Written Test 120 min. [50 Marks]

Information about the Written Test
Section (a) contains ten questions of 01 Mark each
Section (b) contains ten questions of 02 Marks each
Section (c) contains 10 questions on various experiments (02 Marks each)

Calculators will be provided on request.

Q1. Which one of the following measurements can give information about the nature of charge carriers of a semiconductor?
(a) Hall effect
(b) Electrical conductivity
(c) Thermal conductivity
(d) Optical absorption

Q2. Which one of the following is a fermion?

(a) alpha-particle
(b) neutron
(c) photon
(d) deuteron

Q3. For a Geiger-Muller (GM) counter, which one of the following statements is/are CORRECT?

(a) Argon is used so that ambient light coming from the surroundings do not produce any signal in the detector
(b) Ethyl alcohol is used as a quenching gas
(c) The electric field strength decreases from the axis to the edge of the tube and the direction of the field is radially outward
(d) The electric field increases from the axis to the edge of the tube and the field direction is radially inward

Q4. The lattice parameters a, b, c of an orthorhombic crystal are related by $a = 2b = 3c$. In units of a, the inter-planar distance for the (110) planes is

(a) 0.45
(b) 0.23
(c) 0.90
(d) 1.3

(P.T.O.)

Q5. Which one of the following CANNOT be explained by considering a harmonic approximation for the lattice vibrations in solids?

(a) Debye's T^3 law
(b) Dulong-Petit's law
(c) Optical branch in phonon dispersion of diatomic solids
(d) Thermal expansion of solids

Q6. For an intrinsic semiconductor, m_e^* and m_h^* are, respectively, the effective masses of electrons and holes near the corresponding band edges. At a finite temperature the position of the Fermi level

(a) depends on m_e^* but not on m_h^*
(b) depends on m_h^* but not on m_e^*
(c) depends on both m_e^* and m_h^*
(d) depends neither on m_e^* nor on m_h^*

Q7. A phosphorous doped silicon semiconductor (doping density: 10^{17} /cm^3) is heated from 100 °C to 200 °C. During this heating process, which one of the following statements is CORRECT?

(a) Position of Fermi level moves towards the conduction band
(b) Position of dopant level moves towards the conduction band
(c) Position of Fermi level moves towards the middle of energy gap
(d) Position of dopant level moves towards the middle of energy gap

Q8. Identify the correct statement for the following vectors $\boldsymbol{a} = 3\hat{\imath} + 2\hat{\jmath}$ and $\boldsymbol{b} = \hat{\imath} + 2\hat{\jmath}$

(a) They are linearly independent
(b) They are linearly dependent
(c) They are orthogonal
(d) Both are normalized

Q9. If $y = 5x^2 + 3$, then the tangent at $x = 0, y = 3$

(a) passes through $x = 0, y = 0$
(b) has slope of $+1$
(c) is parallel to the x-axis
(d) has slope of -1

Q10. For $0 \leq x \leq 2\pi$, $\sin x$ and $\cos x$ are both decreasing functions in the interval _____

(a) $0, \pi/2$
(b) $\pi/2, \pi$
(c) $\pi, 3\pi/2$
(d) $3\pi/2, 2\pi$

(P.T.O.)

Part B: 10 QUESTIONS (2 MARKS EACH)

Q11. A beam of X-ray of intensity I_o is incident normally on a metal sheet of thickness 2 mm. The intensity of the transmitted beam is $0.025I_o$. The linear absorption coefficient (in m^{-1}) of the metal sheet is _____.

(a) 1.844
(b) 18.44
(c) 184.44
(d) 1844.4

Q12. A metal with body centred cubic (bcc) structure shows the first (i.e., smallest angle) diffraction peak at the Bragg angle of $\theta = 30^o$. The wavelength of X-ray used is 2.1 Å. The volume of the PRIMITIVE unit cell of the metal is

(a) 26.2 $Å^3$
(b) 13.1 $Å^3$
(c) 9.3 $Å^3$
(d) 4.6 $Å^3$

Q13. Consider the linear differential equation $\frac{dy}{dx} = xy$. If $y = 2$ at $x = 0$, then the value of y at $x = 2$ is

(a) e^{-2}
(b) $2e^{-2}$
(c) e^2
(d) $2e^2$

Q14. A point charge q is kept inside an irregular shaped cavity of a neutral spherical conductor. The radius of the conductor is R. The electrostatic potential at a point d from the centre of the sphere ($d > R$) is

(a) 0
(b) $\frac{q}{4\pi\,\epsilon_0 R}$
(c) $\frac{q}{4\pi\,\epsilon_0 d}$
(d) $-\frac{q}{4\pi\,\epsilon_0 d}$

(P.T.O.)

Q15. Three parallel conducting plates A, B, and C are kept in such a way that the separation between A and B is d_1 and that between B and C is d_2. A charge Q is given to the middle plate (B) while the other two (A and C) are electrically neutral. The two outer plates, A and C are now connected by a wire. Ignoring any edge effects, which of the following is true?

(a) The charges on all the faces of the outer plates A and C remain the same as they were before connecting them.
(b) The net charge on each of the outer plates is zero after connecting A and C.
(c) The charges on the inner sides of the two outer plates A and C depend on the separation of them with respect to the middle plate.
(d) The charges on the outer side of the two outer plates are not equal.

Q16. An infinitely long solenoid carrying a steady current is kept with its axis coinciding with the z-axis. Which of the following is true regarding the magnetic field inside the solenoid?

(a) is maximum along the axis of the solenoid
(b) is uniform
(c) is along the $\hat{\varphi}$ direction of the solenoid
(d) is in the radial direction

Q17. In the case of Newton's rings experiment using glass plate and biconvex lens, which of the following is correct?

(a) The central fringe (where the lens and the glass plate tough) is dark
(b) The central fringe (where the lens and the glass plate tough) is bright
(c) The fringe system expands if an oil (of refractive index 1.8) is introduced between the lens and the glass plate.
(d) The fringe system does not change if an oil (of refractive index 1.8) is introduced between the lens and the glass plate.

Q18. Which of the following is true for a prism when white light is incident on it?

(a) Red light is least deviated
(b) Violet is least deviated
(c) Light undergoes dispersion but no deviation
(d) Light always undergoes total internal reflection as it enters and leaves the prism

Q19. A particle of mass m is confined in the potential

$$V(x) = \frac{1}{2} m\omega^2 x^2 \quad \text{for } x > 0$$

$$= 0 \quad \text{for } x \leq 0$$

Let the wave-function of the particle be given by

$$\psi(x) = -\frac{1}{\sqrt{5}}\psi_0 + \frac{2}{\sqrt{5}}\psi_1$$

(P.T.O.)

where ψ_0 and ψ_1 are the eigenfunctions of the ground state and the first excited state, respectively. The expectation value of the energy is

(a) $\frac{31}{10}\hbar\omega$

(b) $\frac{11}{10}\hbar\omega$

(c) $\frac{25}{10}\hbar\omega$

(d)) $\frac{13}{10}\hbar\omega$

Q20. A beam of light of wavelength 600 nm from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between the first dark fringes on either side of the central bright fringe is

(a) 1.2 mm

(b) 2.4 mm

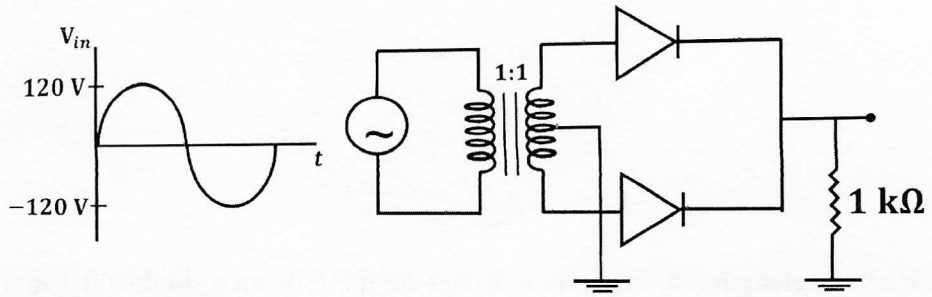
(c) 3.6 mm

(d) 4.8 mm

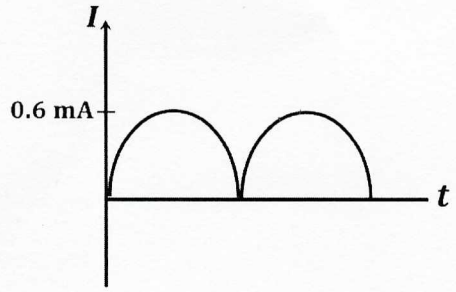
(P.T.O.)

PART C: Experiment based questions (10 QUESTIONS / 2 MARKS EACH)

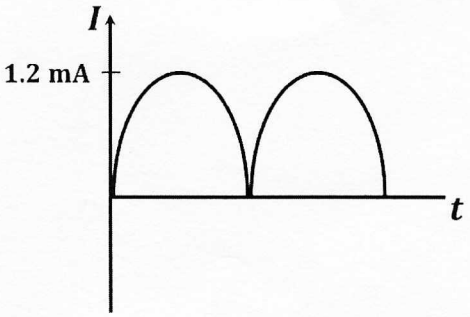
Q21. The output current for the given circuit will be



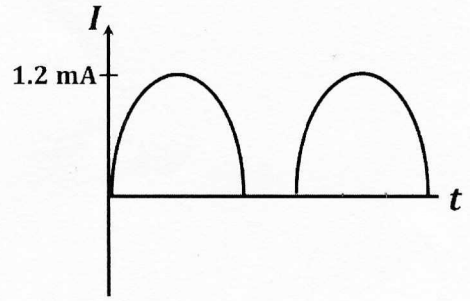
(a)



(b)

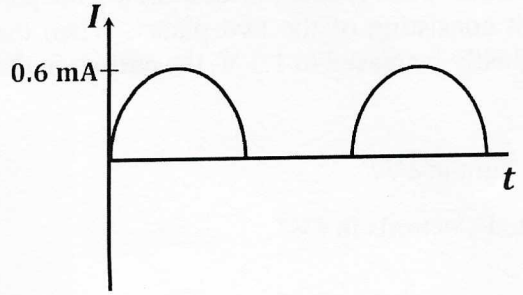


(c)



(P.T.O.)

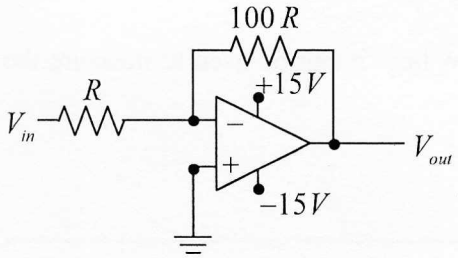
(d)



Q22. Which of the following is false for a tunnel diode?

(a) both the p and n sides are heavily doped
(b) it can act as an oscillator
(c) it has a negative resistance region when reverse biased
(d) it can work in frequencies of GHz range

Q23. For the following circuit, what is the magnitude of V_{out} if $V_{in} = 1.5\ V$?



(a) 0.015 V
(b) 0.15 V
(c) 1.5 V
(d) 15 V

Q24. You are given a tuning fork. Suggest a method to find out its frequency in a laboratory.

Q25. Draw the Pressure -Volume diagram and the entropy-temperature diagram of the Carnot cycle for an ideal gas.

(P.T.O.)

Q26. When ultraviolet light with a wavelength of 230 nm shines on a metal plate, electrons are emitted from the plate. These electrons reach an identical plate (anode) after crossing the gap between the plates, causing a current in the circuit consisting of the two plates. When the voltage of the battery connected to the circuit is gradually increased to 1.3 V, the current in the circuit falls to zero. (Take $hc = 1240$ eVnm)

a) What is the energy of the photons in the beam of light in eV?

b) What is the maximum kinetic energy of the emitted electrons in eV?

Q27. The main scale of a Vernier has makings for every 1 mm. The total number of divisions on the vernier scale is 20, which matches with 16 main scale divisions. Calculate the least count of this vernier scale.

Q28. You are asked to find the voltage drop across a resistor in a circuit and the current in another circuit. Show how will you measure these quantities with the help of a voltmeter and an ammeter? What is your comment about the internal resistances of the voltmeter and ammeter for getting very high accuracy of the readings?

Q29. You are given a metallic wire. How will you determine its electrical resistivity?

Q30. You are given a Zener diode. Draw a circuit to show how it can be used to measure the Zener voltage?

---------- Paper Ends ----------

Answer Keys:

Part A

Q1	(a)	
Q2	(b)	
Q3	(a),(b),(c)	
Q4	(a)	
Q5	(d)	
Q6	(c)	
Q7	(c)	
Q8	(a)	
Q9	(c)	
Q10	(b)	

Part B

Q11	(d)	
Q12	(b)	
Q13	(d)	
Q14	(c)	
Q15	(c)	
Q16	(b)	
Q17	(a)	
Q18	(a)	
Q19	(a)	
Q20	(b)	

Part C

Q21	cancelled	
Q22	(c)	
Q23	(d)	
Q24	- descriptive -	
Q25	- plotting -	
Q26	(a) 5.39 eV, (b) 4.09 eV	

Q27	0.2 mm	
Q28	- circuit -	
Q29	- measurement -	
Q30	- circuit -	