JNU-ENTRANCE EXAMINATION- 2009

M.Sc. PHYSICS

Maximum Marks: 90

INSTRUCTIONS FOR CANDIDATES

1. All questions are compulsory.
2. For each question, one and only one of the four choices given is the correct answer.
3. Each correct answer will be given +3 marks.
4. Each wrong answer will be given -1 mark.
5. Use of calculator is permitted.

Q.1. The sum of the infinite series

$$1-\frac{\pi^2}{2!2^4}+\frac{\pi^4}{4!2^8}-\frac{\pi^6}{6!2^{12}}+.....$$

is

(a) convergent and equals zero

(b) convergent and equals $1/\sqrt{2}$

(c) convergent and equals $\sqrt{2}$

(d) divergent

Q.2. The eigenvalues of the matrix $\begin{pmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{pmatrix}$ are

(a) -1, -1 and 2

(b) -1, 1 and 2

(c) -1, -2 and 2

(d) -1, 2 and 2

Q.3. Planck's constant (h), the speed of light in vacuum (c) and Newton's gravitational constant (G) are three fundamental constants of nature. Which of the following combinations has the dimension of length?

(a) $\sqrt{hG}/c^{3/2}$ (b) $\sqrt{hG}/c^{5/2}$ (c) $\sqrt{hc/G}$ (d) $\sqrt{Gc}/h^{3/2}$

Q.4. Consider a simple harmonic oscillator made up of mass attached to a spring. What will be the effect on the motion if the mass were to stay completely immersed in a liquid?

(a) The motion is simple harmonic but with a frequency which is lower compared to when it is in air

(b) The motion is always of the damped harmonic type

(c) The motion is always overdamped

(d) The motion is either of the damped harmonic type, or it is overdamped, depending on the liquid

Q.5. The kinetic energy T and the potential energy V of a spring-mass system executing a simple harmonic motion vary with time. At an instant of time, at which the product TV assumes its maximum value, let the displacement be a fraction f of the amplitude of oscillation. The absolute value of f is

(a) $1/\sqrt{3}$ (b) $1/\sqrt{2}$ (c) 1/3 (d) ½

Q.6. Three identical rings of radius a are placed on the xy-plane so that each ring touches the other two tangentially. Each ring, which may be considered to be infinitesimally thin, has a mass M. The centers of the three rings are equidistant from the z-axis-this common distance being $2a/\sqrt{3}$. What is the moment of inertia of this system about the z-axis?

(a) $3Ma^2/4$ (b) $3Ma^2/2$ (c) $6\,Ma^2$ (d) $7Ma$

Q.7. A particle of mass 1 kg is moving along the x-axis. There is no force on the particle except during the time interval between $t = 0\ s$ and $t = 5\ s$, when a force of the form $F(t) = 12\ t^2\ \text{N/s}^2$ acts on it. If the velocity of the particle at $t = 0$ is 500 m/s, its velocity at $t = 10\ s$ is

(a) 800 m/s (b) 1000 m/s (c) 1700 m/s (d)4500 m/s

Q.8. Raindrops hit the ground with a terminal velocity that is achieved due to a balance between the gravitational force and viscous drag force of air. Assume a raindrop to be a perfectly spherical water droplet of radius R. The momentum that it transfers when it hits the ground is proportional to

(a) R (b) R^2 (c) R^3 (d) R^5

Q.9. A wooden block B is at rest on the horizontal surface of a wooden platform P. The coefficient of static friction between these two is μ. The platform starts moving suddenly with a uniform acceleration a. The minimum value of a so that the block B starts moving with respect to the platform P is (g denotes the acceleration due to gravity)

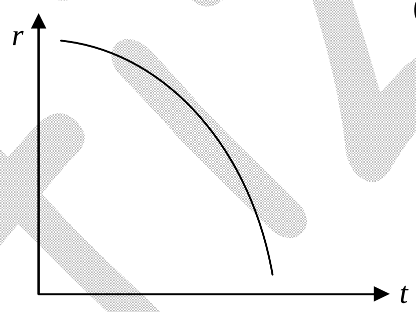
(a) $(1-\mu)g$ (b) $(1+\mu)g$ (c) μg (d) $(1-\mu^2)g$

Q.10. An ideal gas expands in a process in which its pressure depends on the volume as $P = P_0 e^{-\alpha V}$, where P_0 and α are two positive constants. If n is the number of moles in the gas, the maximum temperature that it will attain in this process is (R is the universal gas constant)

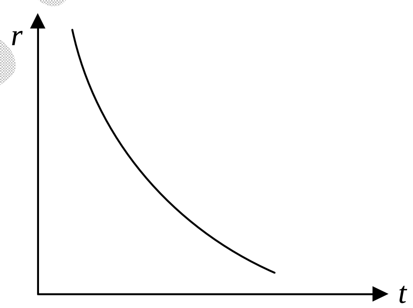
(a) $P_0 / e\alpha nR$ (b) $P_0 / \alpha n^3 R$ (c) $eP_0 / \alpha nR$ (d) $P_0^2 / \alpha nR$

Q.11. Consider the process of melting of a spherical ball of ice. Assume that the heat is being absorbed uniformly through the surface and that the rate of absorption is proportional to the instantaneous surface area. Which of the following graphs depicts the change of radius r (vertical axis) as a function of time t (horizontal axis)?

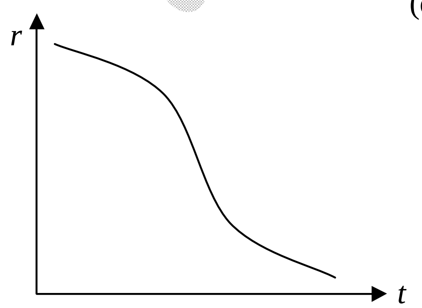
(a)



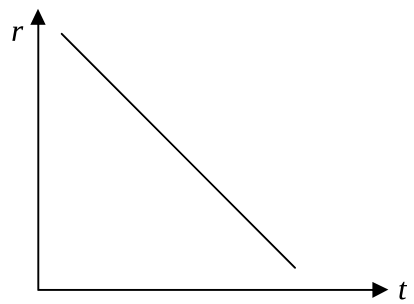
(b)



(c)



(d)



Q.12. An ideal gas undergoes an isothermal change of volume. The initial and final volumes are given to be 1.0 liter and 2.7 liters respectively. If in this process the entropy per mole changes from S_1 to S_2, the value of the difference $S_2 - S_1$ is nearest to (R is the universal gas constant)

(a) $+2.7\ R$ (b) $+1.7\ R$ (c) $+1.0\ R$ (d) $-1.0\ R$

Q.13. Let U, T, S and P denote, respectively, the internal energy, temperature, entropy and pressure of a thermodynamic system. Then a change ΔF in the free energy $F = U\text{-}TS$ measures

(a) the heat exchanged at constant pressure

(b) the work done by the system at constant entropy

(c) the work done on the system at constant temperature

(d) the heat exchanged at constant temperature

Q.14. Which of the following integrals depends only on the initial and final states of a thermodynamic system (i.e., independent of the path of transformation)?

(a) $\int pdV$ (b) $\int dQ$ (c) $\int \frac{dQ}{T}$ (d) $\int T^2 dS$

Q.15. Two cylindrical rods A and B of identical length and cross-section are joine end-to-end. The free ends of A and B are at 20 ^{o}C and 40 ^{o}C respectively. The thermal conductivity of A is three times that of B. In the steady state, the temperature at the junction of A and B is

(a) 25^{o}C (b) 30^{o}C (c) 35^{o}C (d) $\sqrt{800}\ ^{o}C$

Q.16. The amount of energy required to charge a metallic sphere of radius 2.0 m to a potential of 3000 V in air is

(a) 1×10^{-3} *joule* (b) 2×10^{-3} *joule*

(c) 3×10^{-3} *joule* (d) 4×10^{-3} *joule*

Q.17. In a region of space that does not contain any electric charge, the electrostatic potential satisfies Laplace's equation. Suppose that the potential in such a situation is given by the formula

$$V(x,y,z) = A\left(bx^2 + \frac{1}{2}y^2 - z^2\right)$$

where A and b are constants. Then the value of b

(a) can be arbitrary (b) must be zero

(c) must be ½ (d) must be 1

Q.18. Suppose that the electric field on the xy-plane is given by

$$\vec{E} = P\left[xy\hat{i} + \left(\frac{1}{2}x^2 + y^2\right)\hat{j}\right]$$

The magnitude of the difference in potential between the origin (0, 0) and the point (1, 2) is

(a) $\frac{5}{4}P$ (b) $\frac{11}{3}P$

(c) $\frac{7}{2}P$ (d) not unique, it depends on the path joining the two points

Q.19. Four electric charges of strength Q, Q, $-Q$ and $-Q$ are placed respectively at the points $(-b, 0)$ $(b, 0)$, $(0, -a)$ and $(0, a)$ on the xy-plane. At a distance d very far away from these charges ($d>>a, b$), the electric field will appear to be approximately that of

(a) a point charge

(b) a dipole

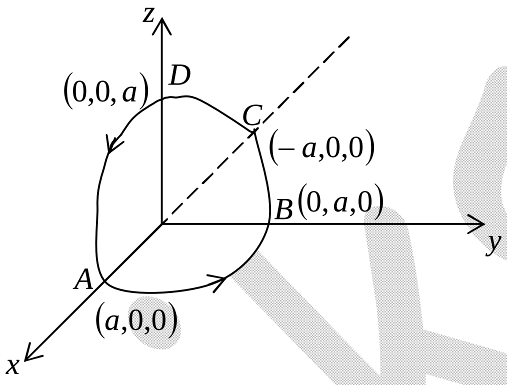
(c) a quadrupole

(d) a mixture of a dipole and a quadrupole

Q.20 The potential due to an electric dipole P placed at the origin is known to be form $\phi(\vec{r}) = \vec{p}.\vec{r}/r^3$. The total flux of the electric field through a spherical surface of radius R with the dipole at the centre is given by

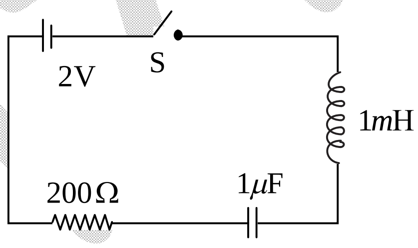
(a) zero (b) $-\frac{2\pi}{3}\frac{|\vec{p}|}{R}$ (c) $+\frac{2\pi}{3}\frac{|\vec{p}|}{R}$ (d) $+\frac{4\pi}{3}\frac{|\vec{p}|}{R}$

Q.21. In the following figure, *ABC* and *CDA* are two semicircular conducting wires of radius *a* with the origin as their common centre. The are *ABC* lies on the *xy*-plane whereas *CDA* lies on the *xz*-plane. They are joined as shown. This combined loop carries a current in the direction indicated in the figure below. Which of the following unit vectors denotes the direction of the resulting magnetic field vector at the origin?



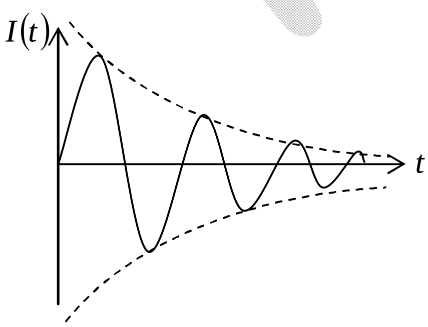
(a) (1, 0, 0) (b) $\left(0,\frac{1}{\sqrt{2}},\frac{1}{\sqrt{2}}\right)$ (c) $\left(\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}\right)$ (d) (-1, 0, 0)

Q.22. In the *LCR* circuit shown below, the switch *S* is suddenly closed at $t = 0$:

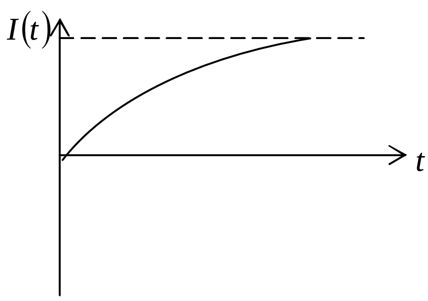


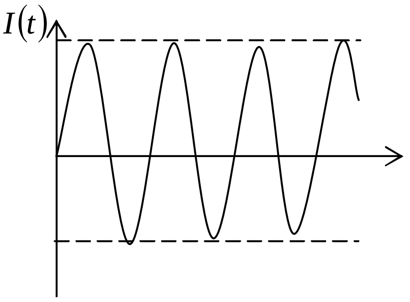
Which of the following diagrams represents the subsequent flow of current I(t) as a function of time t?

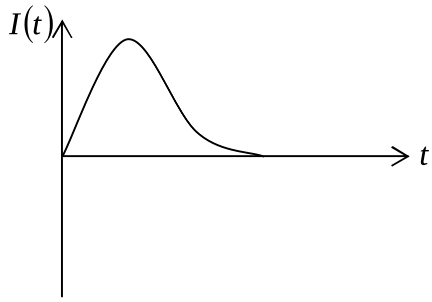
(a)



(b)



(c) 

(d) 

Q.23. The kinetic energy of a free relativistic particle is $E = mc^2$, where E and m are its total energy and rest mass respectively. Let v_0 be the speed at which the kinetic energy equals the rest mass energy of the particle. Then

(a) $v_0 = c/\sqrt{2}$ (b) $v_0 = \sqrt{3}c/2$

(c) $v_0 = c$ (d) $v_0 > c$ (so this can never happen)

Q.24. A galaxy is receding relative to us at a speed of 3000 km/s. It emits hydrogen redline of wavelength 6560 ´. When seen by us, the wavelength of this radiation will appear to be

(a) higher by approximately 65 ´ (b) lower by approximately 65 ´

(c) lower by approximately 6 ´ (d) higher by approximately 6 ´

Q.25. The angular frequency ω of deep water waves varies as the inverse square root of the wavelength λ, i.e, $\omega(\lambda) \propto 1/\sqrt{\lambda}$. Which of the following is the relation between its group velocity v_g and phase velocity v_p?

(a) $v_g = v_p/2$ (b) $v_g = v_p$ (c) $v_g = 2v_p$ (d) $v_g = \lambda v_p$

Q.26. Suppose you are using light of wavelength 6250 ´ in combination with a plane diffraction gritting which has 1600 lines per cm. The upper limit on the order of diffraction maxima that can possible be seen with this arrangement is closest to

(a) 25 (b) 18 (c) 10 (d) 2

Q.27. In a Young's double-slit experiment, the two slits are such that the dark fringes are perfectly dark (i.e., the intensity vanishes at these points). Now, we double the width of one of the two slits. What will be the effect on the interference pattern?

(a) The fringe pattern as well as the contrast between the dark and bright fringes pattern will change

(b) The fringe pattern will not change but the contrast between the dark and bright fringes will change

(c) The fringe pattern will change but the contrast between the dark and bright fringes will not change

(d) There will be no change in either the interference pattern or the contrast between the dark and bright fringes

Q.28. The wavelength of one of the visible lines in the spectrum of the hydrogen atom is approximately 6560 ´ . It is known that this corresponds to a transition between the states with the principal quantum numbers n = 2 and n = 3. What will be the frequency corresponding to the transition from the ground state to the first excited state?

(a) 4.56×10^{14} Hz (b) 2.47×10^{15} Hz

(c) 1.65×10^{15} Hz (d) 3.29×10^{15} Hz

Q.29. The intensity *vs.* wavelength distribution of a blackbody is found to have its maximum at the wavelength λ_{max} = 0.2 cm. Moreover, the total energy radiated J is measured to be 30 watts. If the temperature of the blackbody is now doubled, the new values of λ_{max} and J will be

(a) 0.1 cm and 120 watts (b) 0.1 cm and 240 watts

(c) 0.1 cm and 480 watts (d) 0.4 cm and 60 watts

Q.30. The radioactivity of a sample of Co^{55} decreases by 4% every hour (The decay product is not radioactive.) The half-life of Co^{55} is approximately

(a) 1 hour (b) 1 day (c) 1 month (d) 1 year