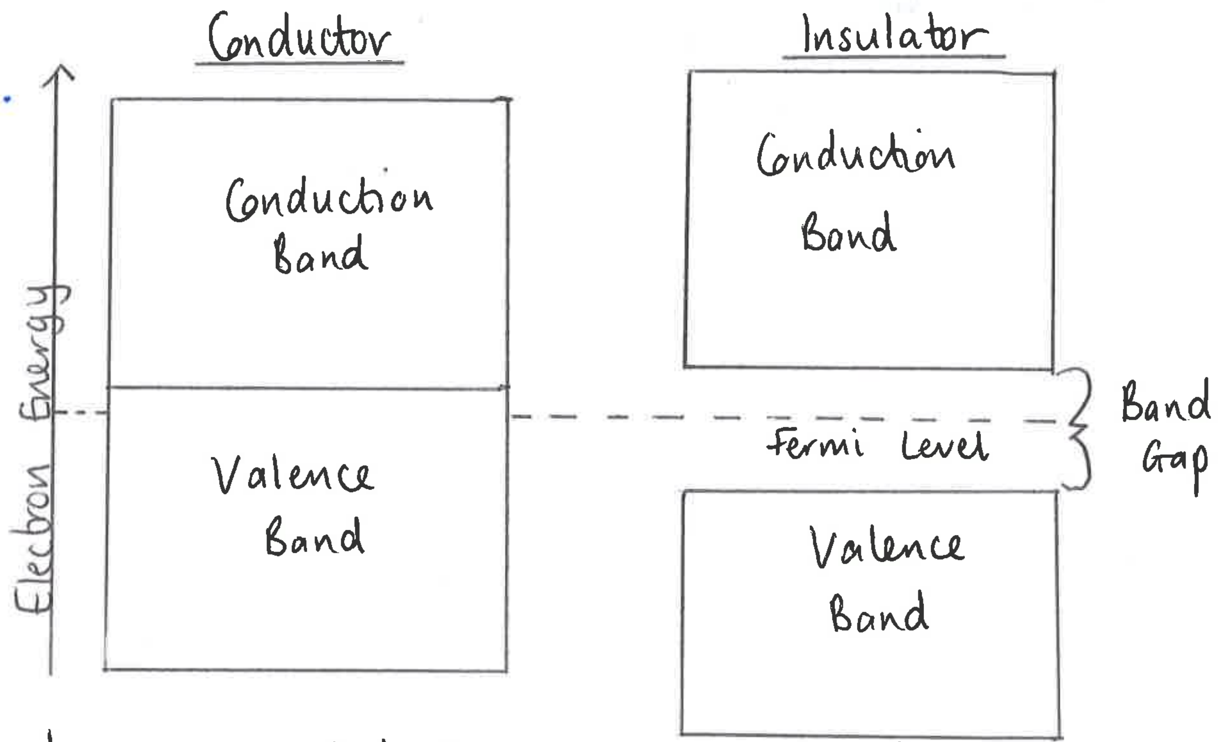
Unit 3: Electricity - Electrons At Work

1.



2. In a metal the valence band is completely filled and the conduction band is partially filled. The electrons in the conduction band are free to move under the action of an electric field so the metal has a high conductivity.

In an insulator there are no free electrons in the conduction band. The energy gap between the two bands is large and there is not enough energy at room temperature to move electrons from the valence band into the conduction band. Insulators have a very low conductivity.

In a pure semiconductor the energy gap between the valence and conduction bands is bigger than in metal. At room temperature there is enough energy to move some electrons from the valence band into the conduction band. As the temperature is increased the number of electrons in the conduction band increases so the conductivity of the semiconductor increases.

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2. (cont'd)
A - Valence
B - Conduction
C - Conduction
D - An electric field
E - High
F - Conduction
G - Valence
H - Conduction
I - Low
J - Bigger
K - Valence
L - Conduction
M - Increases
N - Increases.

3.(a). Conductivity is a material's ability to support the movement of charge carriers such as electrons or holes.

(b). Doping a semiconductor involves introducing an impurity element to a pure semiconductor material such as introducing boron atoms to a crystal of pure silicon. This creates p-type semiconductor as there are now 'holes' in the structure where there would have been electrons in pure silicon.

(c). In pure silicon all the covalent bonds between the atoms are filled with 2 electrons and none are free for conduction in theory. With boron doping holes exist throughout the structure. These holes have mobility when a p.d. is

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3.(c) (cont'd). placed across the structure. Now some charge carriers can move through the structure hence the resistance is lower.

4.(a). If germanium is doped with phosphorus an n-type semiconductor is formed.

(b). When the germanium is doped with phosphorus non-bonded electrons form the charge carriers but each phosphorus atom has a matching number of protons in its nucleus to its number of electrons making it neutral, as will be the germanium atoms. Hence, the overall charge is still zero.

P-N Junctions

5.(a). The diode is forward biased.

(b). With the applied p.d. in the direction shown electrons in the n-type material move to the left and holes in the p-type material move to the right. The depletion layer in the centre becomes thinner and thinner and if the p.d. of the supply is greater than the barrier potential (typically 0.7v for silicon based semiconductors) the barrier is broken down and a current flows through the device.

(c). The only charge that moves across the junction are electrons (negative charges).

6.(a). The junction has to be forward biased for radiation to be emitted.

(b).(i) In an LED, light is emitted.

(ii) In a simple p-n junction heat is generated but this will leave the crystal by conduction normally as its

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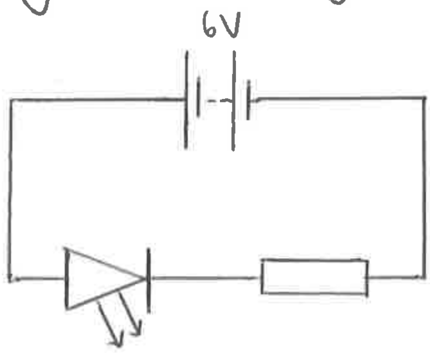
6. (b)(ii) (cont'd.) construction does not allow the emission of an IR photon directly from the junction.

7. (a)



(b) $V_R = V_S - V_L$

$V_R = 6.0 - 1.8$

$V_R = \underline{4.2\ V}$

$V = IR$

$R = \frac{V}{I}$

$R = \frac{4.2}{0.02} = \underline{210\ \Omega}$

The resistance of the protective resistor is 210 Ω.

8. (a). The photodiode is operating in photovoltaic mode.

(b). In this mode the diode has no bias voltage applied. Photons that are incident on the junction have their energy absorbed, freeing electrons and creating electron-hole pairs. A voltage is generated by the separation of the electron and hole.

(c). Increasing the light intensity will lead to more electron-hole pairs being produced and therefore a higher voltage will be generated by the diode. The voltage produced is proportional to the light intensity.