ICS 2200: CAT I

Question 1 (15 Marks)

a. (**11 Marks**).

i. (**4 Marks**) $R = \frac{\rho l}{A} = \frac{1.73\times10^{-8}\times65}{0.75\times10^{-6}}$; $R_1 = R_4 = 1.499\Omega$

ii. .

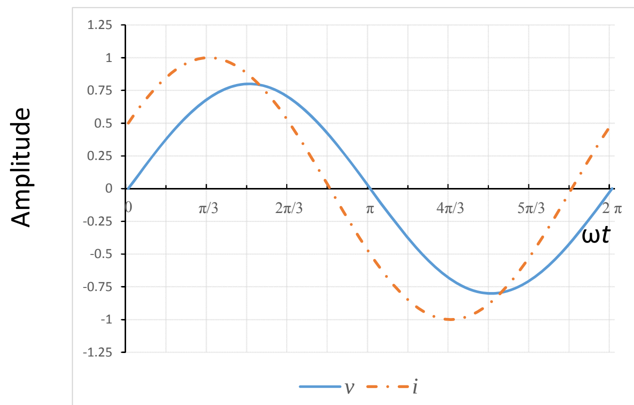
A. (**1 Marks**) $v_s = V_m \sin \omega t$; Comparing coefficients, $V_m = 339.4$; $V_{sRMS} = \frac{V_m}{\sqrt{2}} = \frac{339.4}{\sqrt{2}} = 240$Volts

B. (**2 Marks**) KCL at Node A $I_{1RMS} = I_{2RMS} + I_{3RMS} = 3$A

C. (**4 Marks**) KVL around loop formed by source, R_1, R_2 and R_4. $V_{sRMS} = I_{1RMS}R_1 + I_{1RMS}R_4 + V_{AB}$. $V_2 = V_{AB} = 231$ Volts.

b. (**4 Marks**).

i. (**3 Marks**)



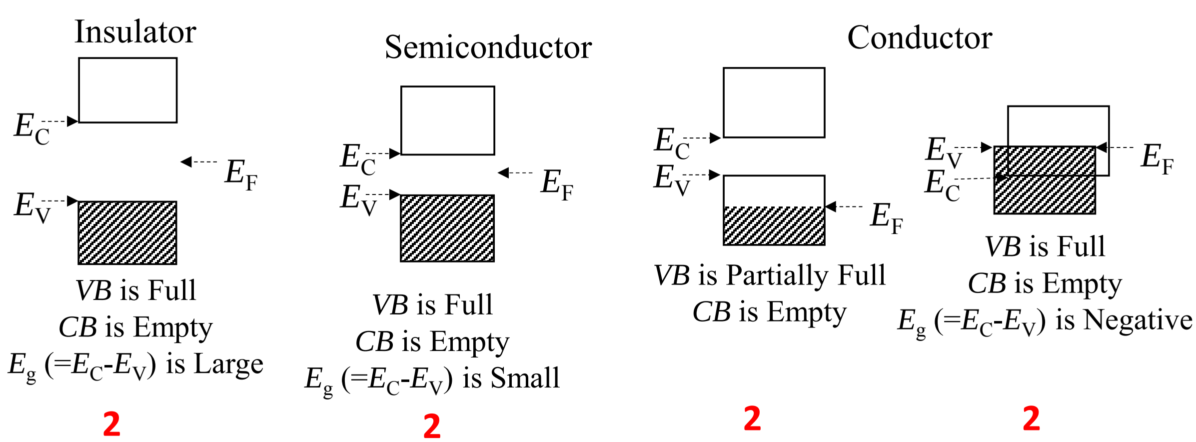
Key Features:

1. The current waveform has a higher amplitude than the voltage waveform
2. The voltage waveform passes through the origin (v = 0 when t = 0)
3. The current waveform is maximum at $\omega t = \pi/3$, Zero at $\omega t = 5\pi/6$ and $\omega t = 11\pi/6$ and minimum at $\omega t = 4\pi/3$

ii. $i = I_m \sin\left(\omega t + \frac{\pi}{6}\right)$ (**1 Mark**)

Question 2 (15 Marks)

a. (**8 Marks**) Four possibilities: 1 insulator, 1 semiconductor, 2 metals – partially filled CB for monovalent metals and overlapping bands for other metals.



NOTE: There is no such thing as fully filled!

b. (**7 Marks**)

i. (**2 Marks**) : *Al*: 2:8:3 ; *Si*: 2:8:4 Alternative Answer: *Al*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$; *Si*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

ii. (**2 Marks**) *Al*: Metallic; *Si*: giant Covalent

iii. (A) (**1 Mark**) P- Type;

(B) (**2 Marks**) In the crystal structure, an aluminium atom with 3 valence electrons replaces a silicon atom with 4 valence electrons. The 3 valence electrons complete bonds between the aluminium atom and 3 silicon atoms. The bond between the aluminium atom and a fourth silicon atom is incomplete (NOTE: This is NOT a hole!). An electron from a complete silicon – silicon bond can move from its position and complete the aluminium – silicon bond. This leaves behind an incomplete Si – Si bond with a net positive charge, i.e. a hole. The number of holes increase without an increase in the number of free electrons – this is a P-type semiconductor.

(ADDITIONAL NOTE: Electrons DO NOT bond. Rather, atoms use electrons to bond (sharing, losing or gaining electrons).

ICS 2200: CAT II

Question 1 (10 Marks)

a. (**2 Marks**).

A. Battery +ve to P; battery negative to N

B. Battery +ve to N, battery –ve to N

b. .

A. (**2 Marks**) Depletion region narrows, potential barrier is lowered (plus sketch)

B. (**2 Marks**) Depletion region widens, potential barrier is raised (plus sketch)

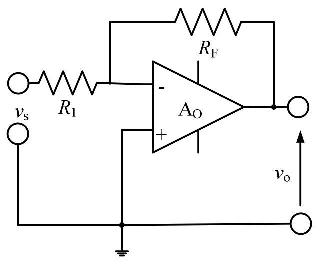
c. (**4 Marks**) Forward Bias: Lower potential barrier and at junction allows change carriers to easily cross the depletion region. Large current can flow.

Reverse Bias: Raised potential barrier at junction and wide depletion region without mobile charge carriers means very little current can flow.

Device allows current to flow in one direction and blocks flow of current in the other direction – it is a rectifier.

Question 2 (10 Marks)

a. (**3 Marks**). Inverting amplifier (output is opposite polarity to input)



b. (**2 Marks**) Amplifier gain, $A_f = \frac{v_o}{v_s} = \frac{-5}{5\times10^{-2}} = -100$

c. (**5 Marks**) $A_f = -\frac{R_F}{R_1} = -100$. $R_F = 100R_1$.

$R_{in} = R1 = 2.5\text{k}\Omega$; $R_F = 100R_1 = 250\text{k}\Omega$

Question 3 (10 Marks)

a. (**2 Marks**). For isolating ac source and load from the DC biasing voltages and currents.

b. .

Silicon transistor, $V_{BE} = 0.7V$ **1 Mark**

$V_{CC} = I_B R_B + (I_B + I_C) R_C + V_{BE}$

$V_{CC} = I_B R_B + I_B(1+\beta) R_C + V_{BE}$

$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_C}$

$= \frac{11.3}{220\times10^3 + 101 \times 2\times10^3}$

$= 26.78\ \mu A$

3 Marks

$I_C = \beta I_B$

$= 100 \times 26.78$

$= 2.678\ mA$

1 Mark

KVL output loop

$V_{CC} = V_{CE} + I_B(1+\beta) R_C$ **2 Marks**

$V_{CE} = V_{CC} - I_B(1+\beta) R_C$

$= 12 - 2.678\times10^{-5} \times 101 \times 2\times10^3$

$= 6.59$ Volts

c. .

Redo Calculations with new value of β

3 Marks

$I_B = \frac{V_{CC} - V_{BE}}{R_B (1+\beta) R_C}$

$= \frac{11.3}{220\times10^3 + 81 \times 2\times10^3}$

$= 29.58\ \mu A$

$I_C = \beta I_B$

$= 80 \times 29.58$

$= 2.366\ mA$

$V_{CE} = V_{CC} - I_B(1+\beta) R_C$

$= 12 - 29.58\times10^{-6} \times 81 \times 2\times10^3$

$= 7.16$ Volts