IIT JAM 2019 Physics (PH) Question Paper

Time Allowed :3 Hours	**Maximum Marks :**100	**Total questions :**60

General Instructions

General Instructions:

i) All questions are compulsory. Marks allotted to each question are indicated in the margin.

ii) Answers must be precise and to the point.

iii) In numerical questions, all steps of calculation should be shown clearly.

iv) Use of non-programmable scientific calculators is permitted.

v) Wherever necessary, write balanced chemical equations with proper symbols and units.

vi) Rough work should be done only in the space provided in the question paper.

1. The function $f(x) = \frac{8x}{x^2+9}$ is continuous everywhere except at

(A) $x = 0$

(B) $x = \pm 9$

(C) $x = \pm 9i$

(D) $x = \pm 3i$

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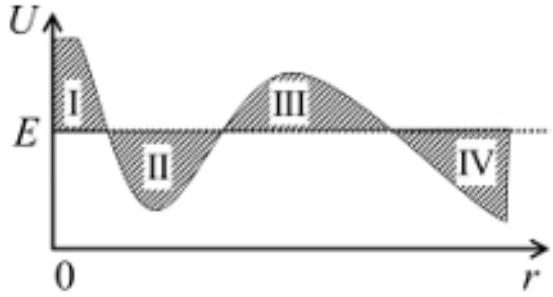
2. A classical particle has total energy E. The plot of potential energy $U(r)$ as a function of distance r from the centre of force located at $r = 0$ is shown in the figure. Which of the regions are forbidden for the particle?



(A) I and II

(B) II and IV

(C) I and IV

(D) I and III

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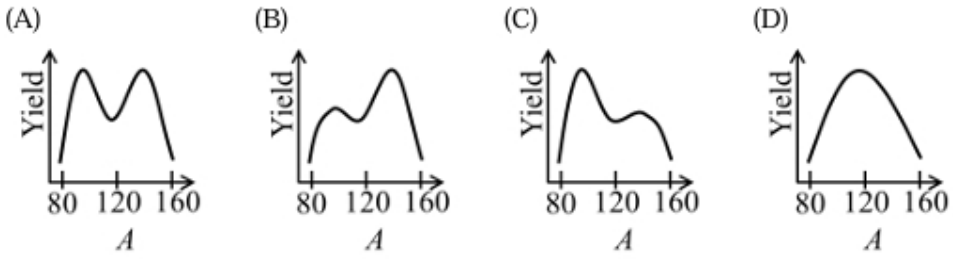
3. In the thermal neutron induced fission of ^{235}U, the distribution of relative number of the observed fission fragments (Yield) versus mass number (A) is given by



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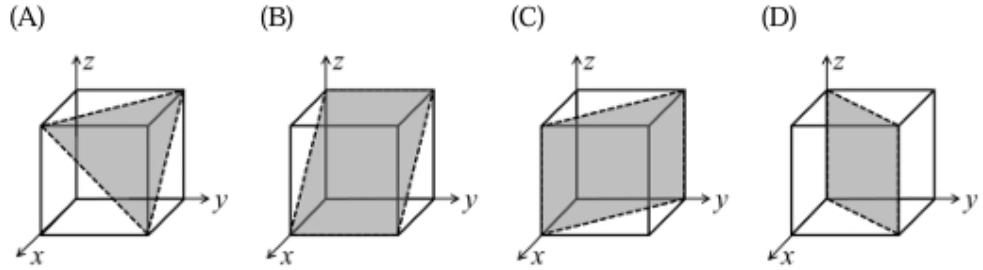
4. Which one of the following crystallographic planes represent (101) **Miller indices of a cubic unit cell?**



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5. The Fermi-Dirac distribution function $[n(\epsilon)]$ **is**

$$n(\epsilon) = \frac{1}{e^{(\epsilon-\epsilon_F)/k_BT} + 1}$$

where k_B is the Boltzmann constant, T is the temperature and ϵ_F is the Fermi energy.

(A) $n(\epsilon) = \frac{1}{e^{(\epsilon-\epsilon_F)}/k_BT-1}$
(B) $n(\epsilon) = \frac{1}{e^{(\epsilon-\epsilon_F)}/k_BT+1}$
(C) $n(\epsilon) = \frac{1}{e^{(\epsilon-\epsilon_F)}/k_BT+1}$
(D) $n(\epsilon) = \frac{1}{e^{(\epsilon-\epsilon_F)/k_BT+1}}$

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6. If $\phi(x, y, z)$ **is a scalar function which satisfies the Laplace equation, then the gradient of** ϕ **is**

(A) Solenoidal and irrotational
(B) Solenoidal but not irrotational
(C) Irrotational but not solenoidal
(D) Neither solenoidal nor irrotational

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7. In a heat engine based on the Carnot cycle, heat is added to the working substance at constant

(A) Entropy

(B) Pressure

(C) Temperature

(D) Volume

---

8. Isothermal compressibility is given by

(A) $\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$

(B) $\frac{1}{P}\left(\frac{\partial P}{\partial V}\right)_T$

(C) $-\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$

(D) $-\frac{1}{P}\left(\frac{\partial P}{\partial V}\right)_T$

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9. For using a transistor as an amplifier, choose the correct option regarding the resistances of base-emitter (R_{BE}) and base-collector (R_{BC}) junctions.

(A) Both R_{BE} and R_{BC} are very low

(B) Very low R_{BE} and very high R_{BC}

(C) Very high R_{BE} and very low R_{BC}

(D) Both R_{BE} and R_{BC} are very high

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10. A unit vector perpendicular to the plane containing $\vec{A} = i + j - 2k$ and $\vec{B} = 2i - j + k$ is

(A) $\frac{1}{\sqrt{26}}(-i + 3j - 4k)$

(B) $\frac{1}{\sqrt{19}}(-i + 3j - 3k)$

(C) $\frac{1}{\sqrt{35}}(-i + 5j - 3k)$

(D) $\frac{1}{\sqrt{35}}(i - j - 3k)$

---

11. A thin lens of refractive index $\frac{3}{2}$ is kept inside a liquid of refractive index $\frac{4}{3}$. If the focal length of the lens in air is 10 cm, then its focal length inside the liquid is

(A) 10 cm

(B) 30 cm

(C) 40 cm

(D) 50 cm

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12. The eigenvalues of

$$\begin{pmatrix} 3 & i & 0 \\ -i & 3 & 0 \\ 0 & 0 & 6 \end{pmatrix}$$

are

(A) 2, 4 and 6

(B) 2i, 4i and 6

(C) 2i, 4 and 8

(D) 0, 4 and 8

---

13. For a quantum particle confined inside a cubic box of side L, the ground state energy is given by E_0. The energy of the first excited state is

(A) $2E_0$

(B) $\sqrt{2}E_0$

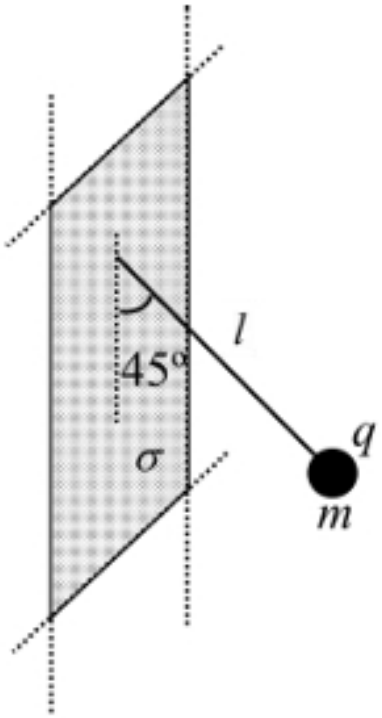
(C) $3E_0$

(D) $6E_0$

---

14. A small spherical ball having charge q and mass m, is tied to a thin massless non-conducting string of length l. The other end of the string is fixed to an infinitely extended thin non-conducting sheet with uniform surface charge density σ. Under equilibrium, the string makes an angle of 45° with the sheet as shown in the figure. Then σ is given by

g is the acceleration due to gravity and ϵ_0 is the permittivity of free space.



(A) $\frac{mg\epsilon_0}{q}$

(B) $\sqrt{2}\frac{mg\epsilon_0}{q}$

(C) $2\frac{mg\epsilon_0}{q}$

(D) $\frac{mg\epsilon_0}{q\sqrt{2}}$

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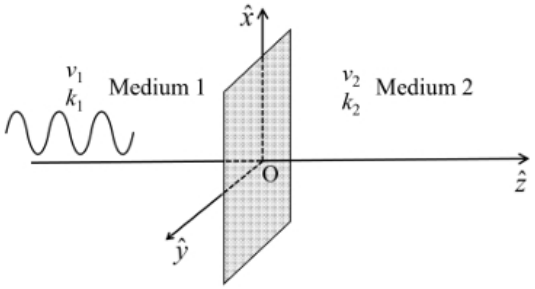
15. Consider the normal incidence of a plane electromagnetic wave with electric field given by

$$\vec{E} = E_0 \exp\left[i(k_1 z - \omega t)\right]\hat{x}$$

over an interface at $z = 0$ separating two media [wave velocities v_1 and v_2 (with $v_2 > v_1$) and wave vectors k_1 and k_2, respectively], as shown in the figure. The magnetic field vector of the reflected wave is

(ω is the angular frequency)



(A) $\frac{E_0}{v_1} \exp[i(k_1 z - \omega t)]\hat{y}$

(B) $\frac{E_0}{v_1} \exp[i(-k_1 z - \omega t)]\hat{y}$

(C) $-\frac{E_0}{v_1} \exp[i(-k_1 z - \omega t)]\hat{y}$

(D) $-\frac{E_0}{v_1} \exp[i(k_1 z - \omega t)]\hat{y}$

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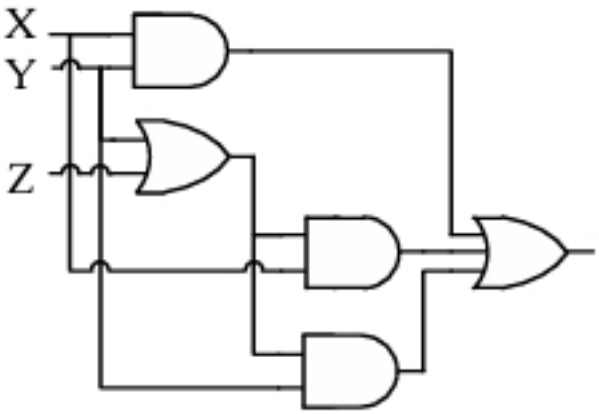
16. The output of the following logic circuit can be simplified to

(Logic circuit diagram provided)



(A) $X + YZ$

(B) $Y + XZ$

(C) XYZ

(D) $X + Y + Z$

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17. A red star having radius r_R at a temperature T_R and a white star having radius r_W at a temperature T_W, radiate the same total power. If these stars radiate as perfect black bodies, then

(A) $r_R > r_W$ and $T_R > T_W$

(B) $r_R < r_W$ and $T_R > T_W$

(C) $r_R > r_W$ and $T_R < T_W$

(D) $r_R < r_W$ and $T_R < T_W$

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18. The mass per unit length of a rod (length 2 m) varies as $\rho = 3$ kg/m. The moment of inertia (in kg m^2) of the rod about a perpendicular-axis passing through the tip of the rod (at $x = 0$) is

(A) 10

(B) 12

(C) 14

(D) 16

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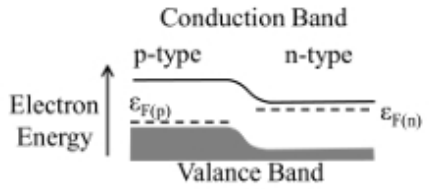
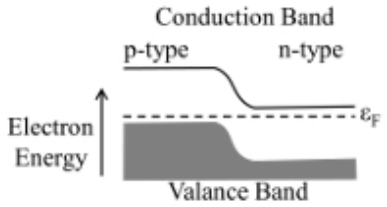
19. For a forward biased p-n junction diode, which one of the following energy-band diagrams is correct? (ϵ_F is the Fermi energy)

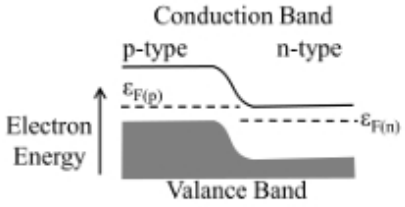
(A)



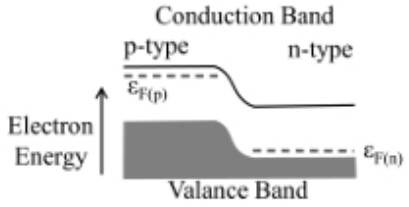
(B)



(C)



(D)



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20. The amount of work done to increase the speed of an electron from $v = c/3$ to $v = 2c/3$ is

$$c = 3 \times 10^8 \text{ m/s}, \text{ rest mass of electron is } 0.511 \text{ MeV}$$

(A) 56.50 keV

(B) 143.58 keV

(C) 168.20 keV

(D) 511.00 keV

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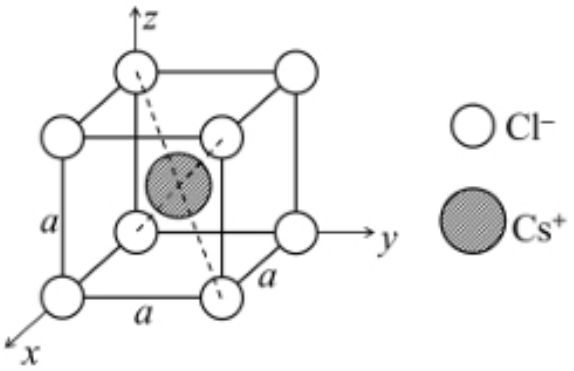
21. The location of Cs^+ and Cl^- ions inside the unit cell of CsCl crystal is shown in the figure. The Bravais lattice of CsCl is



(A) simple cubic

(B) body centered orthorhombic

(C) face centered cubic

(D) base centered orthorhombic

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22. A γ-ray photon emitted from a ^{137}Cs source collides with an electron at rest. If the Compton shift of the photon is 3.25×10^{-13} m, then the scattering angle is closest to (Planck's constant $h = 6.626 \times 10^{-34}$ J s, electron mass $m_e = 9.109 \times 10^{-31}$ kg and velocity of light in free space $c = 3 \times 10^8$ m/s)

(A) 45°

(B) 60°

(C) 30°

(D) 90°

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23. During free expansion of an ideal gas under adiabatic condition, the internal energy of the gas

(A) Decreases

(B) Initially decreases and then increases

(C) Increases

(D) Remains constant

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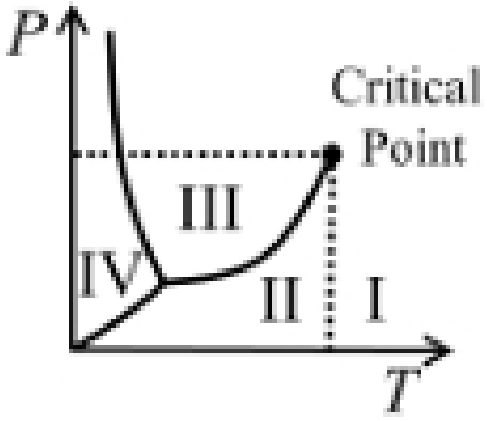
24. In the given phase diagram for a pure substance, regions I, II, III, IV, respectively represent



(A) Vapor, Gas, Solid, Liquid

(B) Gas, Vapor, Liquid, Solid

(C) Gas, Liquid, Vapor, Solid

(D) Vapor, Gas, Liquid, Solid

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25. Light of wavelength λ (in free space) propagates through a dispersive medium with refractive index $n(\lambda) = 1.5 + 0.6\lambda$. The group velocity of a wave traveling inside this medium in units of 10^8 m/s is

(A) 1.5

(B) 2.0

(C) 3.0

(D) 4.0

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26. The maximum number of intensity minima that can be observed in the Fraunhofer diffraction pattern of a single slit (width 10 μm) illuminated by a laser beam (wavelength 0.630 μm) will be

(A) 4

(B) 7

(C) 12

(D) 15

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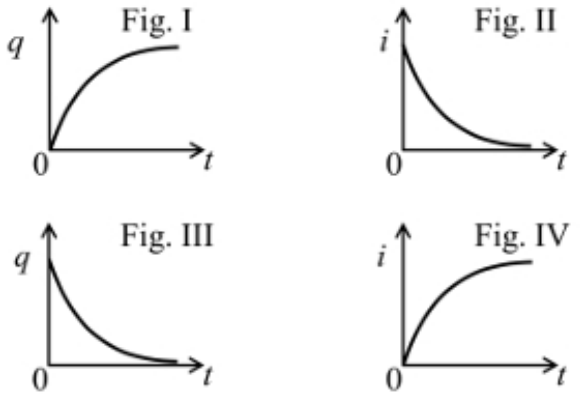
27. During the charging of a capacitor C in a series RC circuit, the typical variations in the magnitude of the charge $q(t)$ deposited on one of the capacitor plates, and the current $i(t)$ in the circuit, respectively are best represented by



(A) Fig. I and Fig. II

(B) Fig. I and Fig. IV

(C) Fig. III and Fig. II

(D) Fig. III and Fig. IV

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28. Which one of the following is an impossible magnetic field $\vec{B}$?

(A) $\vec{B} = 3z^2\hat{x} - 2x^2\hat{z}$

(B) $\vec{B} = -2xy\hat{x} + x^2y\hat{y} + \left(\frac{2yz-x^2}{3}\right)\hat{z}$

(C) $\vec{B} = (xz + 4y)\hat{x} - xy^3\hat{y} + \left(\frac{x^2z-z^2}{2}\right)\hat{z}$

(D) $\vec{B} = -6xz\hat{x} + 3y^2\hat{y}$

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29. If the motion of a particle is described by $x = 5\cos(8\pi t), y = 5\sin(8\pi t)$ and $z = 5t$, then the trajectory of the particle is

(A) Circular

(B) Elliptical

(C) Helical

(D) Spiral

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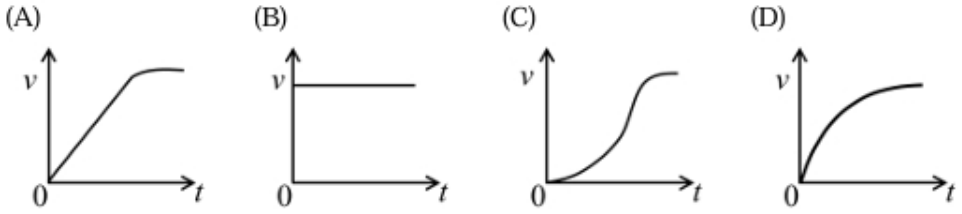
30. A ball of mass m is falling freely under gravity through a viscous medium in which the drag force is proportional to the instantaneous velocity v of the ball. Neglecting the buoyancy force of the medium, which one of the following figures best describes the variation of v as a function of time t?



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31. The relation between the nuclear radius R and the mass number A, given by $R = 1.2A^{1/3}$ fm, implies that

(A) The central density of nuclei is independent of A

(B) The volume energy per nucleon is a constant

(C) The attractive part of the nuclear force has a long range

(D) The nuclear force is charge dependent

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32. Consider an object moving with a velocity $\vec{v}$ in a frame which rotates with a constant angular velocity $\vec{\omega}$. The Coriolis force experienced by the object is

(A) along $\vec{v}$

(B) along $\vec{\omega}$

(C) perpendicular to both $\vec{v}$ and $\vec{\omega}$

(D) always directed towards the axis of rotation

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33. The gradient of a scalar field $S(x, y, z)$ has the following characteristic(s).

(A) Line integral of a gradient is path-independent

(B) Closed line integral of a gradient is zero

(C) Gradient of S is a measure of the maximum rate of change in the field S

(D) Gradient of S is a scalar quantity

---

34. A thermodynamic system is described by the P, V, T coordinates. Choose the valid expression(s) for the system.

(A) $\left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial P}{\partial T}\right)_V$

(B) $\left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial P}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$

(C) $\left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial T}{\partial P}\right)_V = \left(\frac{\partial V}{\partial P}\right)_T$

(D) $\left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial T}{\partial P}\right)_V = \left(\frac{\partial V}{\partial P}\right)_T$

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35. Which of the following statement(s) is/are true?

(A) Newton's laws of motion and Maxwell's equations are both invariant under Lorentz transformations.

(B) Newton's laws of motion and Maxwell's equations are both invariant under Galilean transformations.
(C) Newton's laws of motion are invariant under Galilean transformations and Maxwell's equations are invariant under Lorentz transformations.
(D) Newton's laws of motion are invariant under Lorentz transformations and Maxwell's equations are invariant under Galilean transformations.

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36. For an underdamped harmonic oscillator with velocity $v(t)$,

(A) Rate of energy dissipation varies linearly with $v(t)$
(B) Rate of energy dissipation varies as square of $v(t)$
(C) The reduction in the oscillator frequency, compared to the undamped case, is independent of $v(t)$
(D) For weak damping, the amplitude decays exponentially to zero

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37. Out of the following statements, choose the correct option(s) about a perfect conductor.

(A) The conductor has an equipotential surface
(B) Net charge, if any, resides only on the surface of conductor
(C) Electric field cannot exist inside the conductor
(D) Just outside the conductor, the electric field is always perpendicular to its surface

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38. In the X-ray diffraction pattern recorded for a simple cubic solid (lattice parameter $a = 1$ Å) using X rays of wavelength 1 Å, the first order diffraction peak(s) would appear for the

(A) (100) planes
(B) (112) planes
(C) (210) planes

(D) (220) planes

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39. Consider a classical particle subjected to an attractive inverse-square force field. The total energy of the particle is E and the eccentricity is ϵ. The particle will follow a parabolic orbit if

(A) $E > 0$ and $\epsilon = 1$

(B) $E < 0$ and $\epsilon < 1$

(C) $E = 0$ and $\epsilon = 1$

(D) $E < 0$ and $\epsilon = 1$

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40. An atomic nucleus X with half-life T_X decays to a nucleus Y, which has half-life T_Y. The condition(s) for secular equilibrium is/are

(A) $T_X \approx T_Y$

(B) $T_X < T_Y$

(C) $T_X \ll T_Y$

(D) $T_X \gg T_Y$

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41. In a typical human body, the amount of radioactive ^{40}K is 3.24×10^{-5} percent of its mass. The activity due to ^{40}K in a human body of mass 70 kg is ..... kBq.

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42. Sodium (Na) exhibits body-centered-cubic (BCC) crystal structure with atomic radius 0.186 nm. The lattice parameter of Na unit cell is ..... nm.

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43. Light of wavelength 680 nm is incident normally on a diffraction grating having 4000 lines/cm. The diffraction angle (in degrees) corresponding to the third-order maximum is .....

44. Two gases having molecular diameters D_1 and D_2, and mean free paths λ_1 and λ_2, respectively, are trapped separately in identical containers. If $D_2 = 2D_1$, then $\lambda_1/\lambda_2 =$ .....

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45. An object of 2 cm height is placed at a distance of 30 cm in front of a concave mirror with radius of curvature 40 cm. The height of the image is ..... cm.

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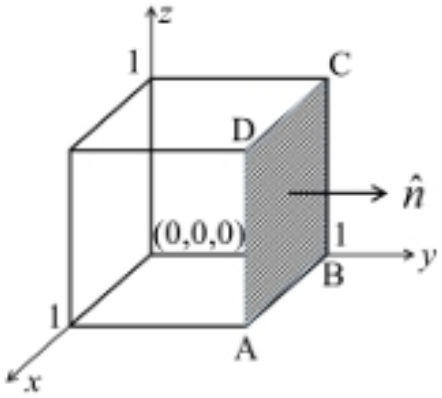
46. The flux of the function $\mathbf{F} = (y^2)\hat{x} + (3xy - z^2)\hat{y} + (4yz)\hat{z}$ passing through the surface ABCD along $\hat{n}$ is .....



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47. The electrostatic energy (in units of $\frac{1}{4\pi\epsilon_0}$ J) of a uniformly charged spherical shell of total charge 5 C and radius 4 m is .....

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48. An infinitely long very thin straight wire carries uniform line charge density $8\pi \times 10^{-2}$ C/m. The magnitude of electric displacement vector at a point located 20 mm away from the axis of the wire is ..... C/m².

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49. The 7th bright fringe in the Young's double slit experiment using a light of wavelength 550 nm shifts to the central maxima after covering the two slits with two

sheets of different refractive indices n_1 and n_2 but having the same thickness 6 μm. The value of $|n_1 - n_2|$ is .....

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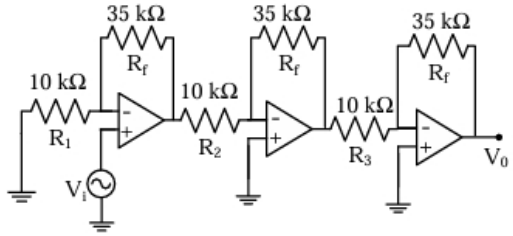
50. For the input voltage $V_i = (200\,\mathbf{mV})\sin(400t)$, the amplitude of the output voltage V_0 of the given OPAMP circuit is ..... V.



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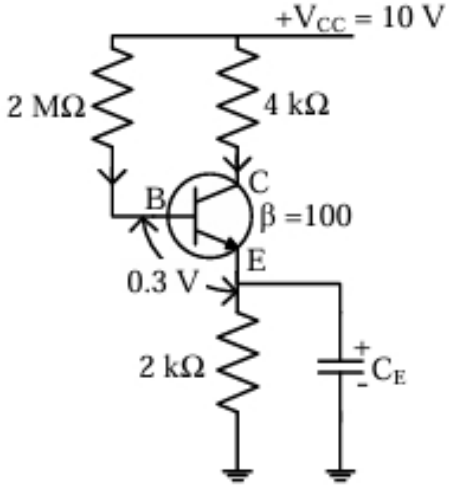
51. The value of emitter current in the given circuit is ..... A.



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52. The value of $\left|\int_0^{\infty} (3+i)\,(\bar{z})^2\,dz\right|$, along the line $3y = x$, where $z = x + jy$, is .....

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53. If the wavelength of K2 X-ray line of an element is 1.544 Å, then the atomic number Z of the element is .....

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54. A proton is confined within a nucleus of size 10^{-13} cm. The uncertainty in its velocity is ..... $\times 10^8$ m/s.

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55. Given the wave function of a particle $\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{\pi x}{L}\right)$ for $0 < x < L$ and 0 elsewhere, the probability of finding the particle between $x = 0$ and $x = L/2$ is .....

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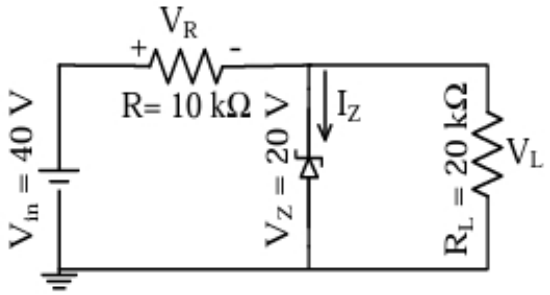
56. The Zener current I_Z for the given circuit is ..... mA.



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57. If the diameter of the Earth is increased by 4% without changing the mass, then the length of the day is ..... hours.
(Take the length of the day before the increment as 24 hours. Assume the Earth to be a sphere with uniform density.)

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58. A diatomic gas undergoes adiabatic expansion against the piston of a cylinder. As a result, the temperature of the gas drops from 1150 K to 400 K. The number of moles of the gas required to obtain 2300 J of work from the expansion is .....

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59. The decimal equivalent of the binary number 110.101 is .....

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60. A surface current $\mathrm{K} = 100\,\hat{x}$ A/m flows on the surface $z = 0$, which separates two media with magnetic permeabilities μ_1 and μ_2 as shown in the figure. If the magnetic

field in the region 1 is $\mathrm{B_1} = 4\hat{x} - 6\hat{y} + 2\hat{z}$ mT, then the magnitude of the normal component of $\mathrm{B_2}$ will be ..... mT.