THE OPTIMIST CLASSES
IIT-JAM TOPPERS

8 AIR — **MANOJ KUMAR SINGH**

9 AIR — **ABHAY**

12 AIR — **PAWAN**

15 AIR — **SATYAM**

21 AIR — **SOUMIL GIRISH SAHU**

29 AIR — **BHOOMIJA**

31 AIR — **AKSHIT AGGARWAL**

32 AIR — **SHIKHAR CHAMOLI**

33 AIR — **RAVI SINGH ADHIKARI**

44 AIR — **GAURAV JHA**

56 AIR — **SWAPNIL JOSHI**

65 AIR — **LOKESH BHATT**

75 AIR — **GOPESH VISHVAKARMA**

77 AIR — **VAIBHAV**

80 AIR — **SHASWAT CHAMOLI**

CSIR-NET-JRF RESULTS 2022

102 AIR — JRF
ANNU
DL01000308

133 AIR — JRF
ALANKAR
UP15000162

155 AIR — JRF
SAHIL RANA
HR09000108

168 AIR — JRF
JAYESTHI
RJ11000161

174 AIR — JRF
DASRATH
RJ06000682

181 AIR — JRF
VIVEK
UK01000439

183 AIR — JRF
UZAIR AHMED
UP02000246

191 AIR — JRF
SURYA PRATAP SINGH
RJ06000232

195 AIR — JRF
HIMANSHU
UP10000095
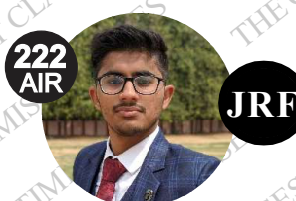
222 AIR — JRF
CHANDAN
RJ09000159

228 AIR — JRF
SAIKHOM JOHNSON
MN01000196

231 AIR — JRF
AJAY SAINI
RJ06001744

258 AIR — JRF
VIKAS YADAV
RJ06001102

283 AIR — JRF
JYOTSNA KOHLI
UK02000262

318 AIR — JRF
SHYAM SUNDAR
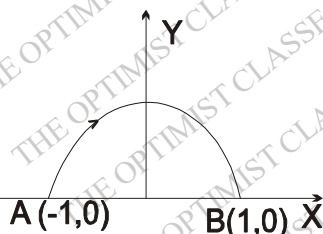RJ06000615

THE OPTIMIST CLASSES

AN INSTITUTE FOR NET-JRF/GATE/IIT-JAM/JEST/TIFR/M.Sc ENTRANCE EXAMS

CONTACT: 9871044043

IIT - JAM PHYSICS

PREVIOUS YEAR QUESTION 2011

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

   (a) -2 (b) 0   (c) 2   (d) 4

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 nth oscillation. If the resultant amplitude of the superposition is zero, what is the phase difference $\Delta\phi$?

   (a) $\dfrac{\pi}{6}$ (b) $\dfrac{\pi}{3}$ (c) $\dfrac{\pi}{2}$ (d) 2π

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

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

   where ω_0 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) $\sqrt{2}\omega_0$ (b) $2\omega_0$ (c) $4\omega_0$ (d) $4\sqrt{2}\omega_0$

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.
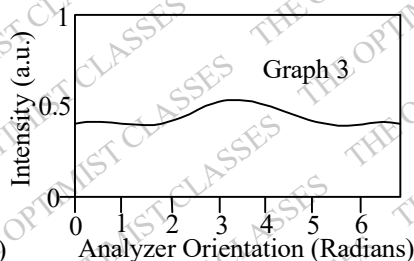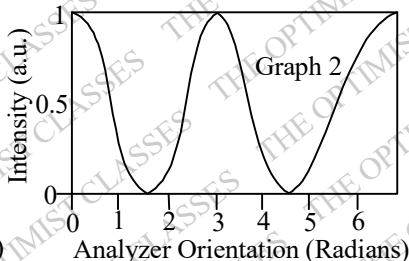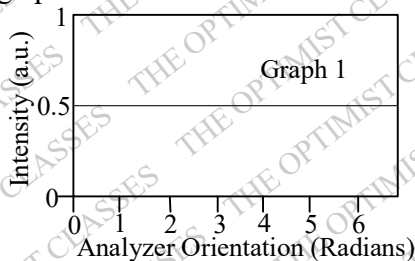
   (a) Graph 1 : Linear polarization, Graph 2: Circular polarization, Graph 3 : Elliptic polarization.

(b) Graph 1 : Circualr polarization, Graph 2 : Linear polarization, Graph 3 : Elliptic polarization.

(c) Graph 1 : Unpolarized, Graph 2 : Circualr polarization, Graph 3 : Linear polarization.

(d) Graph 1 : Unpolarized, Graph 2: Elliptic polarization, Graph 3 : Circular polarization.

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

(a)

(b)

(c)

(d)
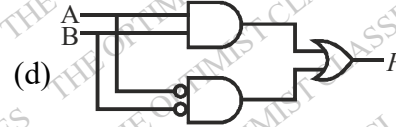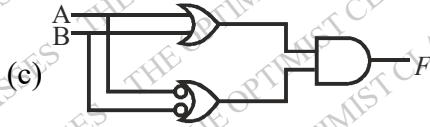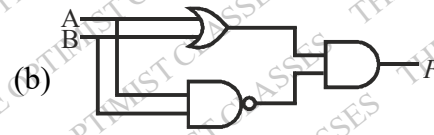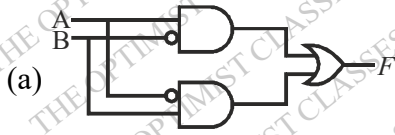
6. Light described by the equation $E = (90 \text{ V/m})\left[\sin(6.28\times10^{15}\text{ s}^{-1})t + \sin(12.56\times10^{15}\text{ s}^{-1})t\right]$ is incident on a metal surface. The work function of the metal is $2.0\ eV$. Maximum kinetic energy of the photoelectrons will be

(a) $2.14 eV$ (b) $4.28 eV$ (c) $6.28 eV$ (d) $12.56 eV$

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) $\sqrt{\dfrac{k_BT}{m}}$ (b) $\sqrt{\dfrac{2k_BT}{m}}$ (c) $\sqrt{\dfrac{2k_BT}{\pi m}}$ (d) $\sqrt{\dfrac{8k_BT}{\pi m}}$

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 ΔS_1. The corresponding change in the entropy of the surrounding is ΔS_2. Which of the following combinations is correct?

(a) $\Delta S_1 = R\ln(V_1/V_2),\ \ \Delta S_2 = -R\ln(V_1/V_2)$

(b) $\Delta S_1 = -R\ln(V_1/V_2),\ \Delta S_2 = R\ln(V_1/V_2)$

(c) $\Delta S_1 = R\ln(V_2/V_1),\ \ \Delta S_2 = 0$

(d) $\Delta S_1 = -R\ln(V_2/V_1),\ \Delta S_2 = 0$

9. Equipotential surface 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 constant. 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) $\vec{E} = -4\hat{y}$

10. The wave function of a quantum mechanical particle is given by $\psi(x) = \dfrac{3}{5}\varphi_1(x) + \dfrac{4}{5}\varphi_2(x)$ 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) $-\dfrac{41}{25}eV$ (b) $-\dfrac{11}{25}eV$ (c) $-\dfrac{36}{5}eV$ (d) $-\dfrac{7}{5}eV$

11. A rain drop falling vertically under gravity gathers moisture from the atmosphere at a rate given by $\dfrac{dm}{dt} = kt^2$,

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)m 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*

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) $\hat{P}+\hat{Q}$

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 thransformation on cooling to $-20°$ 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.
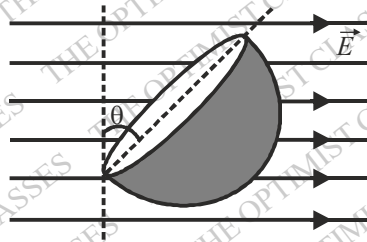
14. A closed Gaussian surface consisting of a hemisphere and a circular disc of radius R, is placed in a uniform electric field, $\vec{E}$, as shown in the figure. The circular disc makes an angle $\theta=30°$ with the vertical. The flux of the electric field vector coming out of the curved surface of the hemisphere is.

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

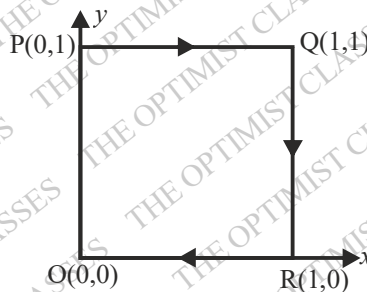(b) $\frac{\sqrt{3}}{2}\pi R^2 E$

(c) $\pi R^2 E$

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

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 300Ω at 200K and 2Ω at 250K. Its energy band gap is [Given: In(15)=2.708, In(10)=2.303]
(a) 0.138 *eV* (b) 0.431 *eV* (c) 0.690 *eV* (d) 0.862 *eV*

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

(a) Calculate the line integral $\int \vec{A}.\overrightarrow{d\ell}$ from point $P\to O$ along the path $P\to Q\to R\to O$ as shown in the figure. **[9]**

(b) Usning Stoke's theorem appropriately. Calculate $\int \vec{A}.\overrightarrow{d\ell}$ for the same path $P\to Q\to R\to O$. **[12]**

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_1 as shown in the figure.
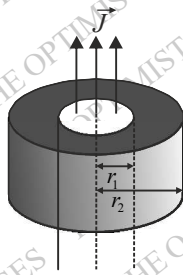

(a) Determine the magnetic field $\vec{H}$ in the region, $r < r_1$ and magnetic induction $\vec{B}$ in the regions, $r_1 < r < r_2$ and $r > r_1$ where r is the radial distance from the axis of the cylinder. **[12]**

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

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 $a\,\dfrac{\partial T}{\partial t}$ an 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. **[9]**

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

(b) Now consider a thin annular shaped material enclosed between two concentratric circles of radii r_0 and $2r_0$ as shown in the figure. The temperature is $2T_0$ at $r = r_0$ and T_0 at $r = 2r_0$. Assuming steady state condition. Find T as a function of radial distance r from the centre O, for $r_0 < r < 2r_0$. **[12]**
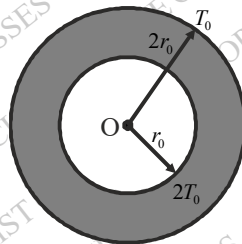
19. An ideal gas reversible engine operates in a closed cycle. The P-V diagram is shown below.
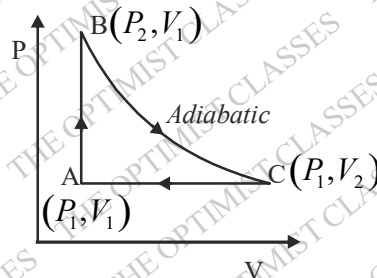
(a) Find out the efficiency of the reversible engine assuming both specific heats, C_P and C_V as constants. **[12]**

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

20. (a) A solid having a simple cubic structure at room temperature with lattice a parameter a and one valence electron per atom, is assumed to shown 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]**

21. For the given circuit using an operational amplifier the input is a sinusoidal signal of amplitude $V_m = 1\,mV\,(peak-to-peak)$.
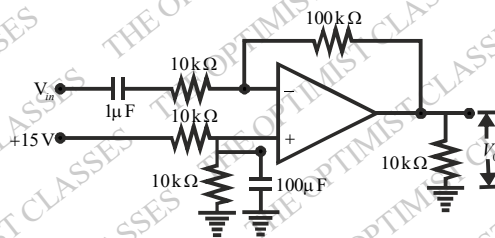
(a) What is the lower cut-off frequency at which the gain is down by 3 dB as compared to the gain at midband? If the bandwidth of the amplifier is 1 MHz for unity gain, what will be the bandwidth of the given circuit? **[12]**

(b) What is the output voltage (V_0) at 15 kHz? **[9]**

22. A partile 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.
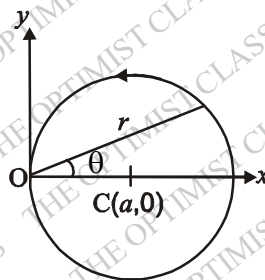
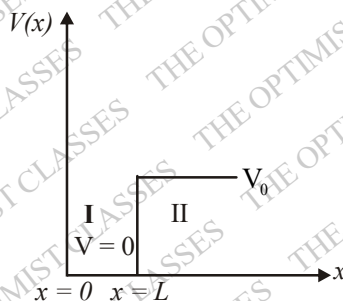(a) Given the orbit equation in a central field motion. **[9]**

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

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

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

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

$$V(x) = \infty \qquad \text{for } x < 0$$
$$= 0 \qquad \text{for } 0 < x < L$$
$$= V_0 \qquad \text{for } x > L$$

(a) Write down the general solutions for wave functions in regions I and II, if the energy of the particle $E < V_0$.

Using appropriate boundary conditions, find the equation that relates E to V_0, m and L. **[12]**

(b) Now, set $V_0 = 0$ 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]

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} in the highest diffraction.

[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]

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 $\vec{E} = E_0 \hat{x} \exp\left\{\dfrac{ik}{2}\left(\sqrt{3}y + z\right) - i\omega t\right\}$, 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]

ANSWER KEY

1.	(b)	2.	(b)	3.	(b)	4.	(b)	5.	(d)	6.	(c)	7.	(d)
8.	(c)	9.	(c)	10.	(a)	11.	(b)	12.	(c)	13.	(b)	14.	(b)
15.	(d)	16.	(*)	17.	(*)	18.	(*)	19.	(*)	20.	(*)	21.	(*)
22.	(*)	23.	(*)	24.	(*)	25.	(*)						