IIT JAM PHYSICS 2016
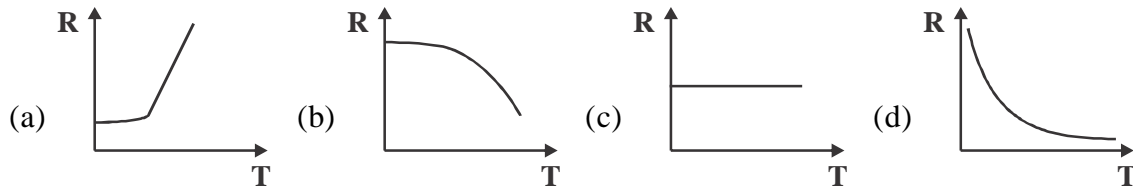## IIT-JAM 2015 PAPER

SECTION-A : MCQ

1. A system consists of N number of particles, $N \gg 1$. Each particle can have only one of the two energies E_1 or $E_1 + \varepsilon \, (\varepsilon > 0)$. If the system is in equilibrium at a temperature T, the average number of particles with energy E_1 is

   (a) $\dfrac{N}{2}$ (b) $\dfrac{N}{e^{\varepsilon/kT}+1}$ (c) $\dfrac{N}{e^{-\varepsilon/kT}+1}$ (d) $Ne^{-\varepsilon/kT}$

2. Temperature dependence of resistivity of a metal can be described by

   (a)   (b)   (c)   (d)

3. A charge q is at the center of two concentric spheres. The outward electric flux through the inner sphere is ϕ while that through the outer sphere is 2ϕ. The amount of charge contained in the region between the two spheres is

   (a) $2q$ (b) q (c) $-q$ (d) $-2q$

4. At room temperature, the speed of sound in air is 340 m/sec. An organ pipe with both ends open has a length $L = 29$ cm. An extra hole is created at the position $L/2$. The lowest frequency of sound produced is

   (a) 293 Hz   (b) 586 Hz   (c) 1172 Hz   (d) 2344 Hz

5. A proton from outer space is moving towards earth with velocity 0.99c as measured in earth's frame. A spaceship, traveling parallel to the proton, measures proton's velocity to be 0.97c. The approximate velocity of the spaceship, in the earth's frame is

   (a) 0.2c   (b) 0.3c   (c) 0.4c   (d) 0.5c

6. A particle with energy E is incident on a potential given by

   $$V(x) = \begin{cases} 0, & x < 0 \\ V_0, & x \geq 0 \end{cases}$$

   The wave function of the particle for $E < V_0$, in the region $x > 0$ (in terms of positive constants A, B and k) is

   (a) $Ae^{kx} + Be^{-kx}$ (b) Ae^{-kx} (c) $Ae^{ikx} + Be^{-ikx}$ (d) zero

7. The electric field of a light wave is given by $\vec{E} = E_0 \left[\hat{i} \sin(\omega t - kz) + \hat{j} \sin\left(\omega t - kz - \dfrac{\pi}{4}\right) \right]$. The polarization state of the wave is

   (a) Left handed circular   (b) Right handed circular
   (c) Left hand elliptical   (d) Right handed elliptical

8. A mass m, lying on a horizontal, frictionless surface, is connected to one end of a spring. The other end of the other end of the spring is connected to a wall, as shown in the figure. At $t = 0$, the mass is given an impulse
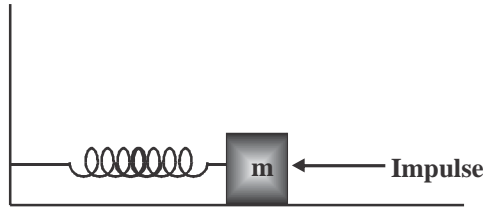

The time dependence of the displacement and the velocity of the mass (in terms of non-zero constants A and B) are given by

(a) $x(t) = A\sin \omega t, v(t) = B\cos \omega t$

(b) $x(t) = A\sin \omega t, v(t) = B\sin \omega t$

(c) $x(t) = A\cos \omega t, v(t) = B\sin \omega t$

(d) $x(t) = A\cos \omega t, v(t) = B\cos \omega t$

9. Consider the coordinate transformation $x' = \dfrac{x + y}{\sqrt{2}}, y' = \dfrac{x - y}{\sqrt{2}}$. The relation between the area elements $dx'dy'$ and $dxdy$ is given by $dx'dy' = Jdxdy$. The value of J is

(a) 2   (b) 1   (c) –1   (d) –2

10. The trace of a 2×2 matrix is 4 and its determinant is 8. If one of the eigenvalue is $2(1 + i)$, the other eigenvalue is

(a) $2(1-i)$ (b) $2(1+i)$ (c) $(1+2i)$ (d) $(1-2i)$

11. A hollow, conducting spherical shell of inner radius R_1 and outer radius R_2 encloses a charge q inside, which is located at a distance $d (< R_1)$ from the centre of the spheres. The potential at the centre of the shell is
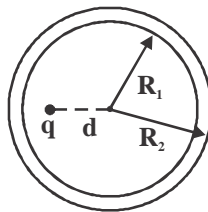
(a) Zero   (b) $\dfrac{1}{4\pi \in_0} \dfrac{q}{d}$ (c) $\dfrac{1}{4\pi \in_0}\left(\dfrac{q}{d} - \dfrac{q}{R_1}\right)$ (d) $\dfrac{1}{4\pi \in_0}\left(\dfrac{q}{d} - \dfrac{q}{R_1} + \dfrac{q}{R_2}\right)$

12. Doppler effect can be used to measure the speed of blood through vessels. Sound of frequency 1.0522 MHz is sent through the vessels along the direction of blood flow. The reflected sound generates a beat signal of frequency 100 Hz. The speed of sound in blood is 1545 m/sec. The speed of blood through the vessel, in m/sec, is

(a) 14.68   (b) 1.468   (c) 0.1468   (d) 0.01468

13. Vibrations of diatomic molecules can be represented as those of harmonic oscillators. Two halogen molecules X_2 and Y_2 have fundamental vibrational frequencies $v_x = 16.7 \times 10^{12}$ Hz and $v_z = 26.8 \times 10^{12}\ Hz$ respectively. The respective force constants are $K_x = 325\ N/m$ and $K_Y = 446\ N/m$. The atomic masses of F, Cl and Br are 19.0, 35.5 and 79.9 atomic mass unit respectively. The halogen molecules X_2 and Y_2 are

(a) $X_2 = F_2$ and $Y_2 = Cl_2$

(b) $X_2 = Cl_2$ and $Y_2 = F_2$

(c) $X_2 = Br_2$ and $Y_2 = F_2$

(d) $X_2 = F_2$ and $Y_2 = Br_2$

14. The variation of binding energy per nucleus with respect to the mass of nuclei is shown in the figure
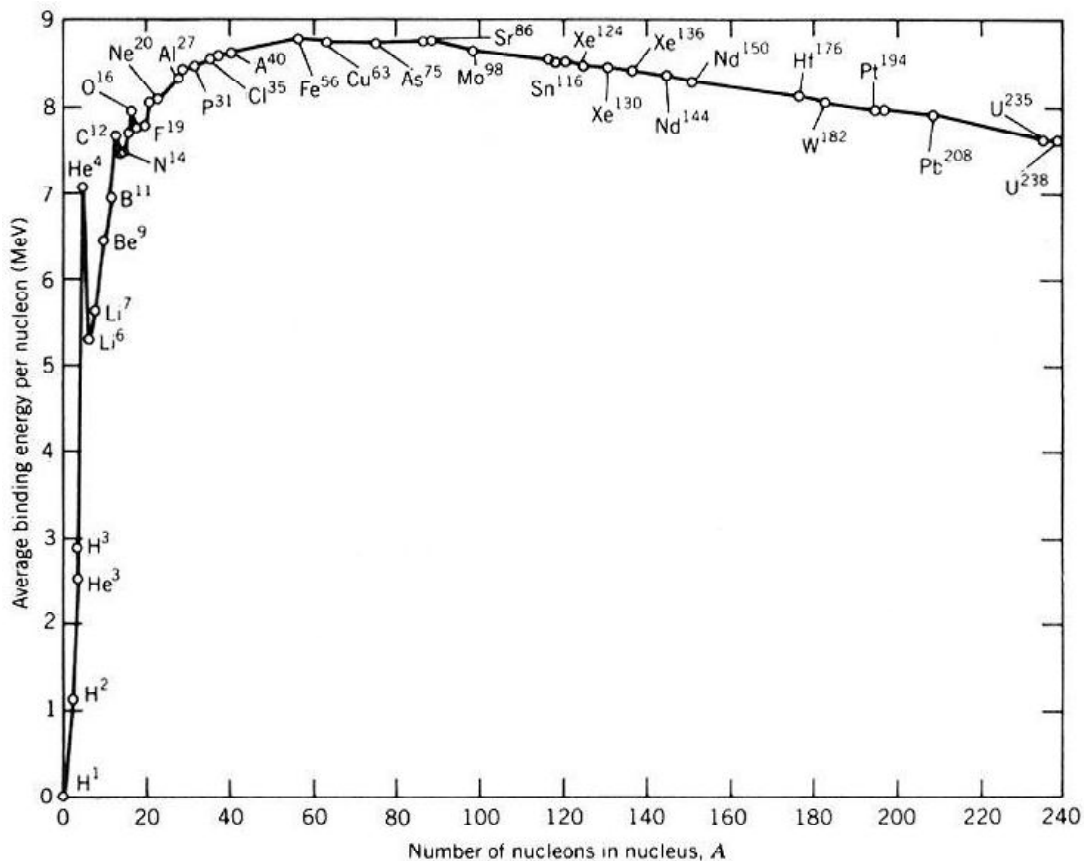

Consider the following reactions:

(1) $^{238}_{92}U \rightarrow ^{206}_{82}Pb + 10p + 22n$

(2) $^{238}_{92}U \rightarrow ^{206}_{82}Pb + 8^4_2He + 6e^-$

Which one of the following statements is true for the given decay modes of $^{238}_{92}U$?

(a) both 1 and 2 are allowed

(b) both 1 and 2 are forbidden

(c) 1 is forbidden and 2 is allowed

(d) 1 is allowed and 2 is forbidden

15. A rigid and thermally isolated tank is divided into two compartments of equal volume V, separated by a thin membrane. One compartment contains one mole of an ideal gas A and the other compartment contains one mole of a different ideal gas B. The two gases are in thermal equilibrium at a temperature T. If the membrane ruptures, the two gases mix. Assume that the gases are chemically inert. The change in the total entropy of the gases on mixing is

(a) 0

(b) $R \ln 2$

(c) $\dfrac{3}{2} R \ln 2$

(d) $2R \ln 2$

16. A zener regulator has an input voltage in the range 15V–20V and a load current in the range of 5 mA–20mA. If the zener voltage is 6.8V, the value of the series resistor should be

(a) 390 Ω   (b) 420 Ω   (c) 440 Ω   (d) 460 Ω
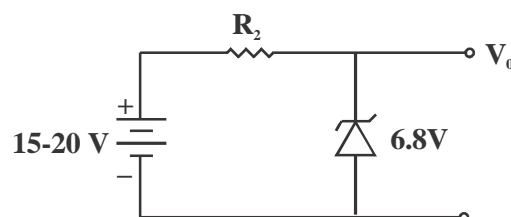
17.   A positively charged particle, with a charge q, enters a region in which there is a uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$, both directd parallel to the positive y-axis. At $t = 0$, the particle is at the origin and has a speed v_0 directed along the positive x-axis. The orbit of the particle, projected on the x-z plane, is a circle. Let T be the time taken to complete one revolution of this circle. The y-coordinate of the particle at $t = T$ is given by

(a) $\dfrac{\pi^2 mE}{2qB^2}$ (b) $\dfrac{2\pi^2 mE}{qB^2}$ (c) $\dfrac{\pi^2 mE}{qB^2} + \dfrac{v_0 \pi m}{qB}$ (d) $\dfrac{2\pi m v_0}{qB}$

18.   A satellite moves around the earth in a circular orbit of radius R centered at the earth. A second satellite moves in an elliptic orbit of major axis 8R, with the earth at one of the foci. If the former takes 1 day to complete a revolution, the latter would take
(a) 21.6 days   (b) 8 days   (c) 3 hours   (d) 1.1 hour

19.   A system comprises of three electrons. There are three single particle energy levels accessible to each of these electrons. The number of possible configurtions for this system is
(a) 1   (b) 3   (c) 6   (d) 7

20.   A rigid triangular molecule consists of three non-collinear atoms joined by rigid rods. The constant pressure molar specific heat (C_p) of an ideal gas consisting of such molecules is
(a) $6R$ (b) $5R$ (c) $4R$ (d) $3R$

21.   Consider the equation $\dfrac{dy}{dx} = \dfrac{y^2}{x}$ with the boundary condition $y(1) = 1$. Out of the following, the range of x in which y is real and finite, is
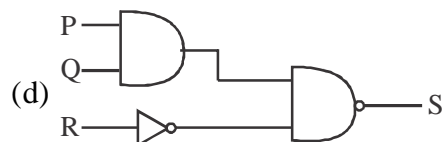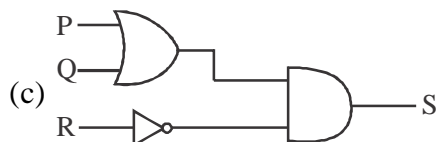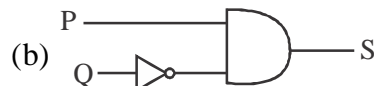(a) $-\infty \le x \le -3$ (b) $-3 \le x \le 0$ (c) $0 \le x \le 3$ (d) $3 \le x \le \infty$

22.   Consider a vector field $\vec{F} = y\hat{i} + xz^3 \hat{j} - zy\hat{k}$. Let C be the circle $x^2 + y^2 = 4$ on the plane $z = 2$, oriented counter-clockwise. The value of contour integral $\oint_C \vec{F} \cdot d\vec{r}$ is

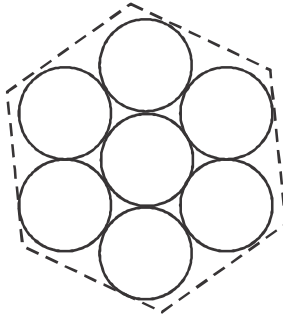(a) 28π (b) 4π (c) -4π (d) -28π

23.   Which of the following circuits represent the Boolean expression
$S = \overline{\overline{P + QR} + \overline{\overline{Q}P}}$

(a)

(b)

(c)

(d)

24.   Seven uniform disks, each of mass m and radius r, are inscribed inside a regular hexagon, as shown. The moment of inertia of this system of seven disks, about an axis passing through the central disk and perpendicular to the plane of the disks, is

(a) $\dfrac{7}{2}mr^2$ (b) $7mr^2$ (c) $\dfrac{13}{2}mr^2$ (d) $\dfrac{55}{2}mr^2$

25. A nucleus has a size of 10^{-15} m. Consider an electron bound within a nucleus. The estimated energy of this electron is of the order of
(a) 1 MeV (b) 10^2 MeV (c) 10^4 MeV (d) 10^6 MeV

26. A conducting wire is in the shape of a regular hexagon, which is inscribed inside an imaginary circle of radius R, as shown. A current I flows through the wire. The magnitude of the magnetic field at the centre of the circle is
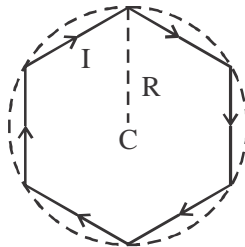

(a) $\dfrac{\sqrt{3}\mu_0 I}{2\pi R}$ (b) $\dfrac{\mu_0 I}{2\sqrt{3}\pi R}$ (c) $\dfrac{\sqrt{3}\mu_0 I}{\pi R}$ (d) $\dfrac{3\mu_0 I}{2\pi R}$

27. An observer is located on a horizontal, circular turntable which rotates about a vertical axis passing through its centre, with a uniform angular speed of 2 rad/sec. A mass of 10 grams is sliding without friction on the turntable. At an instant when the mass is at a distance of 8 cm from the axis, it is observed to move towards the center with a speed of 6 cm/sec. The net force on the mass, as seen by the observer at that instant, is
(a) 0.0024N (b) 0.0032 N (c) 0.004 N (d) 0.006 N

28. The Fourier series for an arbitrary periodic function with period $2L$ is given by

$f(x)=\dfrac{a_0}{2}+\sum\limits_{n=1}^{\infty}a_n\cos\dfrac{n\pi x}{L}+\sum\limits_{n=1}^{\infty}b_n\sin\dfrac{n\pi x}{L}$. For the particular periodic function shown in the figure, the value of a_0 is
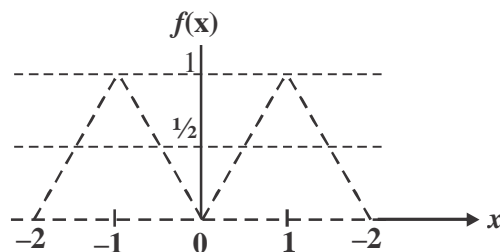
(a) 0 (b) 0.5 (c) 1 (d) 2

29. Miller indices of a plane in cubic structure that contains all the directions [100], [011] and [111] are
(a) (011) (b) (101) (c) (100) (d) (110)

30. The phase of the complex number $(1+i)i$ in the polar representation is

(a) $\dfrac{\pi}{4}$ (b) $\dfrac{\pi}{2}$ (c) $\dfrac{3\pi}{4}$ (d) $\dfrac{5\pi}{4}$

SECTION-B : MSQ

1. For an electromagnetic wave travelling in free space, the electric field is given by $\vec{E} = 100\cos\left(10^8 t + kx\right)\hat{j}\, V/m$. Which of the following statements are true?

(a) The wavelength of the wave in meter is 6π
(b) The corresponding magnetic field is directed along the positive z-direction
(c) The poynting vector is directed along the positive z-direction
(d) The wave is linearly polarized.

2. A particle of mass m is moving in x-y plane. At any given time t, its position vector is given by $\vec{r}(t) = A\cos\omega t\hat{i} + B\sin\omega t\hat{j}$, where A, B and ω are contants with $A \ne B$. Which of the following statements are true?

(a) orbit of the particle is an ellipse
(b) speed of the particle is constant
(c) at any given time t, the particle experiences a force towards origin
(d) the angular momentum of the particle is $m\omega AB\hat{k}$

3. Muons are elementary particles produced in the upper atmosphere. They have a life time of 2.2µs. Consider muons which are traveling vertically towards the earth's surface at a speed of 0.998c. For an observer on earth, the height of the atmosphere above the surface of the earth is 10.4 km. Which of the following statements are true?

(a) the muons can never reach earth's surface.
(b) the apparent thickness of earth's atmosphere in muon's frame of reference is 0.96 km.
(c) the lifetime of muons in earth's frame of reference is 34.8 µs
(d) muons traveling at a speed greater than 0.998c reach the earth's surface.

4. In an ideal op-amp circuit shown below, $R_1 = 3k\Omega$ and $R_2 = 1\,k\Omega$ and $V_i = 0.5\sin\omega t$ (in volt). Which of the following statements are true?
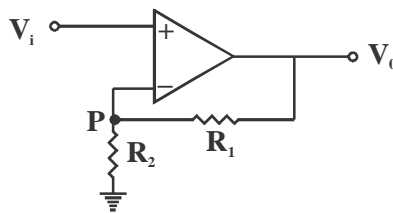

(a) the current through R_1 = the current through R_2.
(b) the potential at P is $V_0\dfrac{R_2}{R_1}$
(c) the amplitude of V_0 is $2V$.
(d) the output voltage V_0 is in phase with V_i.

5. Consider the circuit consisting of an AC function generator $V(t) = V_0\sin 2\pi vt$ with $V_0 = 5V$, an inductor L = 8.0 mH, resistor $R = 5\,\Omega$ and a capacitor C = 100 µF. Which of the following statements are

true if we vary the frequency?
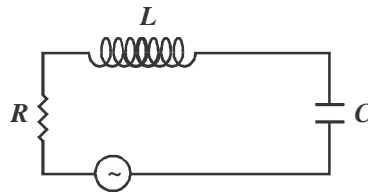
(a) the current in the circuit would be maximum at $v = 178$ Hz.
(b) the capacitor reactance increases with frequency
(c) at resonance, the impedance of the circuit is equal to the resistance in the circuit
(d) at resonance, the current is out of phase with source voltage.

6. The following figure shows a double slit Fraunhofer diffraction pattern produced by two slits, each of width a, separated by a distance b, $a < b$. Which of the following statements are correct?
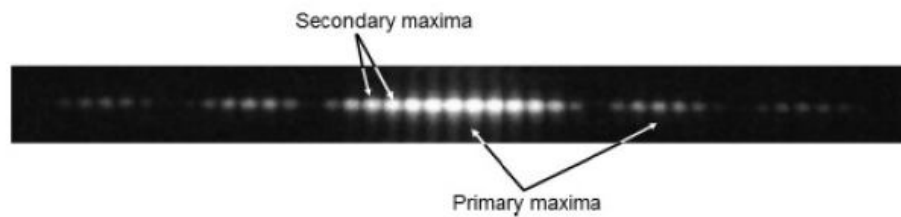
(a) reducing a increases the separation between consecutive primary maxima.
(b) reducing a increases the separation between consecutive secondary maxima
(c) reducing b increases the separation between consecutive primary maxima
(d) reducing b increases the separation between consecutive secondary maxima.

7. A rod is hanging vertically from a pivot. A particle, travelling in horizontal direction, collides with the rod as shown in the figure. For the rod-particle system. Consider the linear momentum and the angular momentum about the pivot. Which of the following statements are NOT true?
(a) both linear momentum and angular momentum are conserved
(b) linear momentum is conserved but angular momentum is not
(c) linear momentum is not conserved but angular momentum is conserved.
(d) neither linear momentum nor angular momentum are conserved.

8. As shown in the P-V diagram. AB and CD are two isotherms at temperatures T_1 and T_2 respectively ($T_1 > T_2$). AC and BD are two reversible adiabats. In this Carnot cycle, which of the following statements are true?
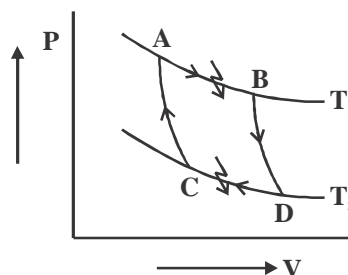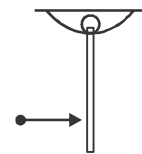
(a) $\dfrac{Q_1}{T_1} = \dfrac{Q_2}{T_2}$

(b) the entropy of the source decreases

(c) the entropy of the system increases

(d) work done by the system $W = Q_1 - Q_2$

9. A unit cube made of dielectric material has a polarization $\vec{P} = 3\hat{i} + 4\hat{j}$ units. The edges of the cube are parallel to the Cartesian axes. Which of the following statements are true?
(a) the cube carries a volume bound charge of magnitude 5 units.

(b) there is a charge of magnitude 3 units on both the surfaces parallel to the y-z plane

(c) there is a charge of magnitude 4 units on both the surfaces parallel to the x-z plane.

(d) there is a net non-zero induced charge on the cube

10. A particle is moving in a two-dimensional potential well

$$V(x, y) = 0, \quad 0 \le x \le L, 0 \le y \le 2L$$

$$= \infty, \quad \text{elsewhere}$$

Which of the following statements about the ground state energy E1 and ground state eigenfunction φ_0 are true?

(a) $E_1 = \dfrac{\hbar^2 \pi^2}{mL^2}$

(b) $E_1 = \dfrac{5\hbar^2 \pi^2}{8mL^2}$

(c) $\varphi_0 = \dfrac{\sqrt{2}}{L} \sin \dfrac{\pi x}{L} \sin \dfrac{\pi y}{2L}$

(d) $\varphi_0 = \dfrac{\sqrt{2}}{L} \cos \dfrac{\pi x}{L} \cos \dfrac{\pi y}{2L}$

SECTION-C : NAT

1. In an experiment on charging of an initially uncharged capacitor, an RC circuit is made with the resistance $R = 10\,k\Omega$ and the capcitor C = 1000 μF along with a voltage source of 6V. The magnitude of the displacement current through the capacitor (in μA), 5 seconds after the charging has started is _____

2. X-rays of wavelength 0.24 nm are Compton scattered and the scattered beam is observed at an angle of 60° relative to the incident beam. The Compton wavelength of the electron is 0.00243 nm. The kinetic energy of scattered electrons in eV is _____

3. GaAs has a diamond structure. The number of GaAs bonds per atom which have to be broken to fracture the crystal in the (001) plane is _____

4. A diode at room temperature (kT = 0.025 eV) with a current of 1 μA has a forward bias voltage V_f = 0.4V. For V_f = 0.5V, the value of the diode current (in μA) is _____

5. The power radiated by sun is 3.8×10^{26} W and its radius is 7×10^5 km. The magnitude of the poynting vector (in W/cm^2) at the surface of the sun is _____

6. Unpolarized light is incident on a calcite plate at an angle of incidence 50°, as shown in the figure. Take $n_0 = 1.6584$ and $n_e = 1.4864$ for calcite. The angular separation (in degrees) between the two emerging rays within the plate is _____
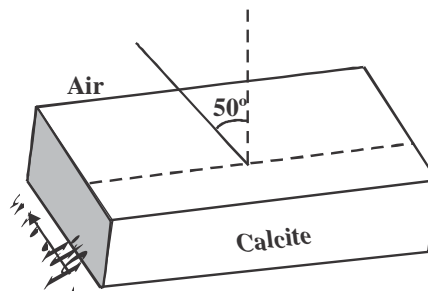

7. A rod is moving with a speed of 0.8c in a direction at 60° to its own length. The percentage contraction in the length of the rod is _____

8. A particle is in a state which is a superposition of the ground state φ_0 and the first excited state φ_1 of a one-dimensional quantum harmonic oscillator. The state is given by $\phi = \dfrac{1}{\sqrt{5}}\varphi_0 + \dfrac{2}{\sqrt{5}}\varphi_1$. The expectation of the energy of the particle in this state (in units of $\hbar\omega$, ω being the frequency of the oscillator) is _____

9. In the given circuit, $V_{CC} = 10V$ and $\beta = 100$ for the n-p-n transistor. The collector voltage $\mathbf{V}_C$ (in volts) is _____
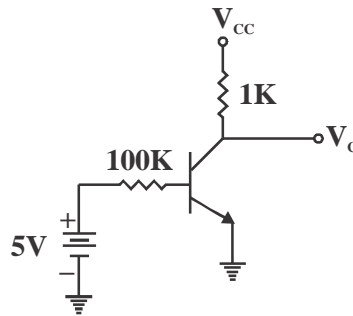

10. In the hydrogen atom spectrum, the ratio of the longest wavelength in the Lyman series (final state n = 1) to that in the Balmer series (final state n = 2) is _____

11. A plane electromagnetic wave of frquency 5×10^{14} Hz and amplitude 10^3 V/m, travelling in a homogeneous dielectric medium of dielectric constant 1.69, is incident normally at the interface with a second dielectric medium of dielectric constant 2.25. The ratio of the amplitude of the transmitted wave to that of the incident wave is _____

12. For the arrangement given in the following figure, the coherent light source A, B and C have individual intensities of 2 mW/m², 2 mW/m² and 2 mW/m², respectively at point P. The wavelength of each of the sources is 600 nm. The resultant intensity at point P (in mW/m²) is _____
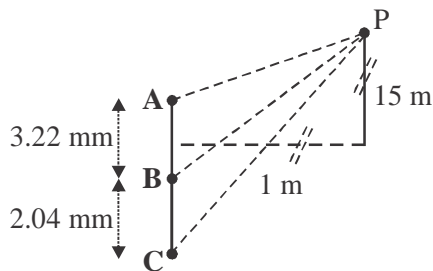

13. In a region of space, a time dependent magnetic field $B(t) = 0.4t$ Tesla points vertically upwards. Consider a horizontal, circular loop of radius 2 cm in this region. The magnitude of the electric field (in mV/m) induced in the loop is _____

14. A homogeneous semi-circular plate of radius R = 3m is shown in the figure. The distance of the center of mass of the plate (in meter) from the point O is _____
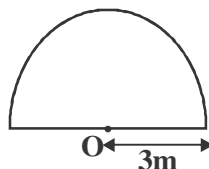
15. A uniform disk of mass *m* and radius R rolls, without slipping down a fixed plane inclined at an angle 30° to the horizontal. The linear acceleration of the disk (in m/sec²) is _____

16. In the thermodynamic cycle shown in the figure, one mole of a monatomic ideal gas is taken through a cycle. AB is a reversible isothermal expansion at a temperature of 800K in which the volume of the gas is doubled. BC is an isobaric contraction to the original volume in which the temperature is reduced to 300K. CA is a constant volume process in which the pressure and temperature return to their initial values. The net amount of heat (in joules) absorbed by the gas in one complete cycle is _____
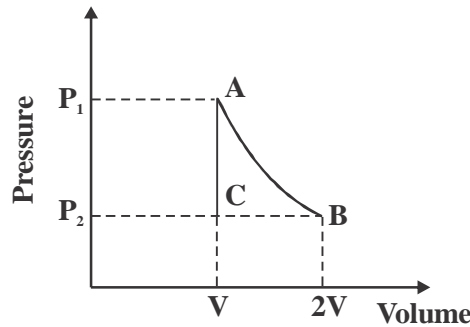
17. A nozzle is in the shape of a truncated cone, as shown in the figure. The area at the wide end is 25 cm² and the narrow end has an area of 1 cm². Water enters the wider end at a rate of 500 gm/sec. The height of the nozzle is 50 cm and it is kept vertical with the wider end at the bottom. The magnitude of the pressure difference in kPa (1 kPa = 10^3 N/m²) between the two ends of the nozzle is _____

50 cm
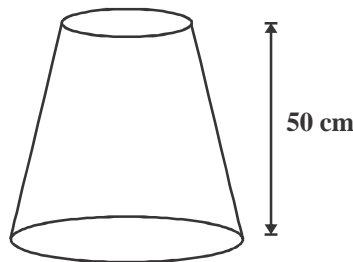
18. One gram of ice at 0°C is melted and heated to water at 39°C. Assume that the specific heat remains constant over the entire process. The latent heat of fusion of ice is 80 Calories/gm. The entropy change in the process (in Calories per degree) is _____

19. A block of mass 2 kg is at rest on a horizontal table. The coefficient of friction between the block and the table is 0.1. A horizontal force 3 N is applied to the block. The speed of the block (in m/s) after it has moved a distance 10 m is _____

20. Consider a 20 μm diameter p-n junction fabricated in silicon. the donor density is 10^{16} per cm³. The charge developed on the n-side is $1.6 \times 10^{-13} C$. Then the width (in μm) of the depletion region on the n-side of the p-n junction is _____