JAM JOINT ADMISSION TEST FOR MSc 2015

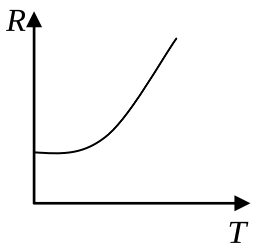
SECTION – A: MCQ

Q1. 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

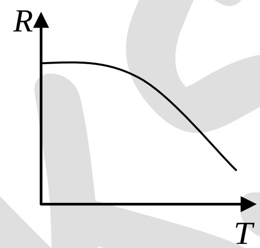
(a) $0.2c$ (b) $0.3c$ (c) $0.4c$ (d) $0.5c$

Q2. Temperature dependence of resistivity of a metal can be described by

(a)



(b)



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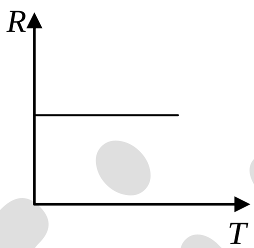
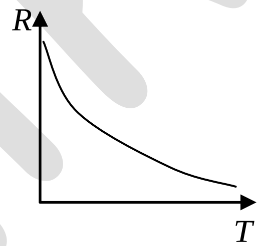


(d)



Q3. The trace of a 2×2 matrix is 4 and its determinant is 8. If one of the eigenvalues is $2(1+i)$, the other eigenvalue is

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

Q4. 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) $2344\,Hz$

Q5. The electric field of a light wave is given by $\vec{E} = E_0\left[\hat{i}\sin(\omega t - kz) + \hat{j}\sin\left(\omega t - kz - \frac{\pi}{4}\right)\right]$.

The polarization state of the wave is

(a) Left handed circular (b) Right handed circular

(c) Left handed elliptical (d) Right handed elliptical

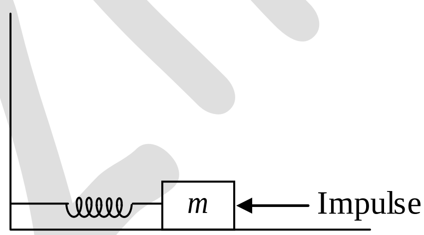
Q6. A particle with energy E is incident on a potential given by

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

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

Q7. A mass m, lying on a horizontal, frictionless surface, is connected to one end of a spring. 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) $x(t) = A\cos\omega t,\ v(t) = B\cos\omega t$

Q8. Consider the coordinate transformation $x' = \frac{x+y}{\sqrt{2}},\ y' = \frac{x-y}{\sqrt{2}}$. 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

Q9. 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) $-2q$

Q10. A system consists of N number of particles, $N >> 1$. 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) $\frac{N}{2}$ (b) $\frac{N}{e^{\varepsilon/kT}+1}$ (c) $\frac{N}{e^{-\varepsilon/kT}+1}$ (d) $Ne^{-\varepsilon/kT}$

Q11. Vibrations of diatomic molecules can be represented as those of harmonic oscillators. Two halogen molecules X_2 and Y_2 have fundamental vibrational frequencies $v_X = 16.7\times10^{12}\ Hz$ and $v_Y = 26.8\times10^{12}\ Hz$, 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 $Y_2 = Br_2$

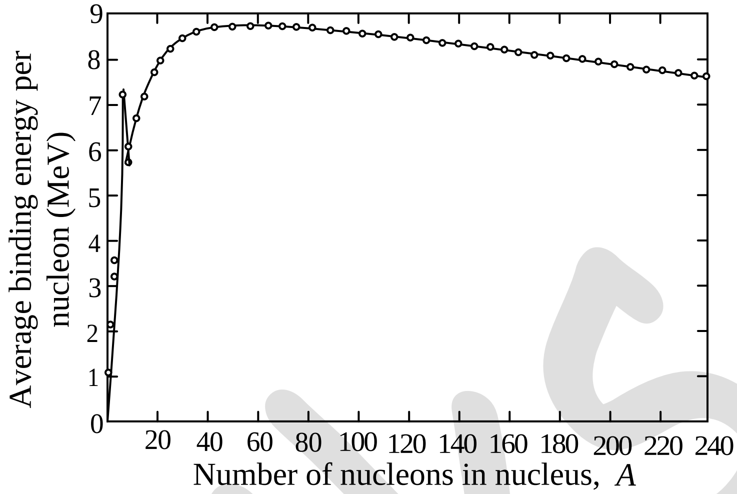
Q12. A rigid triangular molecule consists of three non-collinear atoms joined by rigid rods. The constant pressure molar specific heat (C_p) of an ideal gas consisting of such molecules is

(a) $6R$ (b) $5R$ (c) $4R$ (d) $3R$

Q13. A system comprises of three electrons. There are three single particle energy levels accessible to each of these electrons. The number of possible configurations for this system is

(a) 1 (b) 3 (c) 6 (d) 7

Q14. The variation of binding energy per nucleon with respect to the mass number of nuclei is shown in the figure.



Consider the following reactions:

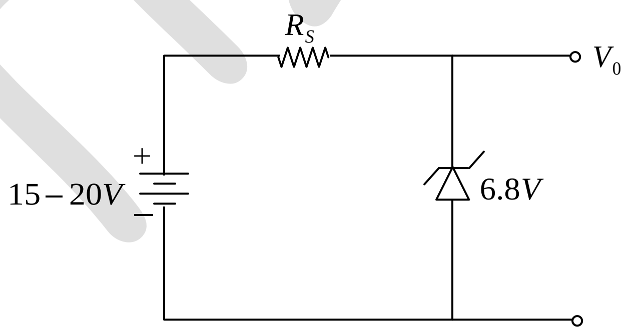
(i) ${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb + 10P + 22n$ (ii) ${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb + 8\,{}^{4}_{2}He + 6e^{-}$

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

(a) Both (i) and (ii) are allowed (b) Both (i) and (ii) are forbidden

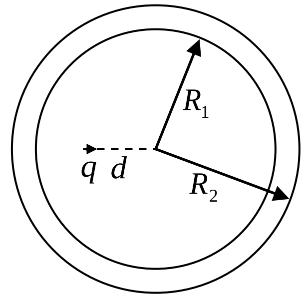
(c) (i) is forbidden and (ii) is allowed (d) (i) is allowed and (ii) is forbidden

Q15. A Zener regulator has an input voltage in the range $15V - 20V$ and a load current in the range of $5\ mA - 20\ mA$. If the Zener voltage is $6.8V$, the value of the series resistor should be



(a) $390\ \Omega$ (b) $420\ \Omega$ (c) $440\ \Omega$ (d) $460\ \Omega$

Q16. 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 $d\left(< R_1\right)$ from the centre of the spheres. The potential at the centre of the shell is



(a) Zero (b) $\frac{1}{4\pi\in_0}\frac{q}{d}$

(c) $\frac{1}{4\pi\in_0}\left(\frac{q}{d}-\frac{q}{R_1}\right)$ (d) $\frac{1}{4\pi\in_0}\left(\frac{q}{d}-\frac{q}{R_2}+\frac{q}{R_2}\right)$

Q17. 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

Q18. 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 directed 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) $\frac{\pi^2 mE}{2qB^2}$ (b) $\frac{2\pi^2 mE}{qB^2}$ (c) $\frac{\pi^2 mE}{qB^2}+\frac{v_0\pi m}{qB}$ (d) $\frac{2\pi mv_0}{qB}$

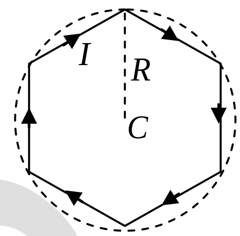
Q19. A rigid and thermally isolated tank is divided into two compartments of equal volume V, separated by a thin membrane. One compartment contains one mole of an ideal gas A and the other compartment contains one mole of a different ideal gas B. The two gases are in thermal equilibrium at a temperature 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) $\frac{3}{2}R\ln 2$ (d) $2R\ln 2$

Q20. 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

Q21. 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 center of the circle is



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

Q22. 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 the contour integral $\oint_C \vec{F} \cdot d\vec{r}$ is

(a) 28π (b) 4π (c) -4π (d) -28π

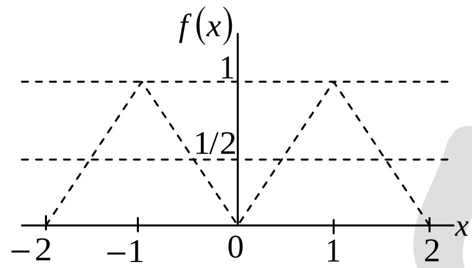
Q23. An observer is located on a horizontal, circular turntable which rotates about a vertical axis passing through its center, with a uniform angular speed of $2\,\text{rad/sec}$. A mass of 10 grams is sliding without friction on the turntable. At an instant when the mass is at a distance of $8\,cm$ 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) $0.0032N$ (c) $0.004N$ (d) $0.006N$

Q24. Miller indicates of a plane in cubic structure that contains all the directions $[100]$, $[011]$ and $[111]$ are

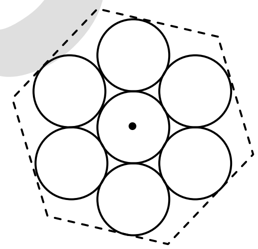
(a) (011) (b) (101) (c) (100) (d) (110)

Q25. The Fourier series for an arbitrary periodic function with period $2L$, is given by $f(x)=\frac{a_0}{2}+\sum_{n=1}^{\infty}a_n\cos\frac{n\pi x}{L}+\sum_{n=1}^{\infty}b_n\sin\frac{n\pi x}{L}$. For the particular periodic function shown in the figure the value of a_0 is



(a) 0 (b) 0.5 (c) 1 (d) 2

Q26. 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) $\frac{7}{2}mr^2$ (b) $7mr^2$

(c) $\frac{13}{2}mr^2$ (d) $\frac{55}{2}mr^2$

Q27. 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) $10^6\ MeV$

Q28. Consider the equation $\frac{dy}{dx}=\frac{y^2}{x}$ 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) $-3\le x\le 0$

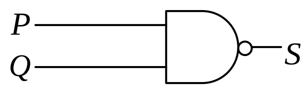
(c) $0\le x\le 3$ (d) $3\le x\le\infty$

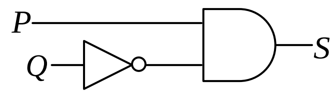
Q29. The phase of the complex number $(1+i)i$ in the polar representation is

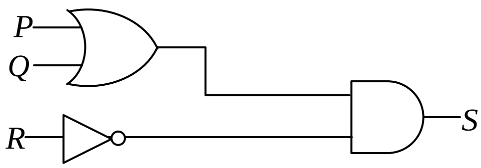
(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$ (c) $\frac{3\pi}{4}$ (d) $\frac{5\pi}{4}$

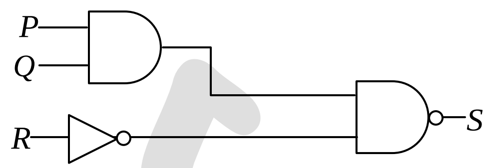
Q30. Which of the following circuits represent the Boolean expression

$$S = \overline{\overline{P + QR + \overline{Q}P}}$$

(a) 

(b) 

(c) 

(d) 

SECTION – B: MSQ

Q1. A unit cube made of a 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

Q2. Muons are elementary particles produced in the upper atmosphere. They have a life time of $2.2\mu s$. 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?

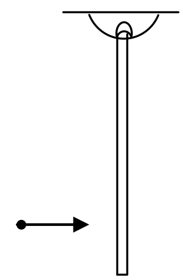
(a) The muons can never reach earth's surface

(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 $34.8\mu s$

(d) Muons traveling at a speed greater than $0.998\,c$ reach the earth's surface

Q3. A rod is hanging vertically from a pivot. A partic1e traveling 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?



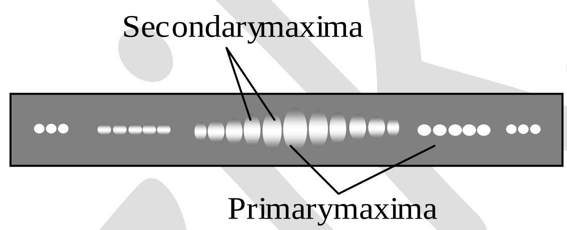
(a) Both linear momentum and angular momentum are conserved

(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 annular momentum are conserved

Q4. 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

Q5. For an electromagnetic wave traveling in free space, the electric field is given by $\vec{E} = 100\cos\left(10^8 t + kx\right)\hat{j}\,\frac{V}{m}$. 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

Q6. 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 constants with $A \neq B$. Which of the following statements are true?

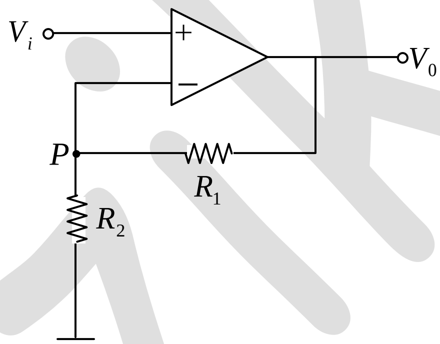
(a) Orbit of the particle is an ellipse

(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 $m\omega AB\hat{k}$

Q7. In an ideal Op-Amp circuit shown below $R_1 = 3k\Omega$, $R_2 = 1k\Omega$ 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

Q8. 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 E_1 and ground state eigenfunction φ_0 are true?

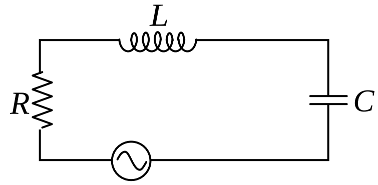
(a) $E_1 = \dfrac{\hbar^2\pi^2}{mL^2}$

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

Q9. Consider the circuit, consisting of an AC function generator $V(t) = V_0 \sin 2\pi\nu t$ with $V_0 = 5V$ an inductor $L = 8.0mH$, resistor $R = 5\Omega$ and a capacitor $C = 100\mu F$. Which of the following statements are true if we vary the frequency?



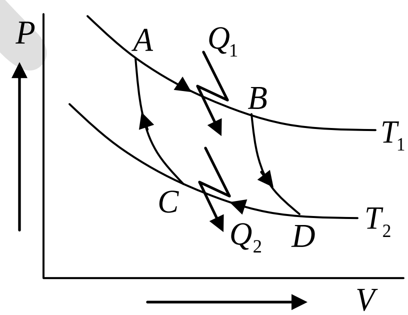
(a) The current in the circuit would be maximum at $\nu = 178Hz$

(b) The capacitive 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 in the circuit is out of phase with the source voltage

Q10. 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) $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

(b) The entropy of the source decreases

(c) The entropy of the system increases

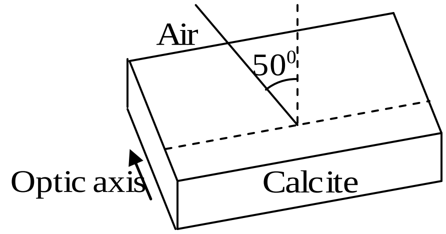
(d) Work done by the system $W = Q_1 - Q_2$

SECTION – C: NAT

Q1. In an experiment on charging of an initially uncharged capacitor, an RC circuit is made with the resistance $R = 10k\Omega$ and the capacitor $C = 1000\mu F$ 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 _______________

Q2. The power radiated by sun is $3.8 \times 10^{26} W$ and its radius is $7 \times 10^5\ km$. The magnitude of the Poynting vector (in $\frac{W}{cm^2}$) at the surface of the sun is _________________

Q3. 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



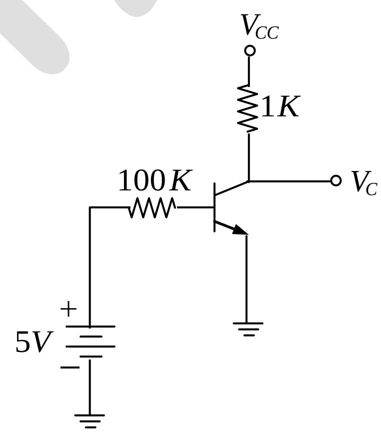
Q4. $X-$rays of wavelength $0.24\,nm$ are Compton scattered and the scattered beam is observed at an angle of 60° relative to the incident beam. The Compton wavelength of the electron is $0.00243 nm$. The kinetic energy of scattered elections in eV is____________

Q5. GaAs has a diamond structure. The number of Ga-As bonds per atom which have to be broken to fracture the crystal in the (001) plane is _______

Q6. 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 _____________

Q7. 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 ___________

Q8. In the given circuit $V_{CC} = 10V$ and $\beta = 100$ for $n-p-n$ transistor. The collector voltage V_C (in volts) is ___________.



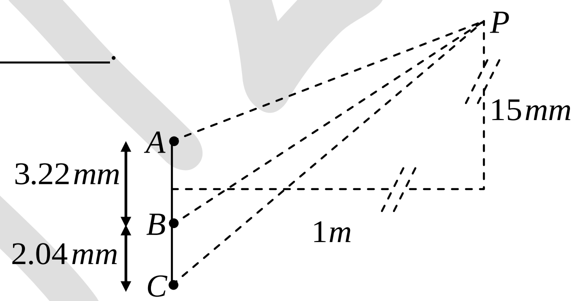
Q9. A particle is in a state which is a superposition of the ground state φ_0 and the first excited state φ_1 of a one-dimensional quantum harmonic oscillator. The state is given by $\Phi = \frac{1}{\sqrt{5}}\varphi_0 + \frac{2}{\sqrt{5}}\varphi_1$. The expectation value of the energy of the particle in this state (in units of $\hbar\omega, \omega$ being the frequency of the oscillator) is ________

Q10. A diode at room temperature $(kT = 0.025\,eV)$ with a current of $1\mu A$ has a forward bias voltage $V_F = 0.4V$. For $V_F = 0.5V$, the value of the diode current (in μA) is _________

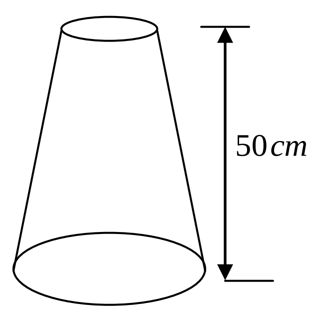
Q11. A uniform disk of mass m and radius R rolls, without slipping, down a fixed plane inclined at an angle 30° to the horizontal. The linear acceleration of the disk (in $m/\sec^2$) is _____________.

Q12. 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 ___________.

Q13. For the arrangement given in the following figure, the coherent light sources A, B and C have individual intensities of $2\,mW/m^2$, $2\,mW/m^2$ and $5\,mW/m^2$ respectively at point P. The wavelength of each of the sources is $600\,nm$. The resultant intensity at point P (in mW/m^2) is ___________.



Q14. A nozzle is in the shape of a truncated cone, as shown in the figure. The area at the wide end is $25\,cm^2$ and the narrow end has an area of $1\,cm^2$. 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 $(1kPa = 10^3\,N/m^2)$ between the two ends of the nozzle is __________

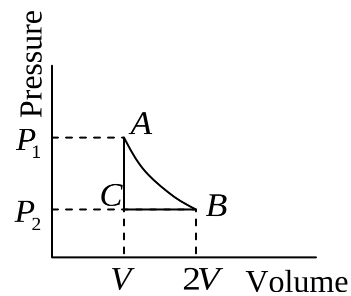


Q15. A plane electromagnetic wave of frequency $5\times10^{14}\,Hz$ and amplitude $10^{3}\,V/m$ traveling in a homogeneous dielectric medium of dielectric constant 1.69, is incident normally at the interface with a second dielectric medium of dielectric constant 2.25. The ratio of the amplitude of the transmitted wave to that of the incident wave is ___________.

Q16. 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 _________________.

Q17. One gram of ice at $0^{o}C$ is melted and heated to water at $39^{o}C$. 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 __________.

Q18. 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 ______________



Q19. Consider a $20\mu m$ diameter $p-n$ junction fabricated in silicon. The donor density is 10^{16} per cm^{3}. The charge developed on the $n-$ side is $1.6\times10^{-13}C$. Then the width (in μm) of the depletion region on the $n-$side of the $p-n$ junction is __________.

Q20. A homogeneous semi-circular plate of radius $R=3m$ is shown in the figure. The distance of the center of mass of the p1ate (in meter) from the point O is _______.