direction
D. is neither random motion nor overall drifting in one direction
E. Drifting in one direction or random motion depends on the applied field

23. In a conductor, conductivity increases as _____.

√ A. temperature decreases
B. temperature decreases
C. resistance increases
D. more electrons move into the valence band
E. the applied electrical field decreases

Answer the following Questions:

1. Answer the following questions on band theory and conductivity.

a. Explain the band theory of solids and how it relates to electrical conductivity. How does the size of the forbidden energy gap relate to the conductivity of the atom?

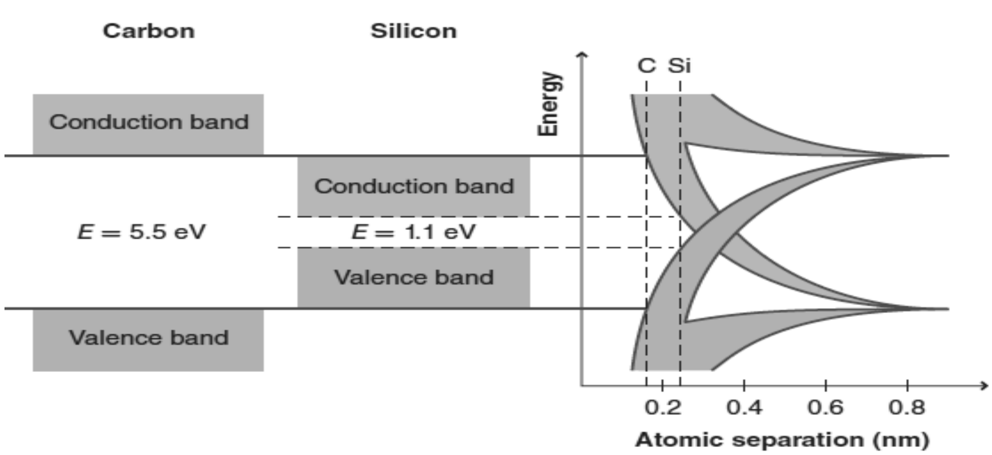
The band theory of solids states that electrons reside in valence bands and conduction bands, which are separated by forbidden energy gaps. To conduct electricity, energy must move electrons from the valence band to the conduction band. Atoms with smaller forbidden energy gaps are better conductors.

b. What makes a good conductor? How does temperature affect conductivity?

Good conductors, like metals, have partially filled electron bands. Electrons that gain energy from an electric field have a place to go in a good conductor—they move from atom to atom. If the temperature increases, the electrons' speed increases and they collide more frequently with atomic cores. Thus, as the temperature rises, the conductivity is reduced.

c. Describe the atomic structure of an insulator and how it gives the insulator its unique qualities.
In an insulator, the valence band is filled to capacity. The conduction band is empty. The forbidden energy gap is large in an insulator, so that even when an electric field is present, almost no electrons can be lifted up to the conduction band. Electrons in an insulator tend to remain in place. Therefore, the material does not conduct electricity

2. Use the diagram to answer the questions below.



a. In a semiconductor, what is the energy difference between the valence band and the conduction band?

The energy difference between the valence and conduction bands in a semiconductor is about 1 eV

b. What is the relationship between the size of a semiconductor's energy gap and the ease with which electrons are lost to the conduction band?

The energy gap is a measure of the energy required to jump from the valence to the conduction band. Thus, the lower the energy gap, the greater the ease with which electrons can make the jump from the valence to the conduction band. Such is the case in semiconductors

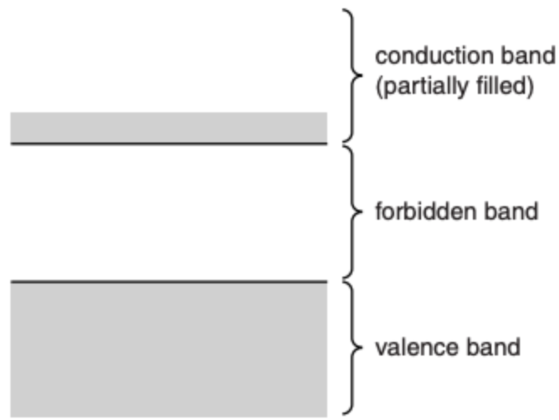
c. What factors increase the conductivity of a semiconductor? Why does this effect occur?

Applying an electric field and increasing the temperature both increase the conductivity of a semiconductor. Both factors add kinetic energy to electrons, making it easier for them to cross the energy gap

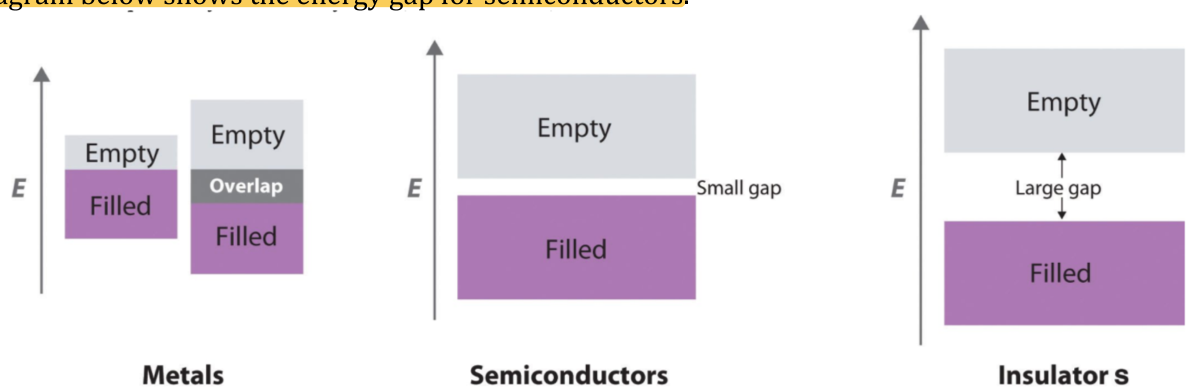
d. What property of semiconductors has made them so useful?
Because a semiconductor has a small energy gap, the conductivity of a semiconductor can be varied, and thus allows for greater control and range of possibilities in building circuits

3. Some of the electron energy bands in a semiconductor material at the absolute zero of temperature are shown in the figure below. Use band theory to explain why, as the temperature of the semiconductor material rises, the electrical resistance of the sample of material decreases.

- As temperature rises electrons gain energy and enter conduction band
- Holes (positively charged) are left in valence band
- More charge carriers (so resistance decreases)
- As temperature rises, lattice vibrations increase
- Effect of increase in number of electrons or holes or charge carriers outweighs effect of increased lattice vibrations (so resistance decreases)



4. The diagram below shows the energy gap for semiconductors.



a. What is the space between the valence band and the conduction band called? What is the significance of the size of the space?

The space between the valence band and the conduction band is called the *energy gap*. The size of the energy gap reflects the amount of energy required for an electron to jump from the valence band to the conduction band.

b. What is the significance of the fact that there is no energy gap for a conductor?

A conductor does not have an energy gap because electrons in a conductor move readily from the valence band to the conduction band.

c. What happens to the electrons in a conductor when an electric field is applied to the conductor?

In an electric field, electrons gain energy from the field. When the electrons are in a conductor, there are energy levels available that are only slightly higher than the electron's ground state and, the electrons can move from one atom to the next in the direction of the force created by the electric field. Such movement of electrons from one atom to the next is an electric current, and the process is known as electric conduction.

d. How is a semiconductor different from a conductor?

Whereas a conductor has no energy gap, a semiconductor has a small energy gap. Thus, a semiconductor can act as either a nonconducting material or as a conducting material, depending on the amount of energy given to the electrons in the semiconductor.

5. This question is about the doped semiconductor.

a. What does E_{gap} represent?
E_{gap} is the energy gap of the original semiconductor

b. What does E_{donor} represent?

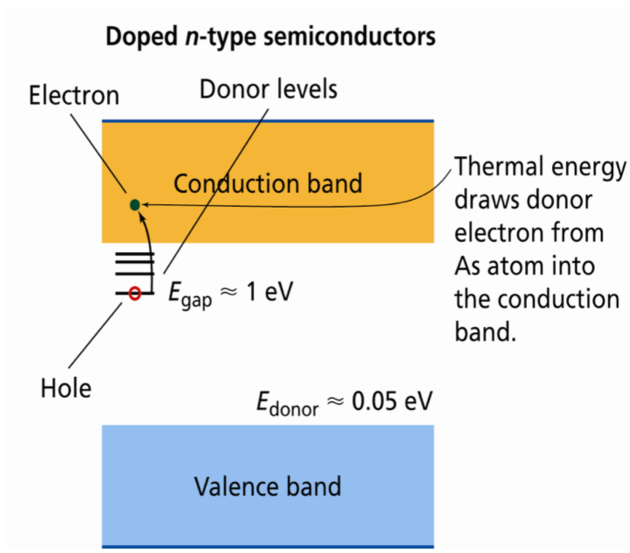
E_{donor} is the energy gap of the electrons contributed by the dopant.

c. How does E_{donor} compare to E_{gap}?

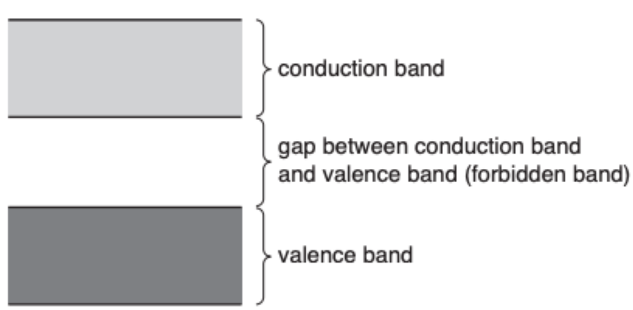
E_{donor} is much lower—only about 0.05 eV instead of about 1 eV.

d. What does the value of E_{donor} tell you about the behavior of the electrons contributed by the dopant?

The electrons can be very easily moved by thermal energy into the conduction band.



6. Some electron energy bands in a solid are shown in the figure below. The width of the forbidden band and the number of charge carriers occupying each band depends on the nature of the solid. Use band theory to explain why:



a. the resistance of a metal at room temperature increases gradually with temperature,
no forbidden band / valence and conduction bands overlap
no change in number of charge carriers (as temperature rises)
increased lattice vibrations so resistance increases

b. the resistance, at constant temperature, of a light-dependent resistor (LDR) decreases with increasing light intensity.
photons captured / absorbed by electrons in valence band
electrons promoted to conduction band
leaving holes in the valence band
more holes and / or electrons so resistance decreases

7. Answer the following questions.

a. How do the energy bands of conductors and insulators differ?

In conductors, the valence bands are partially filled, and the conduction band is only slightly higher than the electrons' ground state energy levels. The partially filled bands make it easy for electrons to move from one atom to the next. In insulators, the valence bands are filled, the conduction band is empty and there is a wide forbidden gap between them.

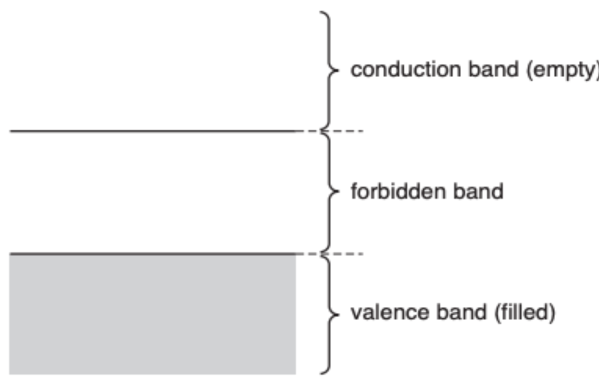
b. Why is silicon a good semiconductor?

Silicon atoms have four valence electrons. The valence electrons form a band that is filled, but the forbidden gap is so small that some can reach the conduction band by means of thermal kinetic energy alone. As a result, silicon conducts naturally to a limited degree, so it is a good semiconductor.

c. Compare and contrast n-type semiconductors and p-type semiconductors.

Both are materials doped with sources of either electrons or holes to increase conductivity. An *n*-type semiconductor is doped with a material that has extra donor electrons, which enable it to conduct electricity. The fact that the conduction band is close to the valence band further facilitates its conductivity. A *p*-type semiconductor is doped with a material that has fewer valence electrons. This creates holes. Electrons from the conduction band drop into these holes, creating new holes in the conduction band. Conduction is enhanced by the availability of the extra holes provided by the acceptor donor atoms.

8. Some of the electron energy bands in a solid are illustrated in the figure below.



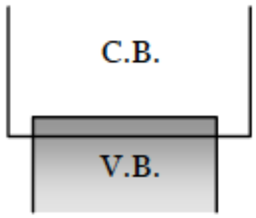
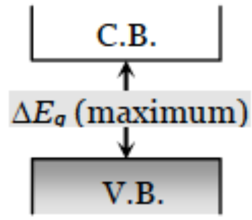
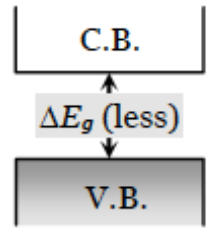
a. In isolated atoms, electron energy levels have discrete values. Suggest why, in a solid, there are energy bands, rather than discrete energy levels

in a solid, electrons in neighboring atoms are close together and influence/interact with each other. This changes their electron energy level. Many atoms in the lattice cause a spread of energy levels into a band.

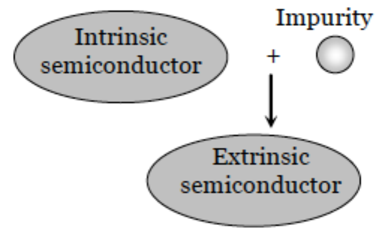
b. A light-dependent resistor (LDR) consists of an intrinsic semiconductor. Use band theory to explain the dependence on light intensity of the resistance of the LDR when it is at constant temperature

Photons of light give energy to electrons in valence band. The electrons move into the conduction band. Increased number of electrons and holes which are charge carriers, increases the current, hence reduces resistance.

9. Complete the table by describing each property listed in the table below.

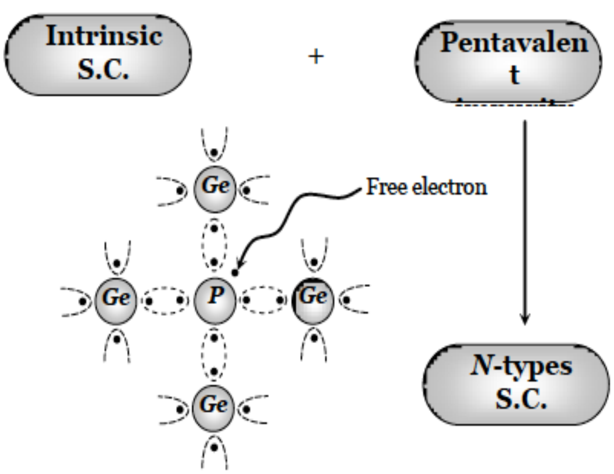
Property	Conductors	Insulators	Semiconductors
Band Structure			
Energy Gap	Zero to very small	Very large About 6 eV for diamond	Around 1 eV Example: Ge: 0.7 eV Si: 1.1 eV
Current Carriers	Free electrons	None	Free electrons and holes
Condition of valance and conduction bands at room temperature	Valence band is completely filled and Conduction band is either partially filled with an extremely small energy gap between the bands or is empty with the two bands overlapping each other	Valence band is completely filled and the conduction band is practically empty. The forbidden energy gap is very large	The energy band structure is similar to that of insulators, but the size of the forbidden energy gap is much smaller than for insulators
Conductivity	On applying even, a small electric field, conductors can conduct electricity	When an electric field is applied across it, the electrons find it very difficult to acquire such a large amount of energy to reach the conduction band. So, no current flows through it.	When an electric field is applied to a semiconductor, the electrons in the valence band find it easier to shift to the conduction band.
Effect of temperature on Conductivity	Decreases	No change	Increases
Effect of temperature on resistance	Increases	No change	Decreases
Examples	Cu, Ag, Au, Na, Pt, Hg ..... etc	Wood, plastic, mica, diamond, glass ,.... .etc	Ge, Si, Ga, As, ... etc

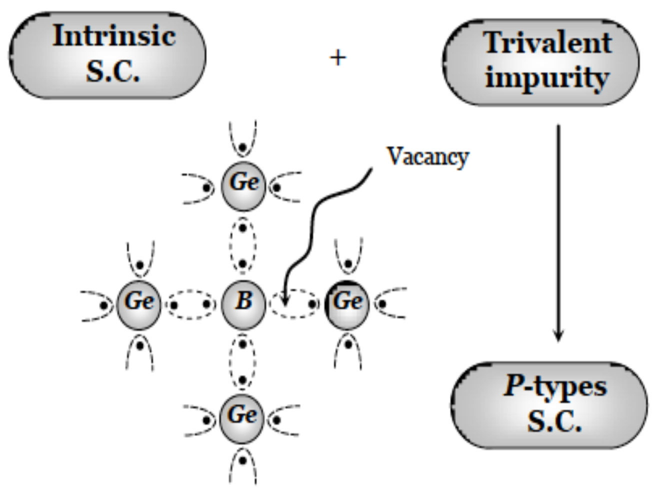
10. In the table below, list the properties of the two types of semiconductors.

<table>
<tr><th>Intrinsic Semiconductor</th><th>Extrinsic Semiconductor</th></tr>
<tr><td>
• A pure semiconductor without any impurity added is called intrinsic semiconductor
• They have four electrons in the outermost orbit of atom and atoms are held together by covalent bonds
• Free electrons and holes are both charge carriers. The number of free electrons in conduction band and the number of holes in the valence band is exactly equal.
• Because of a smaller number of charge carriers at room temperature, intrinsic semiconductors have low conductivity
• Conductivity of the semiconductor increases with temperature because number density of charge carriers increases
• Examples are crystalline forms of pure silicon, germanium, etc.
</td><td>
• It is also called impure semiconductor. Prepared by doping a small quantity of impurity to the pure semiconductor.


• Impurities are of two types: Pentavalent and trivalent impurities.
• The number of free electrons and holes are never equal. There are excess of electrons in n-type and excess of holes in p-type semiconductors.
• Their conductivity is high and they are practically useful
• Examples are silicon and germanium crystals with impurity of arsenic, antimony, phosphorous, etc OR indium, boron, aluminum, etc.
</td></tr>
</table>

11. Differentiate between n −type and p −type semiconductors.

<table>
<tr><th>n −type semiconductor</th><th>p −type semiconductors</th></tr>
<tr><td>Pentavalent impurity added to internsic semiconductor


</td><td>Trivalent impurity added to internsic semiconductor


</td></tr>
<tr><td>Majority charge carriers- Electrons
Minority charge carriers- holes</td><td>Majority charge carriers- holes
Minority charge carriers- Electrons</td></tr>
<tr><td>N-type semiconductor is electrically neutral (not negatively charged)</td><td>P-type semiconductor is electrically neutral (not positively charged)</td></tr>
<tr><td>Impurity is called Donor impurity because one atom generates one e^-</td><td>Impurity is called Acceptor impurity</td></tr>
<tr><td>Doped with pentavalent impurity like Phosphorous, Arsenic, Antimony, etc</td><td>Doped with trivalent impurity like Boron, Gallium, Indium, Aluminum, etc</td></tr>
</table>

12. Complete the table below with the correct terms for the descriptions given.

Description	Term
Is a pure semiconductor which conducts current as a result of thermally freed electrons and holes	Intrinsic semiconductor
They are produced by adding dopant atoms to a semiconductor so they conduct	Extrinsic semiconductor
An electron donor or acceptor atom added to a semiconductor	Dopant
Explains electric conduction in terms of energy bands and forbidden gaps	Band Theory
An element whose atoms have four valence electrons	Silicon
An empty energy level in the valence band	Hole

Learning Outcome	Number of Periods	Suggested Exercises /Assignments
Topic 10– Band Theory of Solids Subtopic 10.3– Diodes Subtopic 10.4– Transistors (KPIs 10.3.1 – 10.4.2)	4 + 2	Chapter 43

- **Practice Questions (Addition to Specified Example Questions)**

Multiple choice question

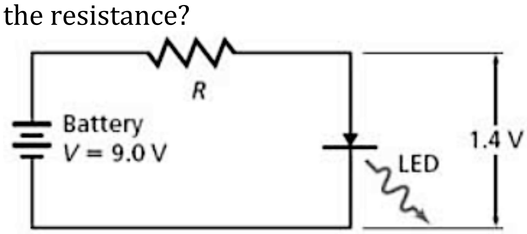
1. Where are depletion layers formed?

A. In silicon chips
B. On the ends of diodes
C. Where the current is strongest
√ D. At boundaries between p and n-type regions of a diode
E. At boundaries between p and p-type regions of a diode

2. A diode whose holes and free electrons are drawn away from each other is ____.

A. forward-biased
√ B. reverse-biased
C. given a net positive charge
D. given a net negative charge
E. converted to a transistor

3. The diagram shows a series circuit with a battery, a resistor, and an LED. If the current is 15 mA, what is the resistance?

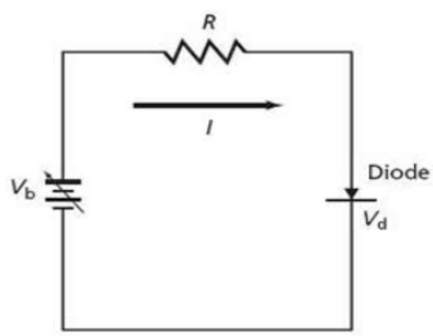


A. $9.3 \times 10^1\ \Omega$
√ B. $5.1 \times 10^2\ \Omega$
C. $6.0 \times 10^2\ \Omega$
D. $6.9 \times 10^2\ \Omega$
E. $9.3 \times 10^2\ \Omega$

4. A reverse-bias diode acts as a very high-value ____.

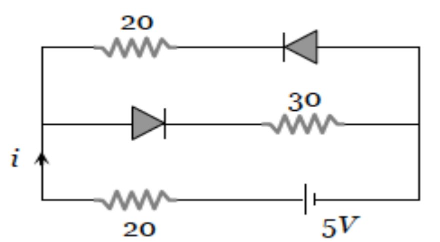
A. battery
√ B. resistor
C. switch
D. transistor
E. semiconductor

5. The diagram shows a circuit connecting a diode, a 550 Ω resistor, and a power supply that forward-biases the diode. If the diode with a voltage drop of 0.7 V has a current of 0.015 A, what is the voltage of the power supply?



A. 7 V
B. 8 V
√ C. 9 V
D. 10 V
E. 12 V

6. What is the current in the circuit?



A. 5/40 A
√ B. 5/50 A
C. 5/10 A
D. 5/20 A
E. 10/15 A

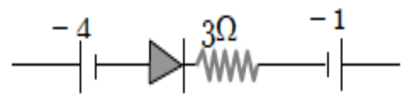
7. Applying a forward bias to a *p*-*n* junction ___.

√ A. narrows the depletion zone
B. increases the number of donors on the *n* side
C. decreases the number of donors on the *n* side
D. increases the electric field in the depletion zone
E. increases the potential difference across the depletion zone

8. How do light-emitting diodes emit light?

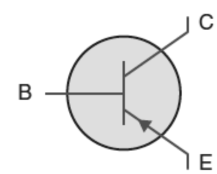
A. They store light from the Sun and emit it back
B. They are made from elements that glow naturally
√ C. Electrons and holes combine and energy is released at the wavelength of light
D. They need the energy from a hydrogen cell
E. They convert thermal energy to light

9. Find the magnitude of the current in the circuit below.



√ A. 0 A
B. 0.1 A
C. 0.2 A
D. 1.0 A
E. 2.0 A

10. What is the type of transistor shown in the diagram below?



√ A. *pnp*
B. *npn*
C. *nnp*
D. *ppn*
E. *ppp*

11. One difference between a diode and a transistor is that ______

A. transistors use two dopants
B. diodes are used in microchips
C. they use different types of dopants
√ D. they use different types of junctions
E. they both are used as rectifiers

12. How does a transistor affect voltage?

A. It causes voltage to decrease
B. It reduces large voltage changes
C. It does not affect voltage
√ D. It amplifies small voltage changes
E. It causes the voltage to go to zero

ثانوية التكنولوجيا التطبيقية
Applied Technology High School

STS
المدرسة الثانوية الفنية
Secondary Technical School

13. Transistors are mainly used as _____.

A. resistors
B. rectifiers
C. insulators
D. capacitors
√ E. Current amplifiers

14. In an npn-transistor, conventional current passes from the ______.

√ A. base to the emitter
B. emitter to the base
C. collector to the emitter
D. diode to the collector
E. rectifier to the collector

15. What carries charge in a *pnp*-transistor?

A. electrons
√ B. holes
C. protons
D. neutrons
E. nothing

16. Current through the collector is ___ the current through the base.

A. a little smaller than
B. a little larger than
C. much smaller than
√ D. much larger than
E. the same as

Answer the following Questions:

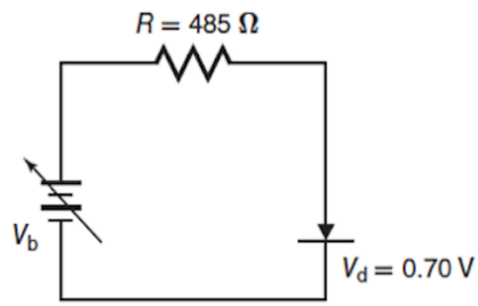
1. A silicon diode is connected in the forward-biased direction to a power supply through a 485 Ω resistor, as shown below.

a. If the diode potential difference is 0.70 V, what is the power supply potential difference when the diode current is 14 mA?

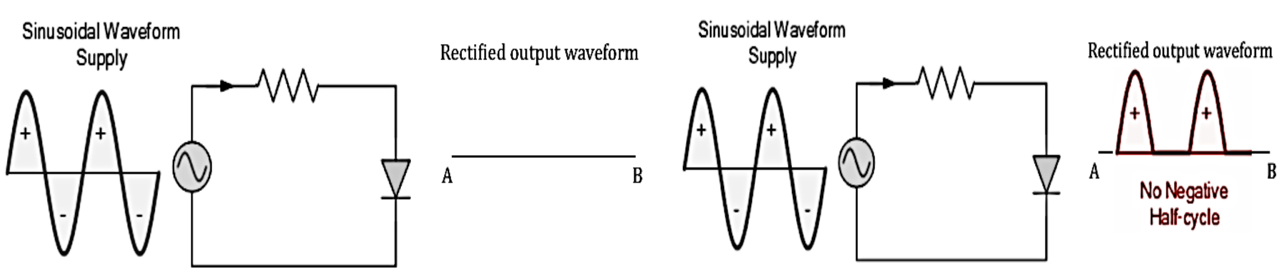
$\Delta V_{supply} = \Delta V_{Resistor} + \Delta V_{diode}$

$\Delta V_{supply} = IR + \Delta V_{diode}$

$\Delta V_{supply} = (14 \times 10^{-3}\ A)(485\ \Omega) + (0.70\ V) = 7.5\ V$



b. The battery is now replaced by a sinusoidal waveform supply as shown below. Draw between points A and B, the rectified output waveform.



c. Antimony has five valence electrons. Would it be used to make an n-type or a p-type semiconductor?
Antimony with five valence electrons, can replace a silicon atom to create an n-type semiconductor

2. A forward-biased silicon diode is connected to a 5.0-V battery. There are also three 220-Ω resistors in the circuit connected in series, and the potential difference across the diode is 0.80 V. What is the current?

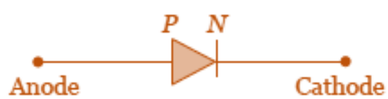
$$V_b = IR_1 + IR_2 + IR_3 + V_d$$

$$I = \frac{V_b - V_d}{R_1 + R_2 + R_3} = \frac{5.0\ V - 0.80\ V}{220\ \Omega + 220\Omega + 220\Omega} = 6.4\ mA$$

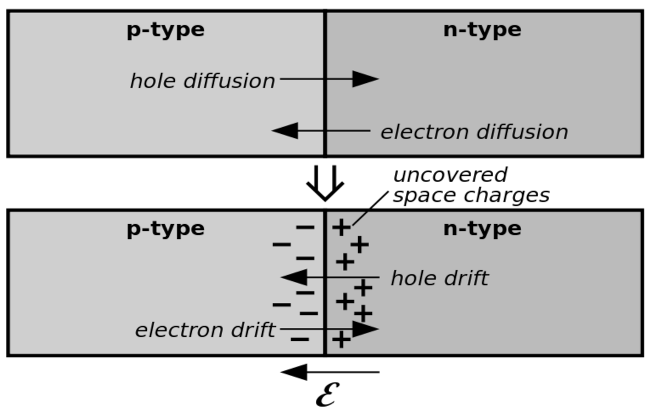
3. Answer the following questions on P-N Junction diode.

a. What is a P-N junction?
When a P-type semiconductor is suitably joined to an N-type semiconductor, then resulting arrangement is called P-N junction.

b. Draw the circuit symbol of a diode.



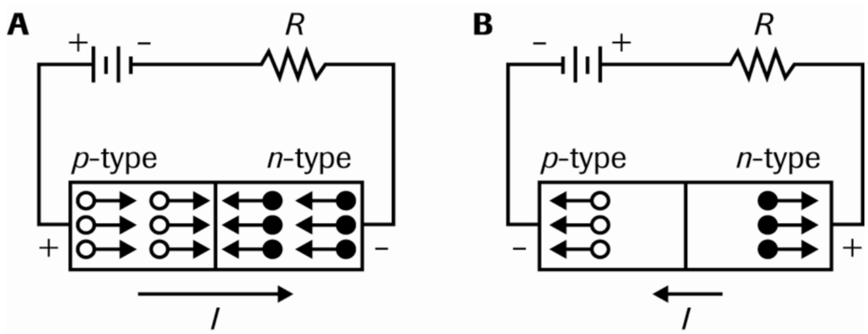
c. Use the diagram below to explain how the depletion region is formed.



Due to the difference in concentration of charge carrier in two sections of P-N junction, the electrons from N-junction diffuse through the junction into P-region and the hole from the P region diffuse into N-region. The net result is that the diffused electrons and holes are gone. In a N-side region near to the junction interface, free electrons in the conduction band are gone due to (1) the diffusion of electrons to the P-side and (2) recombination of electrons to holes that are diffused from the P-side. Holes in a P-side region near to the interface are also gone by a similar reason. As a result, majority charge carriers are depleted in the region around the junction interface, so this region is called the depletion region. Depletion layer acts like a barrier that opposes the flow of electrons from n-side and holes from p-side.

d. What is a potential barrier?
The potential difference created across the P-N junction due to the diffusion of electrons and holes is called potential barrier. Typically;
For Ge: $V_B = 0.3\ V$
For Si: $V_B = 0.7\ V$

4. The figures below show a diode used with two kinds of biasing.



a. What function does the battery serve?
It provides electrons and maintains a potential difference

b. What is the direction of conventional current in each figure, clockwise or counterclockwise?

The direction of conventional current is counterclockwise in A and clockwise in B

c. Which way are electrons flowing in each figure?
Electrons flow clockwise in A and counterclockwise in B.

d. How do *p*-type and *n*-type semiconductors differ?
A *p*-type semiconductor conducts by means of holes; an *n*-type semiconductor conducts by means of electrons.

e. What kind of biasing does each diode have? How can you tell?
A is forward-biased; the plus sign is on the *p*-side and the minus sign is on the *n*-side.
B is reverse-biased; the plus sign is on the *n*-side and the minus sign is on the *p*-side.

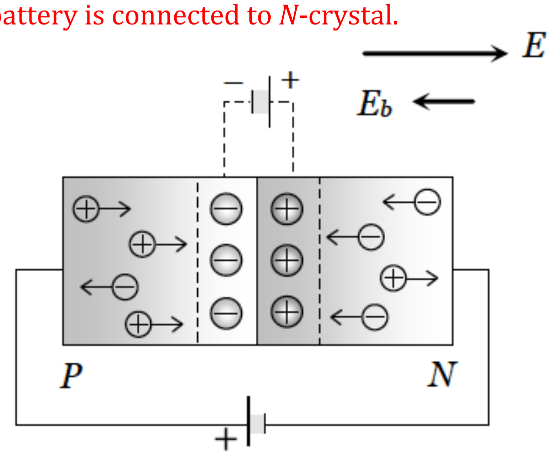
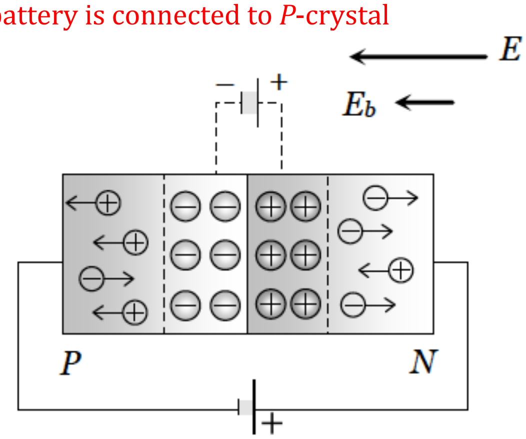
f. Compare the depletion layer in the two diodes.

The depletion layer is wide in B. It does not exist in A.

g. Compare the current through the two diodes. Which is a conductor, and which is a large resistor?

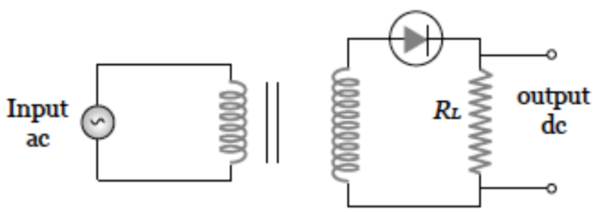
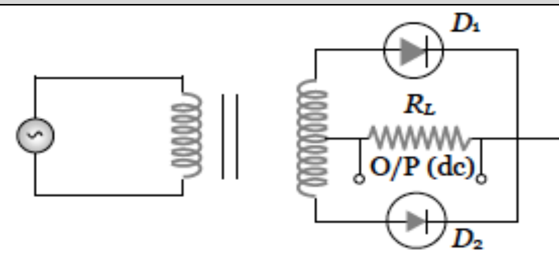
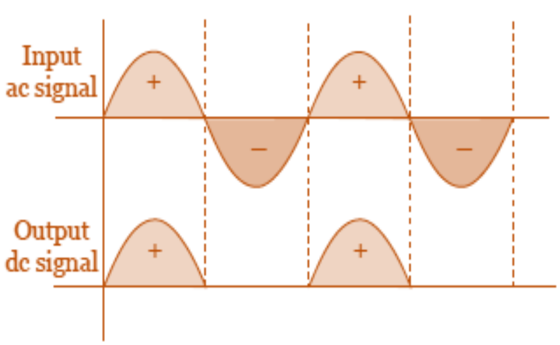
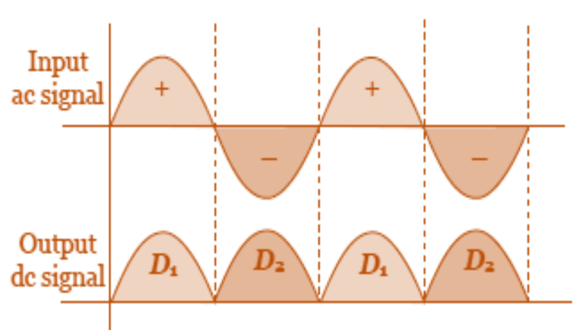
Current easily passes through A, but not much passes through B. A is a conductor; B is a large resistor

5. Differentiate between forward and reverse bias.

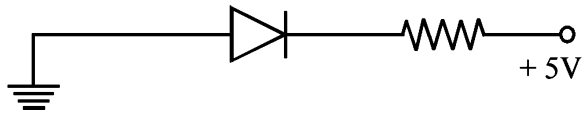
	Forward Bias	**Reverse Bias**
Description and diagram	Positive terminal of the battery is connected to the *P*-crystal and negative terminal of the battery is connected to *N*-crystal. 	Positive terminal of the battery is connected to the *N*-crystal and negative terminal of the battery is connected to *P*-crystal 

Depletion region	Width of the depletion layer decreases	Width of the depletion layer increases
Resistance	Low resistance: ($R_{forward} \approx 10\ \Omega - 25\ \Omega$)	High resistance: ($R_{reverse} \approx 10^5\ \Omega$)
Potential barrier	Forward bias opposes the potential barrier and for $V > V_B$, a forward current is set up across the junction	Reverse bias supports the potential barrier and no current flows across the junction due to the diffusion of the majority carriers. (A very small reverse current may exist in the circuit due to the drifting of minority carriers across the junction)

6. Describe the working of a half wave and full wave rectifier in the given circuits below.

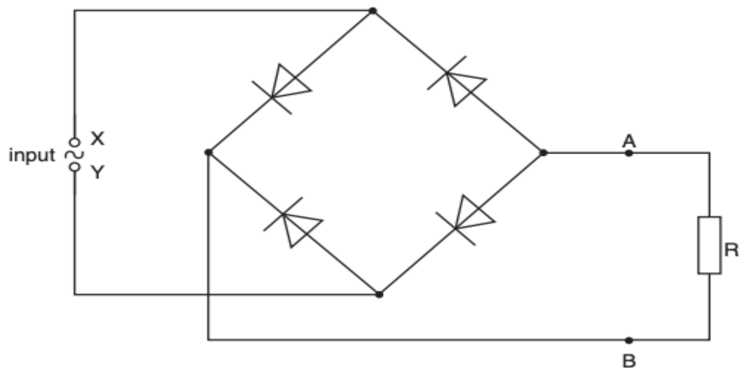
	Half wave rectifier	Full wave rectifier
Diagram		
Working	Junction diode allows current to pass through only if it is forward biased, hence a pulsating voltage will appear across the load only during positive cycles when diode is forward biased.	The circuit uses two diodes connected to the ends of a center tapped transformer. The voltage rectified by the two diodes is half of the secondary voltage i.e., each diode conducts for half cycle of input but alternately so that net output across load comes as half sinusoids with positive values only.
Status of diodes and output	**During positive half cycle:** Diode → Forward biased Output signal → Obtained **During negative half cycle:** Diode → Reverse biased Output signal → Not obtained	**During positive half cycle:** Diode D_1 → Forward biased D_2 → Reverse biased Output signal → Obtained due to D_1 only **During negative half cycle:** Diode D_1 → Reverse biased D_2 → Forward biased Output signal → Obtained due to D_2 only
Output signal compared to input	**Output signal compared to input signal:** 	**Output signal compared to input signal:** 

7. In the following figure, is the junction diode forward biased or reverse biased? Explain.



Reversed biased as the P-crystal of the diode is earthed i.e, at lower potential and N-crystal is at higher potential of 5 V.

8. The circuit for a full-wave rectifier using four ideal diodes is shown in the figure below.

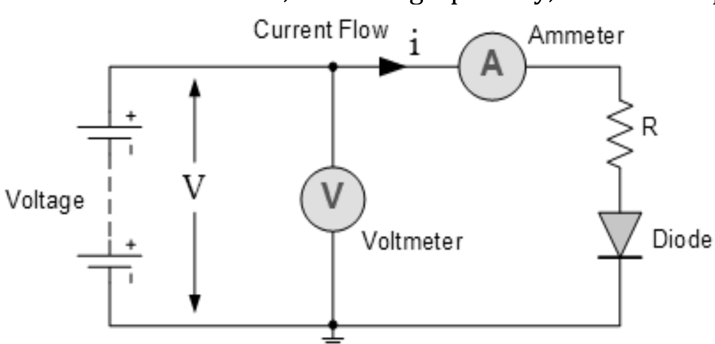


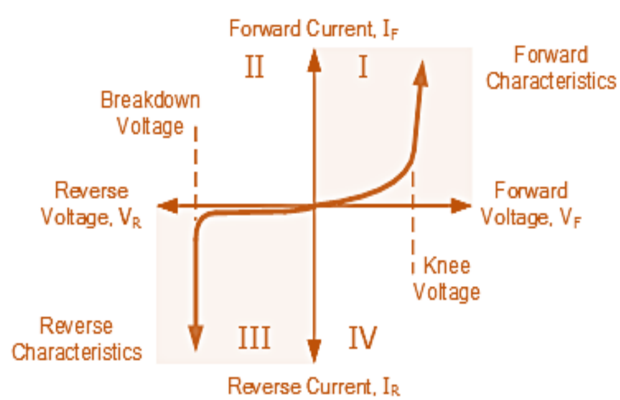
A resistor R is connected across the output AB of the rectifier.

a. On the figure above, draw a circle around any diodes that conduct when the terminal X of the input is positive with respect to terminal Y.
   Top left and bottom right diodes

b. label the positive (+) and the negative (–) terminals of the output AB.
   B shown as (+) and A shown as (–)

9. For the circuit below, describe graphically, the current-potential difference characteristics of the diode.





When the diode is forward biased, anode positive with respect to the cathode, a forward or positive current pass through the diode and operates in the top right quadrant of its I-V characteristics curves as shown. Starting at the zero intersection, the curve increases gradually into the forward quadrant but the forward current and voltage are extremely small.

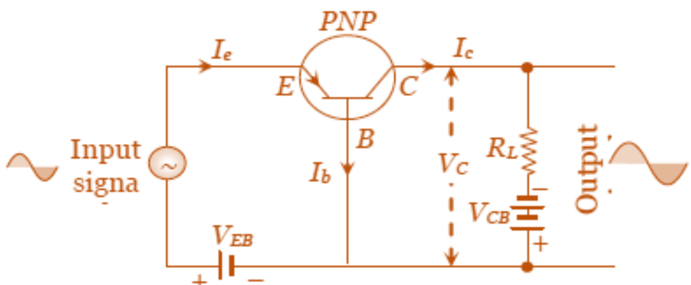
When the forward voltage exceeds the diodes P-N junctions internal barrier voltage, which for silicon is about 0.7 volts, avalanche occurs and the forward current increases rapidly for a very small increase in voltage producing a non-linear curve. The “knee” point on the forward curve.

Likewise, when the diode is reversed biased, cathode positive with respect to the anode, the diode blocks current except for an extremely small leakage current, and operates in the lower left quadrant of its I-V characteristic curves. The diode continues to block current flow through it until the reverse voltage across the diode becomes greater than its breakdown voltage point resulting in a sudden increase in reverse current producing a fairly straight-line downward curve as the voltage losses control.

10. Answer the following questions on transistor.

a. Give one use of a transistor.

Transistor as an amplifier: A device which increases the amplitude of the input signal as shown below.
The transistor can be used as an amplifier in the following three configurations:
Common base amplifier, common emitter amplifier, common collector amplifier



CB amplifier

b. How does a transistor affect voltage?

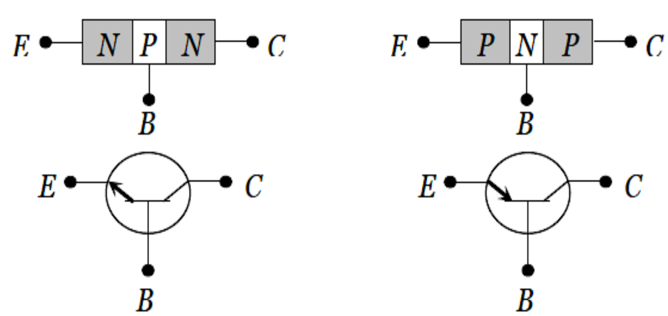
In a transistor, most of the electrons pass through the base and then move on to the collector. The current through the collector is much larger than the current through the base, causing a voltage drop. Small changes in the voltage on the base produce large changes in the collector current and voltage. As a result, a transistor amplifies small voltage changes into much larger changes.

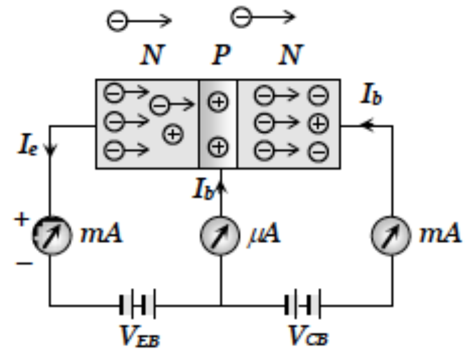
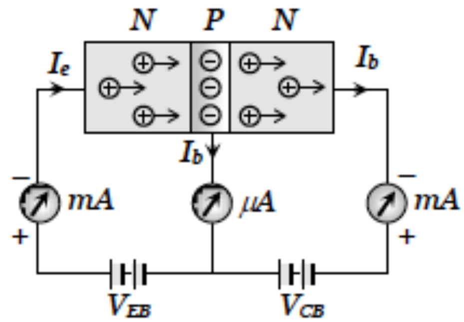
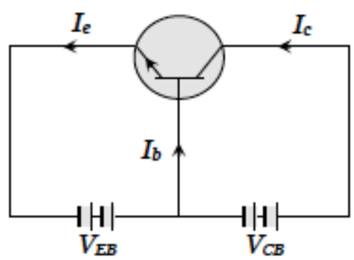
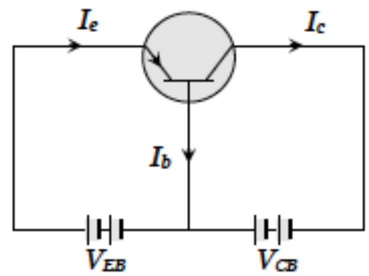
10. Describe the structure of a transistor and differentiate between *pnp* and *npn* transistors, identifying the base, emitter and collector.

A junction transistor is formed by sandwiching a thin layer of P-type semiconductor between two N-type semiconductors or by sandwiching a thin layer of n-type semiconductor between two p-type semiconductors as shown below.

$E - \textit{Emitter (emits majority charge carriers)}$
$C - \textit{Collector (collects majority charge carriers)}$
$E - \textit{Base (provide proper interaction between E and C)}$

In normal operation, base-emitter junction is forward biased and collector-base junction is reverse biased.



	npn –Transistor	*pnp* –Transistor
Diagram		
Circuit		
Current	5% emitter electron combine with the holes in the base region resulting in small base current. Remaining 95% electrons enter the collector region.	5% emitter holes combine with the electrons in the base region resulting in small base current. Remaining 95% holes enter the collector region.

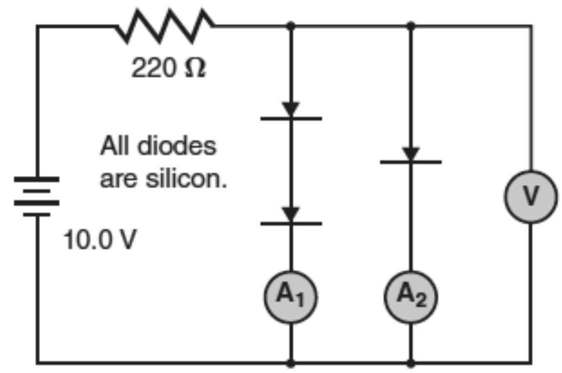
11. How does an *npn*-transistor work?

The *pn*-junctions act like two back-to-back diodes. A battery keeps a positive potential difference between the collector and the emitter; it is forward-biased. The base-collector diode is reverse-biased, so, at first, no current passes. When conventional current passes from the base to the emitter, electrons easily diffuse through the thin base and create a current between the base and the collector. This current causes the base-collector diode to be forward biased and current passes. Small changes in the current on the base amplify into large changes in the collector current.

12. Why does a diode conduct charges in only one direction easily?

When a diode is connected to a battery in such a way that the positive terminal of the battery is attached to the *p*-end, free electrons on the *n*-end are attracted to the positively charged holes on the *p*-end of the diode. They pass the boundary and flow through the *p*-end of the diode. The depletion layer is eliminated and current passes. As a result of electron flow, the *n*-end becomes positive and the *p*-end becomes negative. If the battery terminals are reversed, the area around the junction is depleted of charge carriers and is a poor conductor. The depletion layer increases and very little current passes.

13. Use the circuit below to answer parts (a) and (b).



a. What is the voltmeter reading? Explain

0.70 V; by inspection and the approximation that a silicon diode will drop 0.70 V when it is forward biased.

b. Find the readings on:

i. The ammeter A_1
0 A; as 0.70 V is not enough to turn on two diodes in series

ii. The ammeter A_2
$$I = \frac{V}{R} = \frac{9.3\ V}{220\ \Omega} = 0.042\ A$$

14. For each of the elements in the table below, indicate whether it could be used as dopant to make an ***n-type*** semiconductor, a ***p-type*** semiconductor, or neither.

Element	**Dopant to make *n-type* or p-*type***
Aluminum (Z=13)	Aluminum has 3 valence electrons. So it can be used to make **p-*type***
Nitrogen (Z=7)	Nitrogen has 5 valence electrons. So it can be used to make ***n-type***
Antimony (Z=51)	Antimony has 5 valence electrons. So it can be used to make ***n-type***
Carbon (Z=6)	Carbon has 4 valence electrons. So it can't be used as a dopant
Gallium (Z=31)	Gallium has 3 valence electrons. So it can be used to make **p-*type***

15. State whether the following statements are true or false.

When two atoms are brought together in a solid, the electric field of one atom affects the field of the other atom	True
A rectifier is a diode that converts AC to a current that flows in one direction	True
In good conductors, electrons can be found in the forbidden energy gap	False
When a hole and a free electron combine, their charges cancel each other	True

16. Complete the table below with the correct terms for the descriptions given.

Description	**Term**
It consists of a *p*-type semiconductor joined with an *n*-type semiconductor	Diode
The region around a diode junction that has neither holes nor free electrons	Depletion layer
A reverse-biased diode has a wide	Depletion layer
can be used in rectifier circuits to convert AC to DC	Diode

17. Use the term from the table that best completes the statement. Use the term once only.

base	**dopant**	**intrinsic**
base-emitter	**forward-biased**	***n*-type**
conductivity	**hole**	***p*-type**
depletion layer	**insulator**	**semiconductors**
diode		

1. ___semiconductor_____	The elements classified as ___ typically have four valence electrons.
2. _____diode__________	A(n) ___ is an electronic device that can be used as a rectifier.
3. ____base-emitter______	In computers, small currents in the ___ circuits can turn on or turn off large currents in the collector-emitter circuits.
4. _____n-type__________	When an electron donor such as arsenic, with five valence electrons, is used as a dopant, the doped silicon is called a(n) ___ semiconductor.
5. _____conductivity_____	As the temperature rises, the ___ of metals is reduced.
6. ___forward-biased____	In a ___ diode, electrons fill in the holes and current flows.
7. ____p-type________	Conduction in a(n) ___ semiconductor is enhanced by the availability of extra holes provided by the acceptor dopant atoms.
8. _____insulator______	In a(n) ___ , the forbidden energy gap is very large.
9. ______Intrinsic______	___ semiconductors are made useful by doping.
10. ______dopant______	A(n) ___ increases the conductivity of a semiconductor.
11. _____hole__________	Physicists refer to an electron deficiency as a(n) ___.
12. __depletion layer___	There are no charge carriers in the ___ of a *pn*-junction diode.
13. ______base_________	The central layer of an *npn*-transistor is called the ___.