A

2011 PH

Test Paper Code: PH

Time: 3 Hours **Maximum Marks: 300**

INSTRUCTIONS

1. This question-cum-answer booklet has **X** pages and has **25** questions. Please ensure that the copy of the question-cum-answer booklet you have received contains all the questions.
2. Write your **Registration Number, Name and the name of the Test Centre** in the appropriate space provided on the right side.
3. Write the answers to the objective questions against each Question No. in the **Answer Table for Objective Questions**, provided on Page No. **Y**. Do not write anything else on this page.
4. Each objective question has **4 choices** for its answer: (A), (B), (C) and (D). Only **ONE** of them is the correct answer. There will be **negative marking** for wrong answers to objective questions. The following marking scheme for objective questions shall be used:
   (a) For each correct answer, you will be awarded **6 (Six)** marks.
   (b) For each wrong answer, you will be awarded **-2 (Negative two)** mark.
   (c) Multiple answers to a question will be treated as a wrong answer.
   (d) For each unattempted question, you will be awarded **0 (Zero)** mark.
5. Answer the subjective question only in the space provided after each question.
6. Do not write more than one answer for the same question. In case you attempt a subjective question more than once, please cancel the answer(s) you consider wrong. Otherwise, the answer appearing last only will be evaluated.
7. All answers must be written in blue/black/blue-black ink only. Sketch pen, pencil or ink of any other colour should not be used.
8. All rough work should be done in the space provided and scored out finally.
9. No supplementary sheets will be provided to the candidates.
10. **Clip board, log tables, slide rule, calculator, cellular phone and electronic gadgets in any form are NOT allowed.**
11. The question-cum-answer booklet must be returned in its entirety to the Invigilator before leaving the examination hall. Do not remove any page from this booklet.
12. Refer to special instructions/useful data on the reverse.

A

2011 PH

READ INSTRUCTIONS ON THE LEFT SIDE OF THIS PAGE CAREFULLY

REGISTRATION NUMBER						

Name:

Test Centre:

Do not write your Registration Number or Name anywhere else in this question-cum-answer booklet.

I have read all the instructions and shall abide by them.

.....
Signature of the Candidate

I have verified the information filled by the candidate above.

.....
Signature of the Invigilator

ZOLLEGE.in

ZOLLEGE.in

Special Instructions/ Useful Data

$$\nabla^2 t = \frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial t}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 t}{\partial \theta^2}$$

$$\int_0^\infty x^3 \exp\left(-\alpha x^2\right) dx = \frac{1}{2\alpha^2}$$

Boltzmann constant k_B	**= 1.38×10^{-23} J/K** **= 8.617×10^{-5} eV/K**
Electric permittivity of free space ε_0	**= 8.85×10^{-12} F/m**
Elementary charge e	**= 1.60×10^{-19} C**
Magnetic permeability of free space μ_0	**= 1.26×10^{-6} H/m**
Mass of electron m_e	**= 9.11×10^{-31} kg**
Molar gas constant R	**= 8.31 J/mol-K**
Planck constant h	**= 6.63×10^{-34} J-s** **= 4.14×10^{-15} eV-s**
Speed of light in vacuum	**= 3×10^8 m/s**
π	**= 3.14**

ZOLLEGE

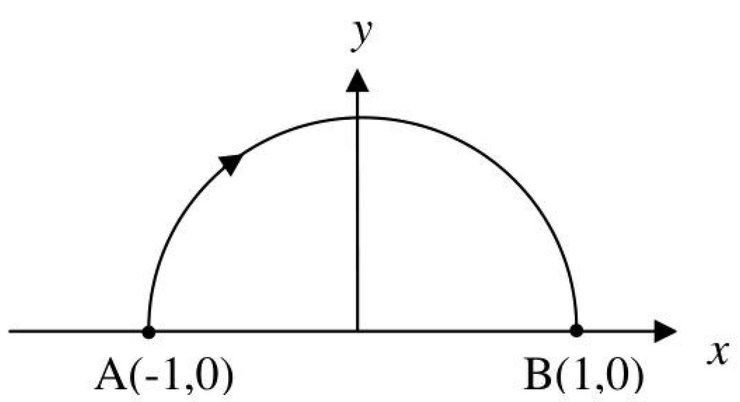
ZOLLEGE.in

A

IMPORTANT NOTE FOR CANDIDATES

- **Attempt ALL the 25 questions.**
- **Questions 1-15 (objective questions) carry *six* marks each and questions 16-25 (subjective questions) carry *twenty one* marks each.**
- **Write the answers to the objective questions in the *Answer Table for Objective Questions* provided on page Y only.**

Q.1 The line integral $\int_A^B \vec{F} \cdot d\vec{l}$, where $\vec{F} = \frac{x}{\sqrt{x^2+y^2}}\hat{x} + \frac{y}{\sqrt{x^2+y^2}}\hat{y}$, along the semi-circular path as shown in the figure below is



(A) –2 (B) 0 (C) 2 (D) 4

Q.2 Six simple harmonic oscillations each of same frequency and equal amplitude are superposed. The phase difference between any two consecutive oscillations i.e., $\phi_n - \phi_{n-1} = \Delta\phi$ is constant, where ϕ_n is the phase of the n^{th} oscillation. If the resultant amplitude of the superposition is zero, what is the phase difference $\Delta\phi$?

(A) $\frac{\pi}{6}$ (B) $\frac{\pi}{3}$ (C) $\frac{\pi}{2}$ (D) 2π

Q.3 A particle of mass m is moving in a potential

$$V(x) = \frac{1}{2} m \omega_0^2 x^2 + \frac{a}{2 m x^2}$$

where ω_o and a are positive constants. The angular frequency of small oscillations for the simple harmonic motion of the particle about a stable minimum of the potential $V(x)$ is

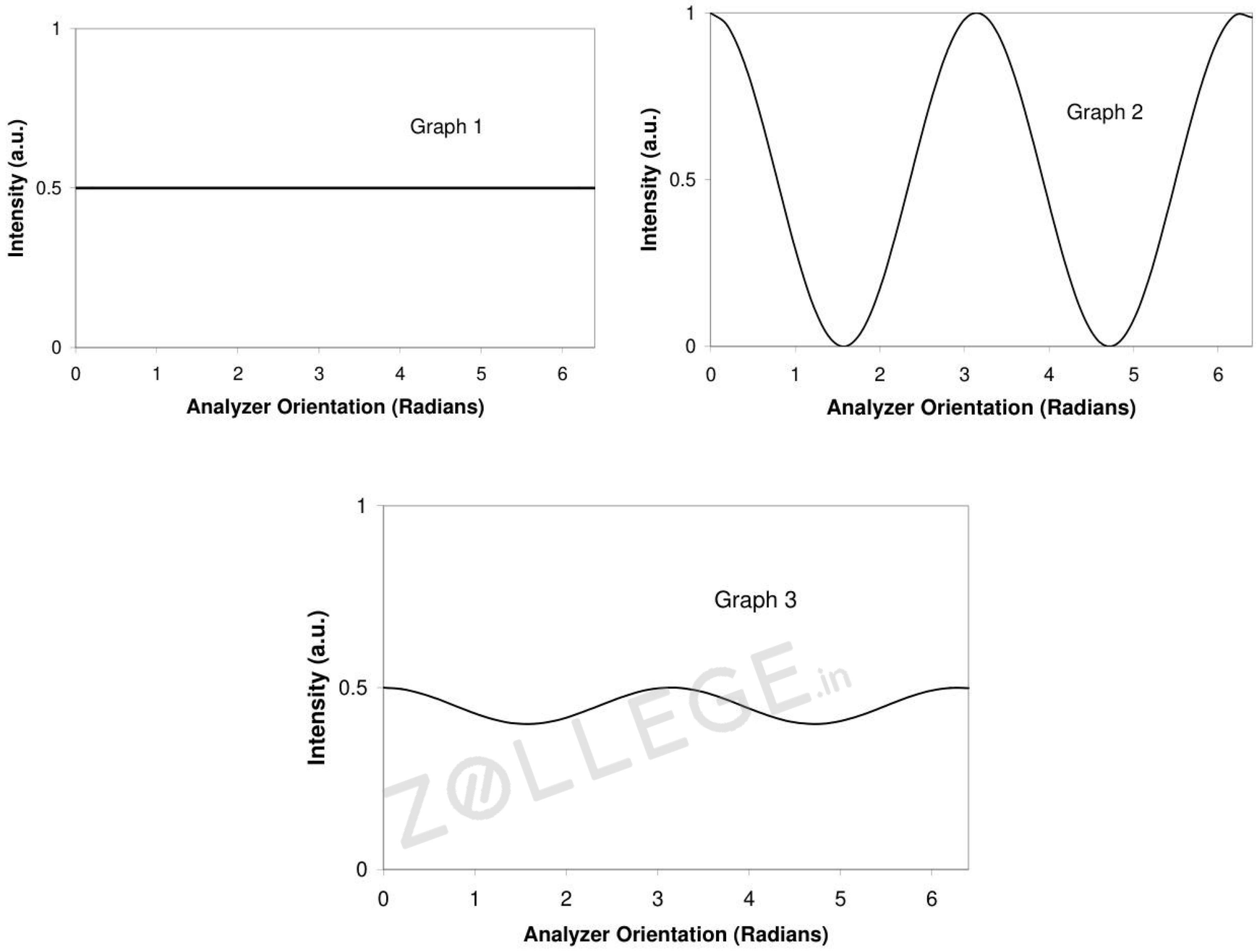
(A) $\sqrt{2}\,\omega_o$
(B) $2\,\omega_o$
(C) $4\,\omega_o$
(D) $4\sqrt{2}\,\omega_o$

Z@LLEGE.in

ZOLLEGE.in

A

Q.4 Intensity of three different light beams after passing through an analyzer is found to vary as shown in the following graphs. Identify the option giving the correct states of polarization of the incident beams from the graphs.



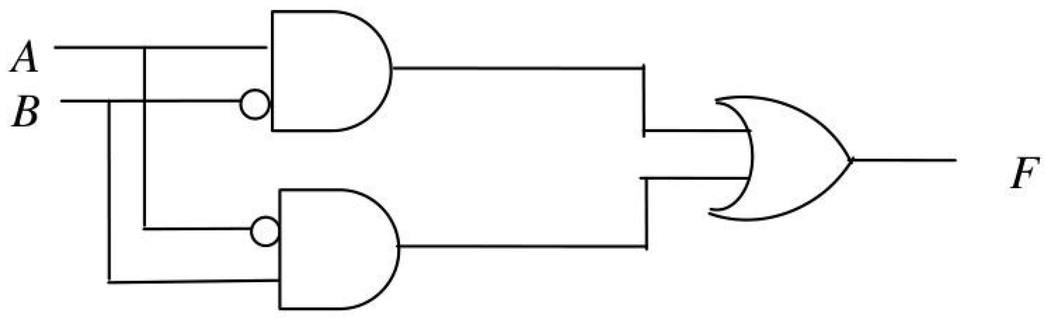
(A) Graph 1: Linear Polarization, Graph 2: Circular Polarization, Graph 3: Elliptic Polarization
(B) Graph 1: Circular Polarization, Graph 2: Linear Polarization, Graph 3: Elliptic Polarization
(C) Graph 1: Unpolarized, Graph 2: Circular Polarization, Graph 3: Linear Polarization
(D) Graph 1: Unpolarized, Graph 2: Elliptic Polarization, Graph 3: Circular Polarization

ZOLLEGE.in

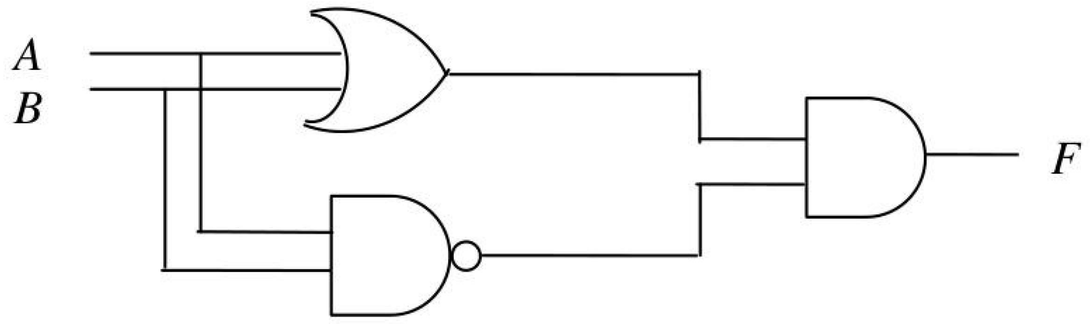
A

Q.5 Which of the following circuits **does not** satisfy the Boolean expression $A\overline{B} + \overline{A}B = F$

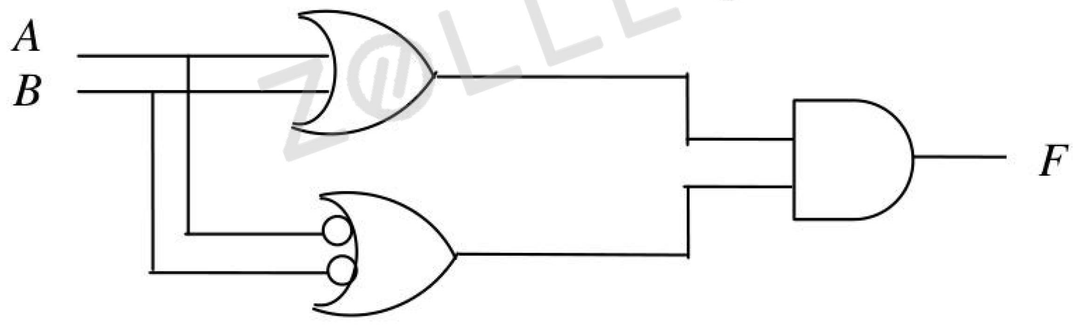
(A)



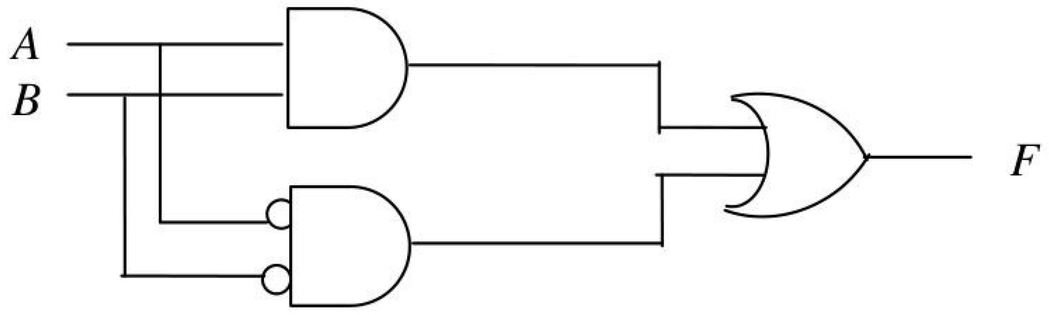
(B)



(C)



(D)



Z@LLEGE.in

ZOLLEGE.in

Q.6 Light described by the equation E= (90 V/m)[sin(6.28×10^{15} s^{-1}) t + sin(12.56×10^{15} s^{-1}) t] is incident on a metal surface. The work function of the metal is 2.0 eV. Maximum kinetic energy of the photoelectrons will be

(A)) 2.14 eV (B) 4.28 eV (C) 6.28 eV (D) 12.56 eV

Q.7 A gas of molecular mass m is at temperature T. If the gas obeys Maxwell-Boltzmann velocity distribution, the average speed of molecules is given by

(A) $\sqrt{\frac{k_B T}{m}}$ (B) $\sqrt{\frac{2k_B T}{m}}$ (C) $\sqrt{\frac{2k_B T}{\pi m}}$ (D) $\sqrt{\frac{8k_B T}{\pi m}}$

Q.8 Consider free expansion of one mole of an ideal gas in an adiabatic container from volume V_1 to V_2. The entropy change of the gas, calculated by considering a reversible process between the original state (V_1 , T) to the final state (V_2 , T) where T is the temperature of the system, is denoted by ΔS_1. The corresponding change in the entropy of the surrounding is ΔS_2. Which of the following combinations is correct?

(A) $\Delta S_1 = \quad R \ln (V_1 / V_2)$, $\Delta S_2 = -R \ln (V_1 / V_2)$
(B) $\Delta S_1 = \quad -R \ln (V_1 / V_2)$, $\Delta S_2 = R \ln (V_1 / V_2)$
(C) $\Delta S_1 = \quad R \ln (V_2 / V_1)$, $\Delta S_2 = 0$
(D) $\Delta S_1 = -R \ln (V_2 / V_1)$, $\Delta S_2 = 0$

Q.9 Equipotential surfaces corresponding to a particular charge distribution are given by $4x^2 + (y-2)^2 + z^2 = V_i$, where the values of V_i are constants. The electric field $\vec{E}$ at the origin is

(A) $\vec{E} = 0$ (B) $\vec{E} = 2\hat{x}$ (C) $\vec{E} = 4\hat{y}$ (D) $\vec{E} = -4\hat{y}$

Q.10 The wave function of a quantum mechanical particle is given by

$$\psi(x) = \frac{3}{5}\varphi_1(x) + \frac{4}{5}\varphi_2(x),$$

where $\varphi_1(x)$ and $\varphi_2(x)$ are eigenfunctions with corresponding energy eigenvalues -1 eV and -2 eV, respectively. The energy of the particle in the state ψ is

(A) $-\frac{41}{25}$ eV (B) $-\frac{11}{5}$ eV (C) $-\frac{36}{25}$ eV (D) $-\frac{7}{5}$ eV

ZOLLEGE.in

Q.11 A rain drop falling vertically under gravity gathers moisture from the atmosphere at a rate given by $\frac{dm}{dt} = k t^2$, where m is the instantaneous mass, t is time and k is a constant. The equation of motion of the rain drop is

$$m\frac{dv}{dt} + v\frac{dm}{dt} = mg$$

If the drop starts falling at $t = 0$, with zero initial velocity and initial mass m_0 (given: $m_0 = 2$ gm, $k = 12$ gm/s^3 and g = 1000 cm/s^2), the velocity (v) of the drop after one second is

(A) 250 cm/s (B) 500 cm/s (C) 750 cm/s (D) 1000 cm/s

Q.12 Given two ($n \times n$) matrices $\hat{P}$ and $\hat{Q}$ such that $\hat{P}$ is Hermitian and $\hat{Q}$ is skew (anti)-Hermitian. Which one of the following combinations of $\hat{P}$ and $\hat{Q}$ is necessarily a Hermitian matrix?

(A) $\hat{P}\,\hat{Q}$ (B) $i\hat{P}\,\hat{Q}$ (C) $\hat{P} + i\hat{Q}$ (D) $\hat{P} + \hat{Q}$

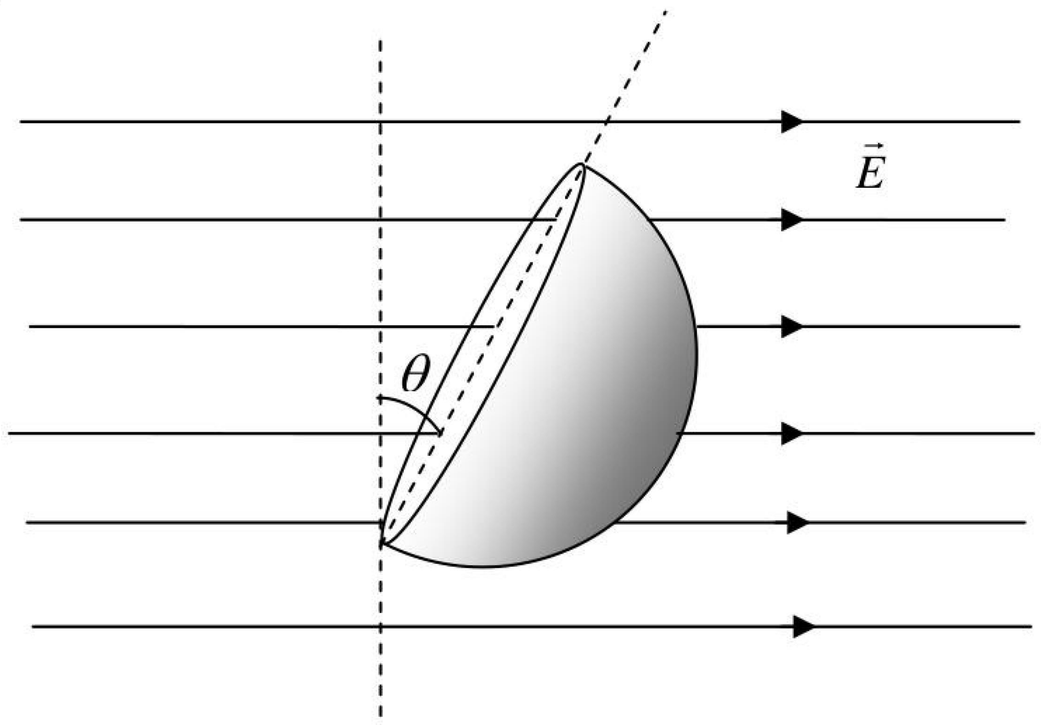
Q.13 An X-ray diffraction (XRD) experiment is carried out on a crystalline solid having *FCC* structure at room temperature. The solid undergoes a phase transformation on cooling to –20 ^{o}C and shows orthorhombic structure with small decrease in its unit cell lengths as compared to the *FCC* unit cell lengths. As a result, the (311) line of the XRD pattern corresponding to the *FCC* system

(A) will split into a doublet.
(B) will split into a triplet.
(C) will remain unchanged.
(D) will split into two separate doublets.

ZOLLEGE.in

ZOLLEGE.in

Q.14 A closed Gaussian surface consisting of a hemisphere and a circular disc of radius R, is placed in a uniform electric field, $\vec{E}$, as shown in the figure. The circular disc makes an angle $\theta = 30^\circ$ with the vertical. The flux of the electric field vector coming out of the curved surface of the hemisphere is



(A) $\frac{1}{2}\pi R^2 E$

(B) $\frac{\sqrt{3}}{2}\pi R^2 E$

(C) $\pi R^2 E$

(D) $2\pi R^2 E$

Z@LLEGE.in

Q.15 In an experiment, the resistance of a rectangular slab of a semiconductor is measured as a function of temperature. The semiconductor shows a resistance of 300 Ω at 200 K and 2 Ω at 250 K. Its energy band gap is [Given: ln(15) = 2.708, ln(10)= 2.303]

(A) 0.138 eV (B) 0.431 eV (C) 0.690 eV (D) 0.862 eV

ZOLLEGE.in

A

Answer Table for Objective Questions

Write the Code of your chosen answer only in the 'Answer' column against each Question Number. **Do not write anything else on this page.**

Question Number	Answer	Do not write in this column
01		
02		
03		
04		
05		
06		
07		
08		
09		
10		
11		
12		
13		
14		
15		

Z@LLEGE.in

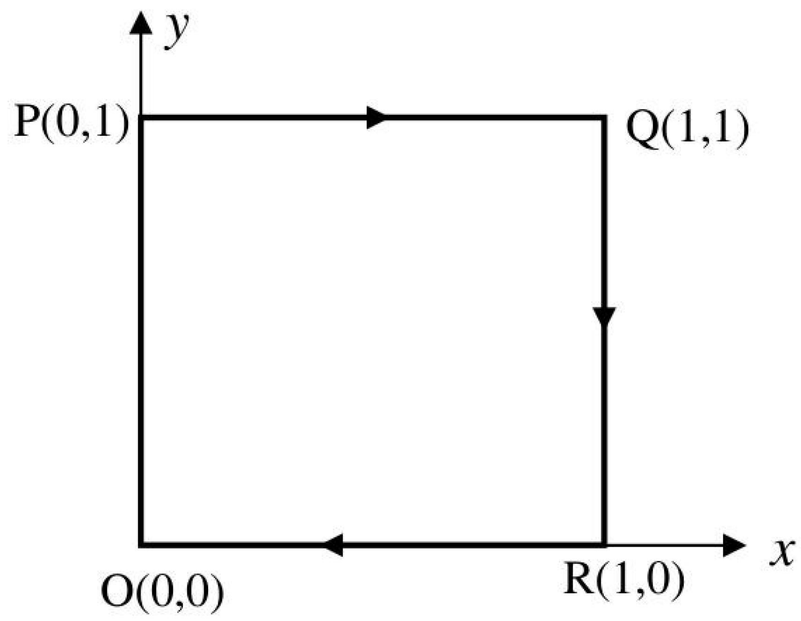
FOR EVALUATION ONLY

Number of Correct Answers		Marks	(+)
Number of Incorrect Answers		Marks	(–)
Total Marks in Question Nos. 1-15			( )

ZOLLEGE.in

A

Q.16 Consider a vector $\vec{A} = -4\,y\,x^2\,\hat{x} - 3\,y^2\,\hat{y}$.



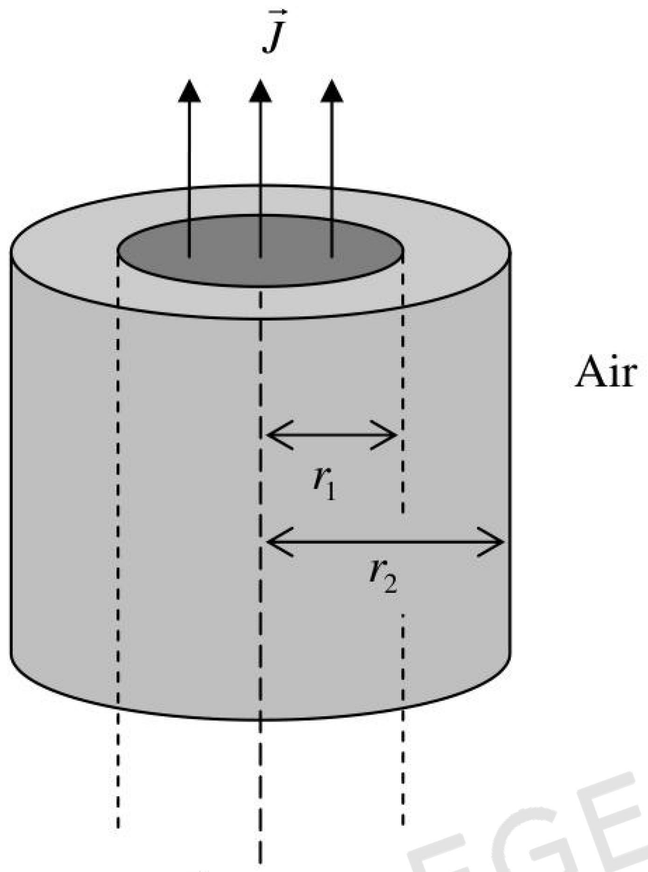
(a) Calculate the line integral $\int \vec{A} \cdot d\vec{l}$ from point P→O along the path P→Q→R→O as shown in the figure. (9)

(b) Using Stoke's theorem appropriately, calculate $\int \vec{A} \cdot d\vec{l}$ for the same path P→Q→R→O. (12)

ZOLLEGE.in

ZOLLEGE.in

Q.17 An infinitely long solid cylindrical conductor of radius r_1, carries a uniform volume current density $\vec{J}$. It is uniformly surrounded by another coaxial cylinder of a linear magnetic medium with permeability μ, up to radius r_2 as shown in the figure.



(a) Determine the magnetic field $\vec{H}$ in the region, $r < r_1$ and magnetic induction $\vec{B}$ in the regions, $r_1 < r < r_2$ and $r > r_2$, where r is the radial distance from the axis of the cylinder. (12)

(b) Sketch the variation of $\vec{H}$ with r in all the three regions. (9)

ZOLLEGE.in

ZOLLEGE.in

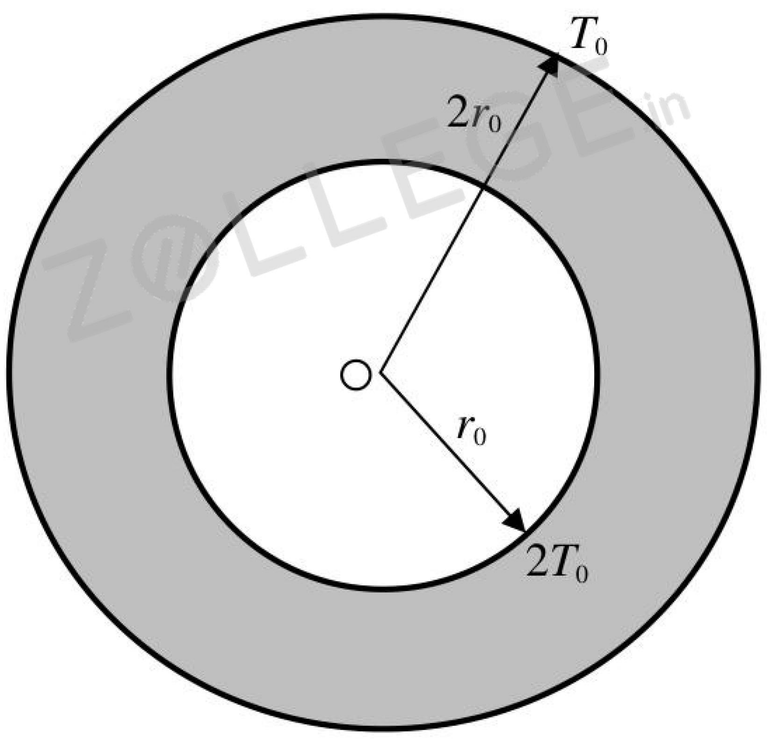
Q.18

(a) Consider heat conduction in a medium. Let $T(x, y, z, t)$ denote the temperature of the medium at time t and position (x, y, z). Consider a volume V enclosed by a surface S inside the medium. The decrease in heat energy per unit volume per unit time is $a\frac{\partial T}{\partial t}$ and outward flux of heat per unit area of the surface per unit time is $b\vec{\nabla}T$, where a and b are material dependent constants. If there is no generation or loss of heat, show that T satisfies the equation

$$\frac{\partial T}{\partial t} = k\nabla^2 T \text{, with } \frac{b}{a} = k .$$

(9)

(b) Now consider a thin annular shaped material enclosed between two concentric circles of radii r_o and $2r_o$ as shown in the figure. The temperature is $2T_o$ at $r = r_o$ and T_o at $r = 2r_o$. Assuming steady state condition, find T as a function of radial distance r from the centre O, for $r_0 < r < 2r_0$.

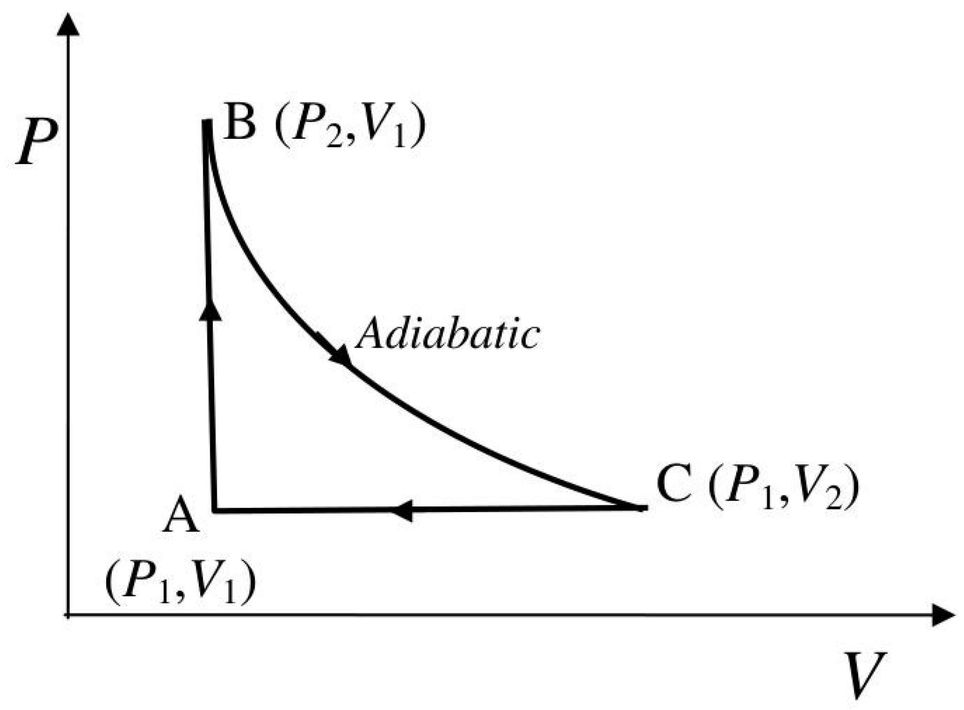


(12)

ZOLLEGE.in

A

Q.19 An ideal gas reversible engine operates in a closed cycle. The *P-V* diagram is shown below.



(a) Find out the efficiency of the reversible engine assuming both specific heats, C_P and C_V as constants. (12)

(b) Identify the thermodynamic processes and draw the corresponding *T-S* diagram schematically. (9)

Z@LLEGE.in

ZOLLEGE.in

Q.20

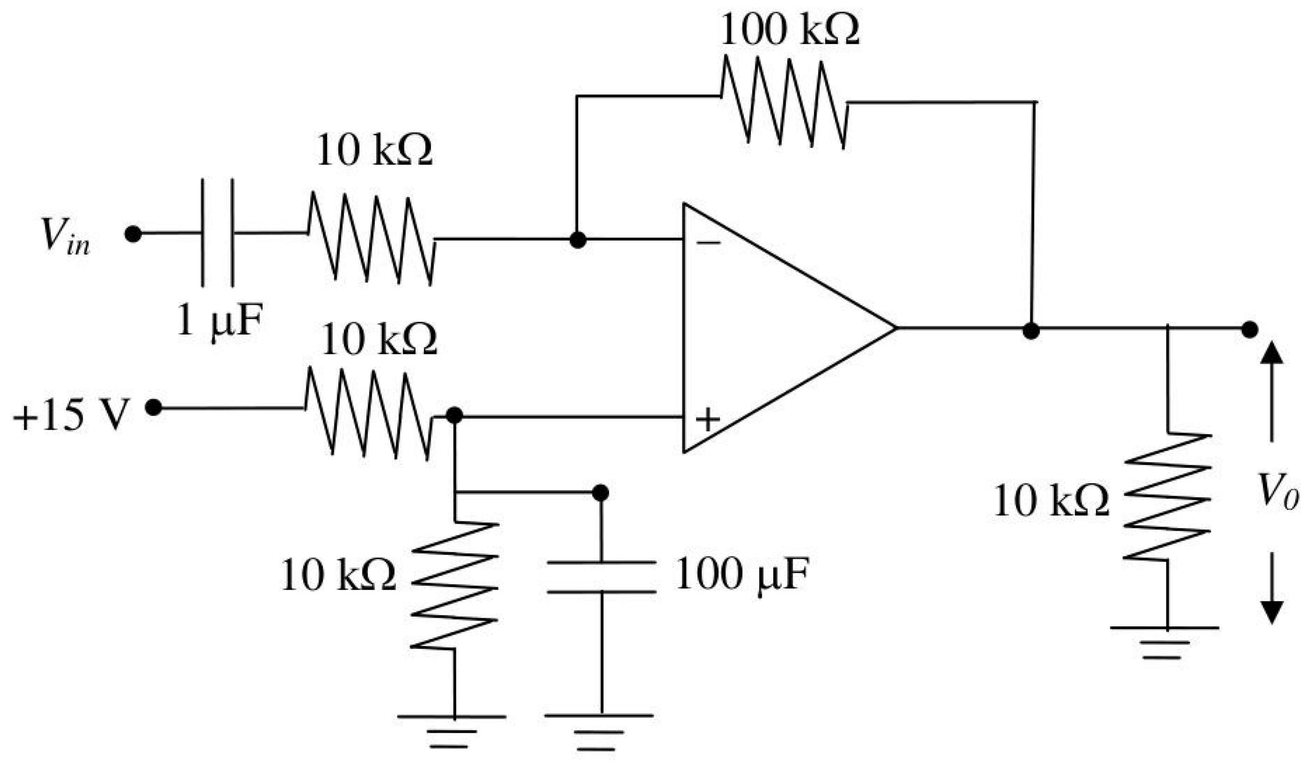
(a) A solid having a simple cubic structure at room temperature with lattice parameter *a* and one valence electron per atom, is assumed to show free electron behaviour. Calculate the magnitude of the Fermi wave vector and the corresponding equivalent temperature. (12)

(b) Find the ratio of the magnitude of the Fermi wave vector to the radius of the largest sphere that can be inscribed within the first Brillouin zone of the solid. (9)

ZOLLEGE.in

ZOLLEGE.in

Q.21 For the given circuit using an operational amplifier, the input is a sinusoidal signal of amplitude V_{in}= 1 mV (peak-to-peak),

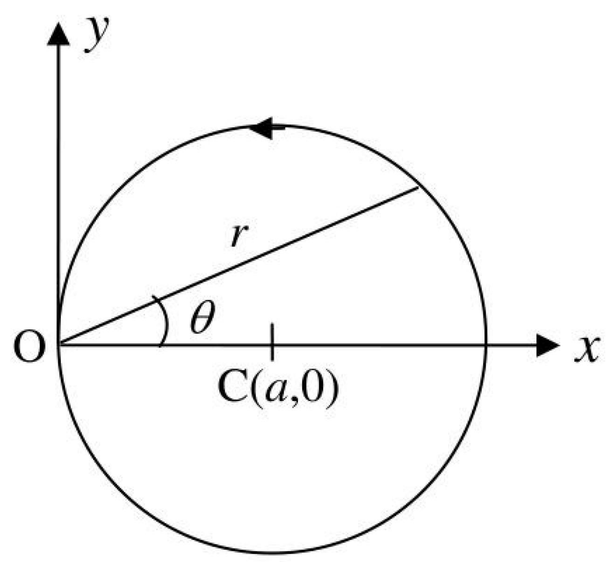


(a) what is the lower cut-off frequency at which the gain is down by 3 dB as compared to the gain at midband? If the bandwidth of the amplifier is 1 MHz for unity gain, what will be the bandwidth of the given circuit? (12)

(b) What is the output voltage (V_o) at 15 kHz? (9)

ZOLLEGE.in

Q.22 A particle of mass m and angular momentum l is moving under the action of a central force $f(r)$ along a circular path of radius a as shown in the figure. The force centre O lies on the orbit.



(a) Given the orbit equation in a central field motion,

$$\frac{d^2u}{d\theta^2} + u = -\frac{m}{l^2u^2}f \text{ , where } u = \frac{1}{r},$$

determine the form of the force in terms of l, m, a and r. (9)

(b) Calculate the total energy of the particle assuming that the potential energy $V(r) \to 0$ as $r \to \infty$. (12)

ZOLLEGE.in

ZOLLEGE.in

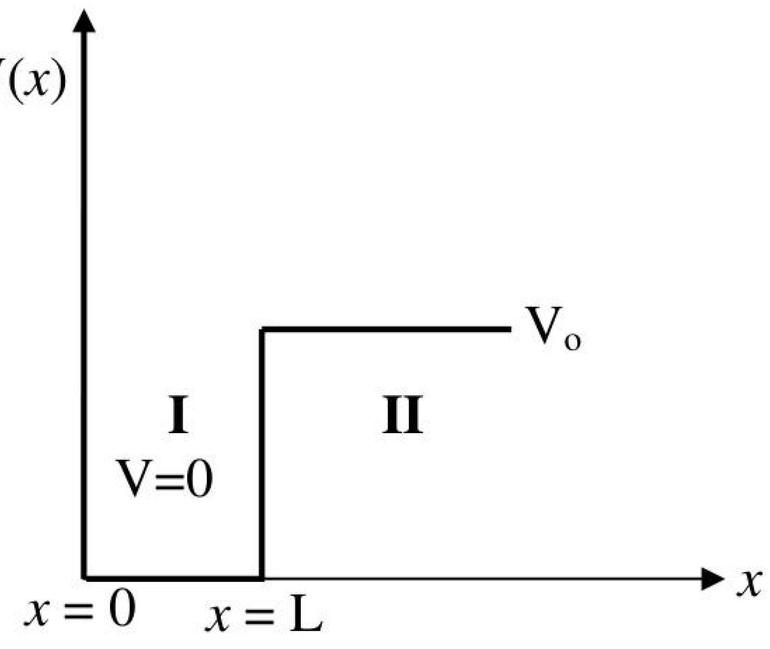
A

Q.23 A particle of mass m moves in a potential given by

$V(x) = \infty$ for $x < 0$

$= 0$ for $0 < x < L$

$= V_o$ for $x > L$



(a) Write down the general solutions for wave functions in regions **I** and **II**, if the energy of the particle $E < V_o$. Using appropriate boundary conditions, find the equation that relates E to V_o, m and L. (12)

(b) Now, set $V_o = 0$ and assume that a beam of particles is incident on the infinite step potential (from $x > 0$) with energy $E(> 0)$. Using the general solution for the wave function, calculate the reflection coefficient. (9)

ZOLLEGE.in

Q.24 A diffraction grating having N slits, each of width b and period d, is illuminated normally by a monochromatic plane wave of wavelength λ.

(a) Obtain an expression for the highest diffraction order that can be observed. What is the phase difference between waves from first and N^{th} slit in the highest diffraction order? (9)

(b) If alternate slits are covered with a retarder that retards the wave by π, obtain an expression for the intensity distribution of the Fraunhofer diffraction pattern? (12)

ZOLLEGE.in

ZOLLEGE.in

Q.25 Unpolarized light is incident on an air-dielectric interface. The interface is the x-y plane, and the plane of incidence is y-z plane. The electric field of the reflected light is given by $\vec{E} = E_0\,\hat{x}\exp\left\{\frac{ik}{2}\left(\sqrt{3}\,y + z\right) - i\omega t\right\}$, where k is the propagation constant in air and ω is the angular frequency of the light. Assume magnetic permeability $\mu = \mu_0$.

(a) Determine the dielectric constant of the second medium. (12)

(b) Determine the direction of the Poynting vector in the dielectric medium. (9)

ZOLLEGE.in

ZOLLEGE.in

A

Space for rough work

ZOLLEGE.in

ZOLLEGE.in

A

Space for rough work

ZOLLEGE.in

ZOLLEGE.in

A

Space for rough work

ZOLLEGE.in

ZOLLEGE.in

A

Space for rough work

ZOLLEGE.in

ZOLLEGE.in

A

Space for rough work

ZOLLEGE.in

ZOLLEGE.in

A

2011 PH Objective Part (Question Number 1 – 15)	
Total Marks	**Signature**

Subjective Part					
Question Number	**Marks**		**Question Number**	**Marks**	
16			21		
17			22		
18			23		
19			24		
20			25		
Total Marks in Subjective Part					

Total (Objective Part)	:	
Total (Subjective Part)	:	
Grand Total	:	
Total Marks (in words)	:	
Signature of Examiner(s)	:	
Signature of Head Examiner(s)	:	
Signature of Scrutinizer	:	
Signature of Chief Scrutinizer	:	
Signature of Coordinating Head Examiner	:	

Z@LLEGE.in

ZOLLEGE.in