PAPER : DU 2019
PHYSICS-PH

INSTRUCTIONS:

(*i*) This test booklet contains 50 Objective type questions.

(*ii*) Each question carries **4 marks**. **1 mark** will be deducted for each incorrect answer. Only one box should be marked and the marking of more than one box will be treated as wrong answer.

OBJECTIVE QUESTIONS

1. In 2's complement representation, the number 10110101 represents the decimal number
(a) –53 (b) 75 (c) 93 (d) –75

2. Water has a constant heat capacity of 4.2 J/K/kg over the temperature range 0º–100º C. A kilogram of water, initially at 0ºC is brought in contact with a heat reservoir at 100 ºC. When the water comes to equilibrium, what is the total change in entropy of the universe?
(a) 2437.8 J/K (b) 1310.8 J/K (c) 184.8 J/K (d) 369.2 J/K

3. The Sun is approximately 25, 000 light years away from the centre of the Milky way and moves around it, in an approximately circular path, in roughly 170 million years. Give that sunlight takes approximately 8 min to reach the Earth, what is the ratio of the masses of the galaxy and the Sun?
(a) 1.5×10^{12} (b) 1.5×10^{11} (c) 5×10^{11} (d) 5×10^{10}

4. An AND gate has two inputs A and B and one inhibit input S. The output is 1 if
(a) A = 1, B = 1, S = 1 (b) A = 1, B = 1, S = 0
(c) A = 1, B = 0, S = 0 (d) A = 1, B = 0, S = 1

5. A wire carrying a current 2A is bent into the shape of a two semi circles, one with a radius 1m and the other with radius 2m. The two semi circles are connected at their ends that is along the two radii. The magnetic field at the centre of the semi-circle is
(a) $\pi\times10^{-7}$ T
(b) cannot be determined from the information provided above.
(c) 16×10^{-7} T
(d) 2×10^{-7} T

6. Under ideal conditions, the electric and magnetic fields inside a superconductor are zero. Which of the following must be true just outside the surface of the superconductor?
(a) B = 0 (b) B is perpendicular to the surface
(c) B is tangential to the surface (d) The magnetic flux is quantized

7. Under certain conditions, a beam of electrons impinging on a crystal surface will diffract and a scattering pattern of the beam can be obtained. What is the approximate kinetic energy of the electrons needed in order to the see the pattern? (Assume the lattice spacing of the crystal to be 0.4 nm)
(a) 100 eV (b) 1 eV (c) 0.1 eV (d) 10 eV

8. Fermat's principle of ray optics states, "A ray oflight follows the path between two points which requires the least time." This principle can beused to derive which of the following?
(I) Snell's law of refraction
(II) The law of reflection
(III) Rayleigh's criterion for resolution
(a) I and II (b) I only (c) I, II and III (d) II only

9. For a mole of ideal gas at T = 35 ºC, what is the work done for an isothermal expansion from a volume V_0 to $10V_0$?
(a) 10^4 J (b) 10^3 J (c) 3×10^3 J (d) 6×10^3 J

10. A single photon of energy 100 MeV decays into an electron and a positron. Which of the following statements is true?
(a) It does not violate any of the above conservation laws.
(b) This process violates energy momentum conservation.
(c) This process violates angular momentum conservation
(d) This process violates lepton number conservation.

11. An electric field *E* can pull an electron out of a Helium atom in the same time that the electron takes to go around the nucleus once. Then *E* is
(a) 2×10^{12} V/m (b) 5×10^{11} V/m (c) 10^{12} V/m (d) 10^{13} V/m

12. A material has a heat capacity at constant volume C that is unchanging over a wide temperature range. Two identical bodies made of this material, at initial temperature T and 9T, respectively, are used to drive a heat engine. The maximum amount of work that can be obtained from this engine is
(a) 9 CT (b) 4 CT (c) 8 CT (d) 3 CT

13. An electrical device operates on 9V and has a resistance of 21Ω. It is connected to a power supply of 120 V output through a transformer. The current in the primary of the transformer is
(a) 0.032 A (b) Cannot be determined from the information supplied.
(c) 0.23 A (d) 2.32 A

14. The frequency of oscillation of an LC circuit is ω. The plates of the parallel plate capacitor are pulled apart to twice the original distance and a dielectric constant *k* is inserted. The frequency of oscillation for the new configuration is
(a) $\omega\sqrt{2/k}$ (b) $k\omega/2$ (c) $2\omega/k$ (d) $\omega\sqrt{2/k}$

15. One mole of a monoatomic perfect gas is initially at a constant temperature T_0. It expands from a volume V_0 to $2V_0$ under constant pressure. The heat absorbed by the gas is
(a) $\frac{3}{2}RT_0$ (b) $\frac{5}{2}RT_0$ (c) $2RT_0$ (d) RT_0

16. A scalar meson decays into three pseudoscalar mesons. The decay happens through
(a) strong interaction (b) weak interaction
(c) gravitational interaction (d) electromagnetic interaction

17. An ideal monoatomic gas, initially at T = 20 ºC, expands adiabatically from a volume V_0 to $5V_0$. What is the final temperature
(a) –33 ºC (b) –113 ºC (c) –20 ºC (d) –173 ºC

18. Consider three identical, ideal capacitors. The first capacitor is charged to a voltage V and then disconnected from the battery. The other two capacitors, initially uncharged and connected in series, are then connected across the first. What is the final voltage across the first capacitor?
(a) V/3 (b) V (c) 2V/5 (d) 2V/3

19. Two rockets approach a planet from opposite directions with speed $\pm\frac{c}{2}$ with respect to the planet. The proper length of the each rocket is *L*. How long does each rocket appear to the other rocket?
(a) $\frac{\sqrt{3}}{5}$ (b) $\frac{3}{5}$ (c) $\frac{\sqrt{3}}{2}$ (d) $\frac{1}{3}$

20. Consider the (2π)-periodic function $f(x)$ defined by

$$f(x)=\begin{cases} x(\pi-x), & x\in[0,\pi] \\ x(x-\pi), & x\in[-\pi,0] \end{cases}$$

Which of the following is true?

(a) $f(x)=\frac{4}{\pi}\sum_{k=0}^{\infty}\frac{\sin([2k+1]x)}{(2k+1)^2}+\frac{4}{\pi}\sum_{k=0}^{\infty}\frac{\cos([2k+1]x)}{k^2}$

(b) $f(x)=\frac{8}{\pi}\sum_{k=0}^{\infty}\frac{\sin(kx)}{k^3}$

(c) $f(x)=\frac{8}{\pi}\sum_{k=0}^{\infty}\frac{\sin[(2k+1)x]}{(2k+1)^3}$

(d) $f(x)=\frac{4}{\pi}\sum_{k=0}^{\infty}\frac{\sin(kx)}{k^2}+\frac{4}{\pi}\sum_{k=0}^{4}\frac{\cos(kx)}{k^2}$

21. Consider a rotating spherical planet such that the effective gravitational attraction at the equator is only 75% of that at the pole. If the linear velocity of a point on the equator is v_0, what is the escape velocity for a polar particle?

(a) $v_0\sqrt{2}$ (b) $2v_0$ (c) $v_0\sqrt{8}$ (d) $4v_0$

22. If the Fourier transfor of $e^{-\alpha x^2}$ is $e^{-k^2/4a}/\sqrt{a}$, then the Fourier transform of $f(x)=x^2\, e^{-\alpha x^2}$ is

(a) $F(k)=\frac{k^2-2a}{4a^{5/2}}e^{-k^2/4a}$ (b) $F(k)=\frac{-k^2+2a}{4a^{5/2}}e^{-k^2/4a}$

(c) $F(k)=\frac{k^2+2a}{4a^{3/2}}e^{-k^2/4a}$ (d) $F(k)=\frac{k^2+2a}{4a^{3/2}}e^{-k^2/4a}$

23. Let C be the unit circle, travelled counterclockwise. Evaluate

$$\oint_C\left[\left(e^{-x^2}-y^3\right)dx+x^3dy\right]$$

(a) 2π (b) $\frac{3\pi}{2}$ (c) $\frac{\sqrt{\pi}}{2}+2$ (d) $\frac{\sqrt{\pi}}{2}-2$

24. A body of mass m moving with a speed v collides with an identical body at rest and sticks with it. The mass M and momentum P of the final clump of matter is $\left(\gamma=\frac{1}{\sqrt{1-v^2/c^2}}\right)$

(a) $M=2m,\ P=2\gamma\, mv$ (b) $M=m\gamma,\ P=\gamma\, mv$

(c) $M=m\sqrt{\gamma},\ P=m\,v/2$ (d) $M=m\sqrt{(2(1+\gamma))},\ P=\gamma\, m\, v$

25. Using Boolean algebra, simplifying the expression,

$$\overline{\overline{(a\cdot b\cdot \overline{c})}+\overline{(\overline{c}\cdot d)}}$$

yields

(a) $a\cdot b+\overline{c}\cdot d$ (b) $a\cdot b\cdot d$ (c) $a\cdot b+d$ (d) $a\cdot b\cdot \overline{c}\cdot d$

26. A large and spherical soap film of thickness *d* has a refractive index 4/3. A narrow beam of yellow light $(\lambda \approx 6400\text{Å})$ is incident on the film at an angle of 30º. What is the value of *d* for which a constructive second order interference would occur for the reflected wave?

(a) 4800 Å (b) 5500Å (c) 5200Å (d) 3900Å

27. The integral,

$$\oint_{-\infty}^{\infty}\frac{d\delta(y)}{dy}\sin y dy$$

is,

(a) π (b) 0 (c) +1 (d) –1

28. A cylinder of length *L* is made up of an inner core of steel of radius *r* and an outer sheath of copper of thickness *r*. The resistivities of steel and copper are ρ_1 and ρ_2 respectively. The total resistance of the cylinder is

(a) $\frac{(3\rho_1+\rho_2)L}{\pi r^2}$ (b) $\frac{\rho_1\rho_2 L}{\pi r^2(\rho_1+\rho_2)}$ (c) $\frac{(2\rho_1+\rho_2)L}{\pi r^2}$ (d) $\frac{\rho_1\rho_2 L}{\pi r^2(3\rho_1+\rho_2)}$

29. A particle confined to move in $0\le x\le\infty$ is described by the wave function $\psi(x)=e^{-x/2}$. Calculate the probability of finding the particle between *x* = 0 and *x* = ln(2)

(a) 2 (b) 1/2 (c) 1 (d) 3/2

30. Let *V* be the region in R^3 determined by the inequalities $x^2+y^2\le 1$ and $0\le z\le 4-x^2-y^2$. Determine

$$\iiint_V (x^2+y^2)d^3r$$

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

31. Let $\psi_0(x)$ and $\psi_1(x)$ be the wave functions corresponding to the ground and the first excited states of a one dimensional harmonic oscillator respectively. Consider the normalized state $\phi(x)=\alpha\psi_0(x)+\beta\psi_1(x)$ where α and β are real numbers. The values of α and β for which, $\langle x\rangle$, the average value of the position is a minimumm are

(a) $\alpha=-\beta=\frac{1}{\sqrt{2}}$ (b) $\alpha=\beta=\frac{1}{\sqrt{2}}$

(c) $\alpha=\frac{1}{\sqrt{3}}$ and $\beta=-\sqrt{2/3}$ (d) $\alpha=\frac{1}{\sqrt{3}}$ and $\beta=\sqrt{2/3}$

32. A particle confined in one dimensional, due to potential $V(x)$, has the following wave function:

$$\psi(x) = \left(\frac{x}{a}\right)^n \exp\left(-\frac{x}{a}\right)$$

where 'a' is a constant. If $V(x) \to 0$ as $x \to \infty$, then $V(x)$ is given by

(a) $\frac{\hbar^2}{2m}\left[\frac{n(n+1)}{x^2} - \frac{n}{ax}\right]$ (b) $\frac{\hbar^2}{2m}\left[\frac{n(n-1)}{x^2} + \frac{n+1}{ax}\right]$

(c) $\frac{\hbar^2}{2m}\left[\frac{n(n+1)}{x^2} + \frac{n-1}{ax}\right]$ (d) $\frac{\hbar^2}{2m}\left[\frac{n(n-1)}{x^2} - \frac{2n}{ax}\right]$

33. Let S be the surface defined by the parametric equations $x = 4\alpha^2 + \beta, y = \sin\beta, z = \cos\alpha$. The equation for the plane tangent to S at the point $(\pi^2, 0, 0)$ is given by

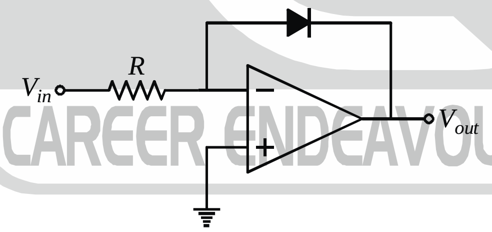
(a) $x + y - 2\pi z = \pi^2$ (b) $4x + y - z = 4\pi^2$ (c) $4x - y + z = 4\pi^2$ (d) $x - y + 4\pi z = \pi^2$

34. For waves in a certain medium, the group velocity is v_g while the phase velocity is v_p. Which of the following is necessarily true ? (c is the velocity of light).

(a) $v_p < c$ and v_g can be anything (b) $v_g < c$ and v_p can be anything

(c) $v_p < v_g < c$ (d) $v_g < c$ and $v_g v_p < c^2$

35. The circuit of following figure uses an ideal op-amp for small positive values of V_{in}. The circuit works as:



(a) an exponential amplifier (b) a half wave rectifier
(c) a logarithmic amplifier (d) a differentiator

36. For $-1 \le x \le +1$, the sum $\sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{2n+1}$ equals

(a) $\sin^2 x$ (b) $\frac{x \exp x}{\pi}$ (c) $\cos^2 x$ (d) $\tan^{-1} x$

37. A narrow light beam of wavelength λ is travelling along the x-axis, when it is faced by a barrier with narrow slits at $y = 0, \pm d$ (and all at $x = 0$). There is a vertical screen at $x = D \gg d$. What is the angle θ that the central bright spot and the next-nearest dark spot subtent at the central slit $[(x, y) = (0, 0)]$

(a) $\theta = \sin^{-1}\frac{\lambda}{2d}$ (b) $\theta = \sin^{-1}\frac{2\lambda}{d}$ (c) $\theta = \sin^{-1}\frac{3\lambda}{d}$ (d) $\theta = \sin^{-1}\frac{\lambda}{d}$

38. A stream of water flowing with a constant speed v manages to move some pebbles. If the density of water is ρ and the acceleration due to gravity is g, then the mass of the heaviest pebble that it can move is (here, A is a constant)

(a) $\frac{A\rho v^5}{g^2}$ (b) $\frac{A\rho v^6}{g^3}$ (c) $\frac{A\rho^2 v^3}{g^4}$ (d) $\frac{A\rho^2 v^8}{g^4}$

39. The expectation value of momentum of a particle whose wave function is:

$\Psi(x) = A\exp\left(-\frac{x^2}{2a^2} + ikx\right)$ is given as:

(a) $\frac{i\hbar}{a^2}$ (b) $\hbar k$ (c) 0 (d) $\frac{\hbar k}{a}$

40. Two particles of mass m each are connected by a massless spring of length ℓ and spring constant k. The system is lying (in the relaxed state) on a frictionless horizontal table. A very short impulse P is applied to the first mass (along the axis of the system) at $t = 0$. When would the *second* mass first come to rest?

(a) $t = \pi\frac{\sqrt{m}}{2k}$ (b) $t = 2\pi\frac{\sqrt{2m}}{k}$ (c) $t = \pi\frac{\sqrt{m}}{k}$ (d) $t = \pi\frac{\sqrt{2m}}{k}$

41. Consider a particle whose normalized wave function is:

$$\psi(x) = \begin{cases} 2\alpha\sqrt{\alpha}\,xe^{-\alpha x} & ; \quad x > 0 \\ 0 & ; \quad x < 0 \end{cases}$$

For what value of x does $P(x) = |\psi(x)|^2$ peak ?

(a) $x = 0$ (b) None of these (c) $x = \frac{1}{\alpha}$ (d) $x = 1$

42. A self-contained machine has, as its input, two equal steady stream of a fluid at temperature T_1 and $4T_1$ respectively. The only output is a single high-speed jet of the same fluid at temperature T. The heat capacity per unit mass of the fluid is C (and is independent of the temperature). What is the maximum possible speed of the jet ?

(a) $\sqrt{CT_1}$ (b) $\sqrt{\frac{CT_1}{4}}$ (c) $\sqrt{2CT_1}$ (d) $\sqrt{4CT_1}$

43. A particle of mass M decays at rest into two particles. One particle has mass m and the other particle is massless. The momentum of the massless particle is

(a) $\frac{M^2 - 2m^2}{4M}c$ (b) $\frac{M^2 - m^2}{2M}c$ (c) $\frac{M^2 + m^2}{2M}c$ (d) $\frac{M^2 - m^2}{4M}c$

44. The distribution of weights of 100 students in a class follows normal distribution with a mean of 58 kg and a standard deviation of 25 kg. How many students have weights in the range 53 – 63 kg ?

(a) 32 (b) 68 (c) 99 (d) 88

45. A gas cell with an optical path length of 10 cm is placed in one arm of a Michelson interferometer. If the light source for the interferometer is a laser with a wavelength of 632.2 nm, then 100 fringes are counted as the gas cell is evacuated. What is the index of refraction of the original gas ?

(a) 0.99968 (b) 1.00063 (c) 1.00032 (d) 1.00016

46. A child of mass 3m sits on a swing, the basis of which has mass m, while the rope (of length l) has a negligible mass. An older child pulls back the swing (with the child) until the rope makes an angle of half-a-radian with the vertical, and, then, pushes with a force mg along the arc of a circle untill the rope is exactly vertical, and releases it. If the rope was always taut, for how long did the child push ?

(a) $\pi\frac{\sqrt{2\ell}}{3g}$ (b) $\frac{\sqrt{2\ell}}{3g}$ (c) $\frac{\pi}{3}\frac{\sqrt{\ell}}{g}$ (d) $\frac{\sqrt{\ell}}{g}$

47. X-rays undergo Bragg reflection from a simple cubic crystal, with a density known with an accuracy of one percent. If the angle of the reflected X-ray with the crystal plane is 6º and is measured with an accuracy of 3 minutes of arc, what is the relative error in the measurement of wavelength?

(a) 5.6×10^{-3} (b) 1.1×10^{-2} (c) 3.3×10^{-3} (d) 6.5×10^{-3}

48. An uncharged spin-half particle of mass m is confined to move on a circular wire of radius a. The particle has magnetic moment μ. A magnetic field B is applied perpendicular to the plane of the wire. Then the energy eigenvalues of the particle are (here n is an integer)

(a) $\frac{\hbar^2 n^2}{4ma^2} \pm 2\mu B$ (b) $\frac{\hbar^2 n^2}{4ma^2} \pm \mu B$ (c) $\frac{\hbar^2 n^2}{2ma^2} \pm 2\mu B$ (d) $\frac{\hbar^2 n^2}{2ma^2} \pm \mu B$

49. A photon of initial wavelength 0.4 Å suffers two successive collision with two electrons. The deflection in the first collision is 90º and in the second collision is 60º. The final wavelength of the photon is

(a) 0.024 Å (b) 0.436 Å (c) 0.4 Å (d) 0.012 Å

50. A sample of a certain element is placed in a 0.300-T magnetic field. How far apart are the Zeeman components of the 450-nm spectral line of this element ?

(a) 0.000283 nm (b) 2.83 nm (c) 0.00283 nm (d) 0.23 nm

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