Applied Technology High School

Secondary Technical School

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

Textbook: 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

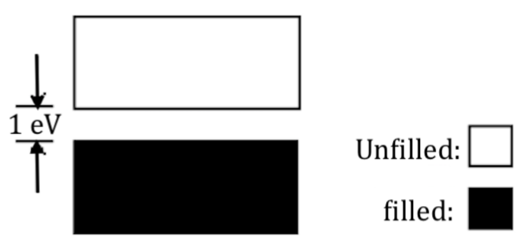
B. the valence band is empty and the conduction band is filled

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:

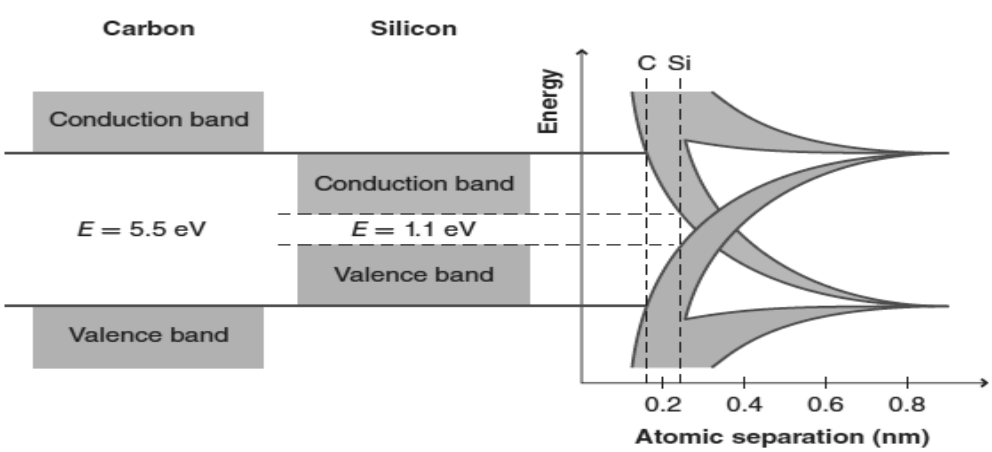
1. Answer the following questions on band theory and conductivity.

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?

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

c. Describe the atomic structure of an insulator and how it gives the insulator its unique qualities.

2. Use the diagram to answer the questions below.



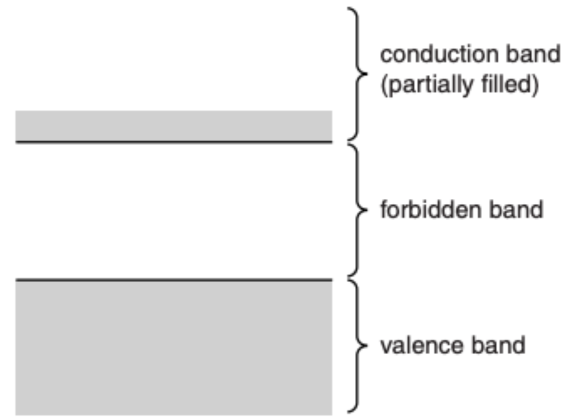
a. In a semiconductor, what is the energy difference between the valence band and the conduction band?

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?

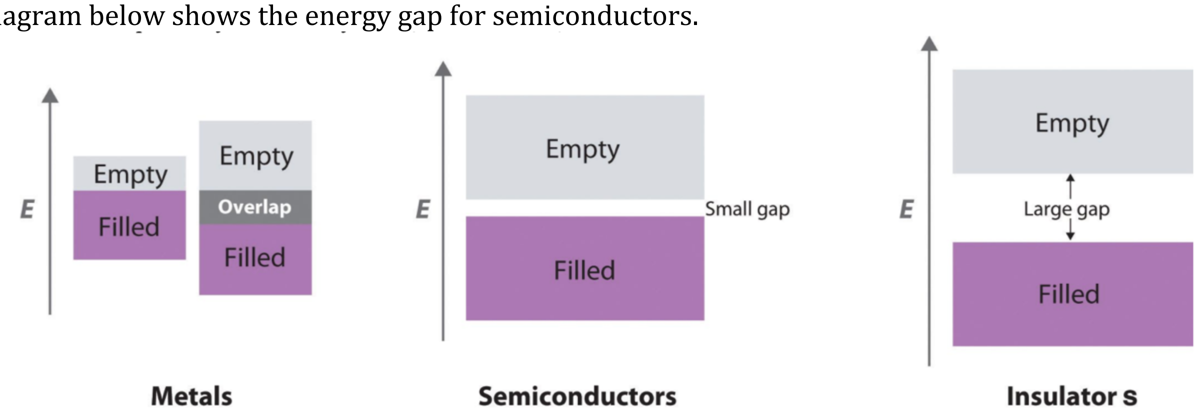
c. What factors increase the conductivity of a semiconductor? Why does this effect occur?

d. What property of semiconductors has made them so useful?

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.



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?

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

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

d. How is a semiconductor different from a conductor?

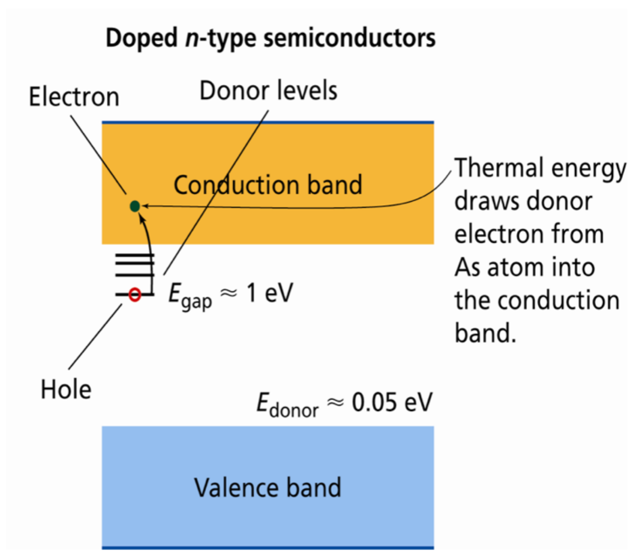
5. This question is about the doped semiconductor.

a. What does E_{gap} represent?

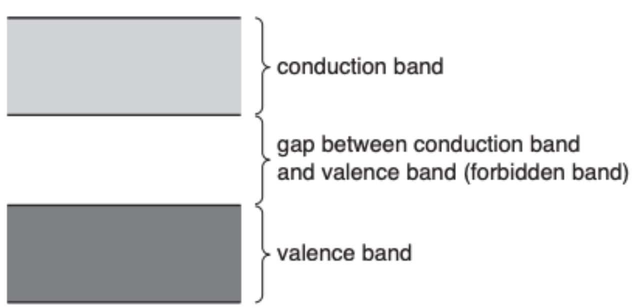
b. What does E_{donor} represent?

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

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



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,

b. the resistance, at constant temperature, of a light-dependent resistor (LDR) decreases with increasing light intensity.

7. Answer the following questions.

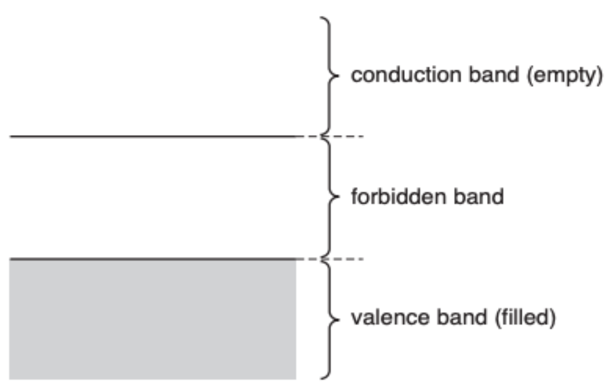
a. How do the energy bands of conductors and insulators differ?

b. Why is silicon a good semiconductor?

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

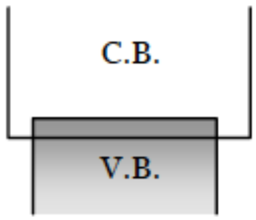
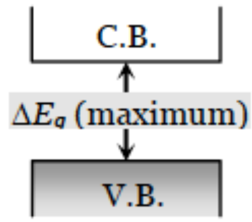
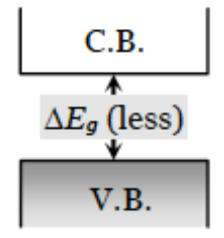
8. Some of the electron energy bands in a solid are illustrated in the figure below.

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



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

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

Property	Conductors	Insulators	Semiconductors
Band Structure			
Energy Gap			
Current Carriers			
Condition of valance and conduction bands at room temperature			
Conductivity			
Effect of temperature on Conductivity			
Effect of temperature on resistance			
Examples			

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

Intrinsic Semiconductor	Extrinsic Semiconductor

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

n −type semiconductor	p −type semiconductors

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	
They are produced by adding dopant atoms to a semiconductor so they conduct	
An electron donor or acceptor atom added to a semiconductor	
Explains electric conduction in terms of energy bands and forbidden gaps	
An element whose atoms have four valence electrons	
An empty energy level in the valence band	

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

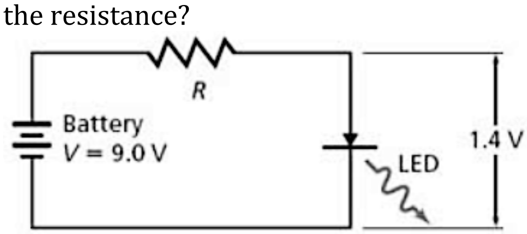
1. Where are depletion layers formed?

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?



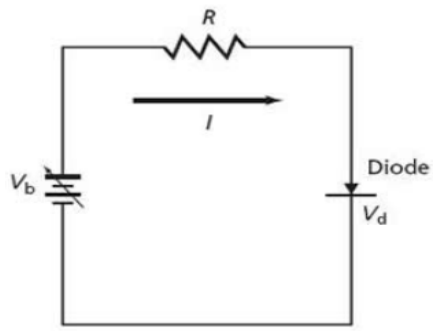
A. $9.3 \times 10^1\ \Omega$
B. $5.1 \times 10^2\ \Omega$
C. $6.0 \times 10^2\ \Omega$
D. $6.9 \times 10^2\ \Omega$
E. $9.3 \times 10^2\ \Omega$

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

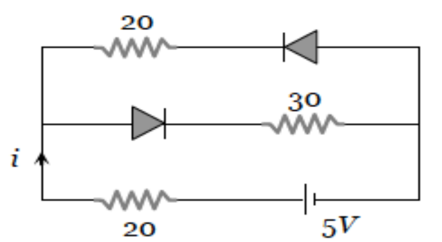
A. battery
B. resistor
C. switch
D. transistor
E. semiconductor

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 ___.

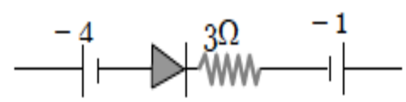
A. narrows the depletion zone
B. increases the number of donors on the *n* side
C. decreases the number of donors on the *n* side
D. increases the electric field in the depletion zone
E. increases the potential difference across the depletion zone

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

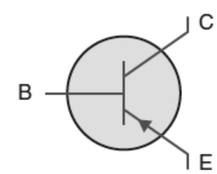
9. Find the magnitude of the current in the circuit below.

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

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

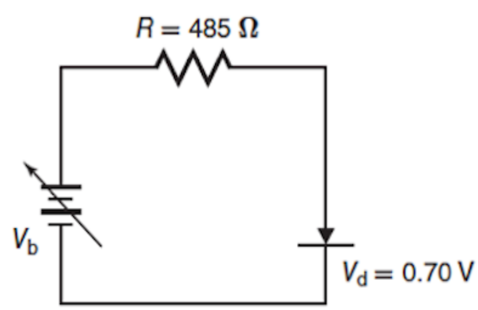
16. Current through the collector is ___ the current through the base.

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

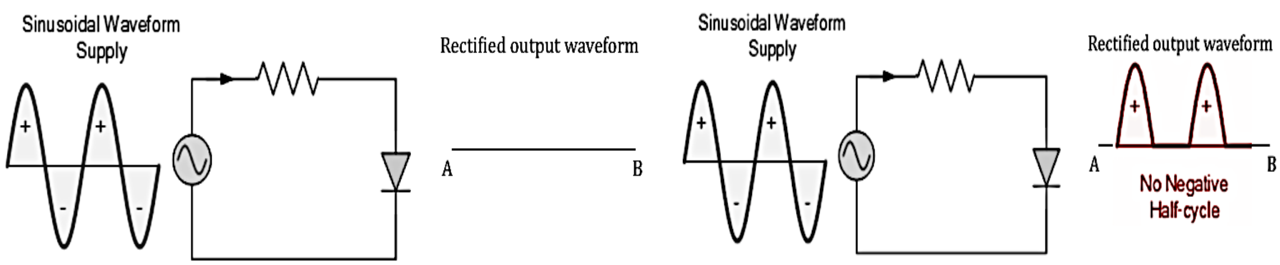
Answer the following Questions:

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?



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?

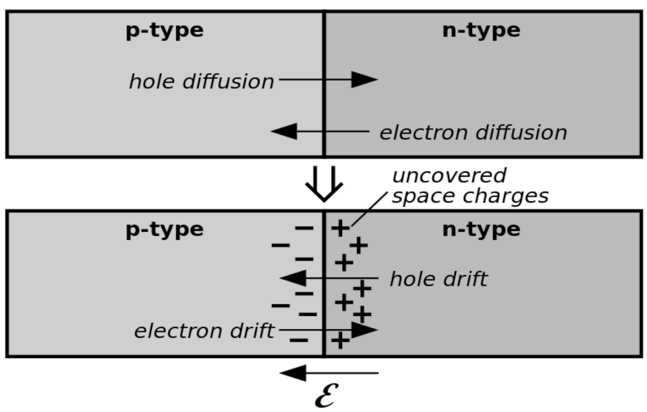
2. A forward-biased silicon diode is connected to a 5.0-V battery. There are also three 220-Ω resistors in the circuit connected in series, and the potential difference across the diode is 0.80 V. What is the current?

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

a. What is a P-N junction?

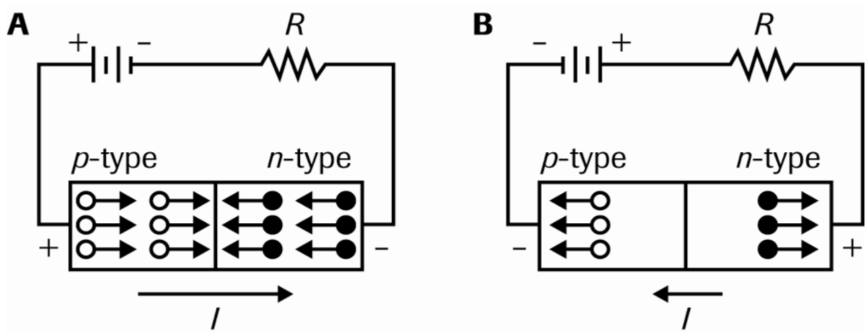
b. Draw the circuit symbol of a diode.

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



d. What is a potential barrier?

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



a. What function does the battery serve?

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

c. Which way are electrons flowing in each figure?

d. How do *p*-type and *n*-type semiconductors differ?

e. What kind of biasing does each diode have? How can you tell?

f. Compare the depletion layer in the two diodes.

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

5. Differentiate between forward and reverse bias.

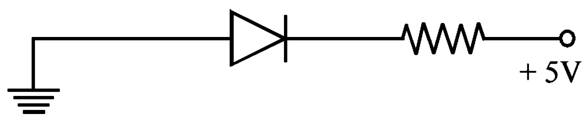
	Forward Bias	**Reverse Bias**
Description and diagram		
Depletion region		
Resistance		

Potential barrier		

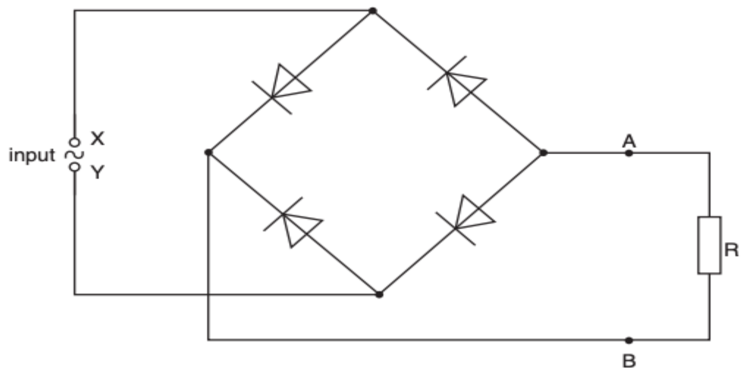
6. Describe the working of a half wave and full wave rectifier in the given circuits below.

	Half wave rectifier	Full wave rectifier
Diagram		
Working		
Status of diodes and output		
Output signal compared to input		

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



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

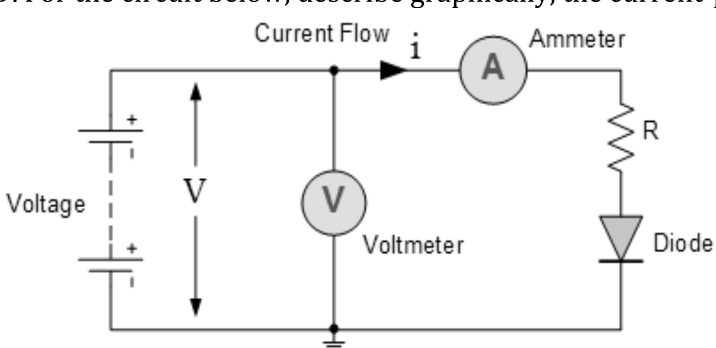


A resistor R is connected across the output AB of the rectifier.

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.

b. label the positive (+) and the negative (–) terminals of the output AB.

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



10. Answer the following questions on transistor.

a. Give one use of a transistor.

b. How does a transistor affect voltage?

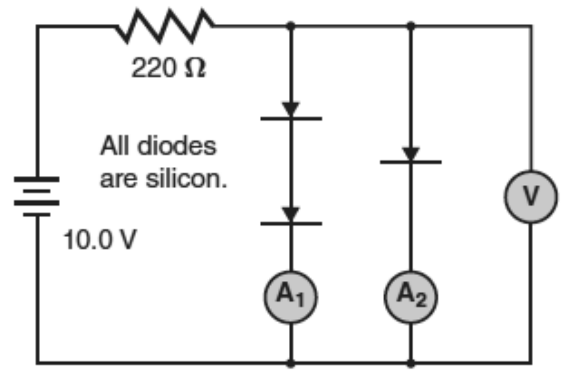
10. Describe the structure of a transistor and differentiate between *pnp* and *npn* transistors, identifying the base, emitter and collector.

	npn –Transistor	*pnp* –Transistor
Diagram		
Circuit		
Current		

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

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

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



a. What is the voltmeter reading? Explain

b. Find the readings on:

i. The ammeter A_1

ii. The ammeter A_2

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)	
Nitrogen (Z=7)	
Antimony (Z=51)	
Carbon (Z=6)	
Gallium (Z=31)	

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	
A rectifier is a diode that converts AC to a current that flows in one direction	
In good conductors, electrons can be found in the forbidden energy gap	
When a hole and a free electron combine, their charges cancel each other	

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	
The region around a diode junction that has neither holes nor free electrons	
A reverse-biased diode has a wide	
can be used in rectifier circuits to convert AC to DC	

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. ______________________ The elements classified as ___ typically have four valence electrons.
2. ______________________ A(n) ___ is an electronic device that can be used as a rectifier.
3. ______________________ In computers, small currents in the ___ circuits can turn on or turn off large currents in the collector-emitter circuits.
4. ______________________ 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. ______________________ As the temperature rises, the ___ of metals is reduced.
6. ______________________ In a ___ diode, electrons fill in the holes and current flows.
7. ______________________ Conduction in a(n) ___ semiconductor is enhanced by the availability of extra holes provided by the acceptor dopant atoms.
8. ______________________ In a(n) ___ , the forbidden energy gap is very large.
9. ______________________ ___ semiconductors are made useful by doping.
10. ______________________ A(n) ___ increases the conductivity of a semiconductor.
11. ______________________ Physicists refer to an electron deficiency as a(n) ___.
12. ______________________ There are no charge carriers in the ___ of a *pn*-junction diode.
13. ______________________ The central layer of an *npn*-transistor is called the ___.