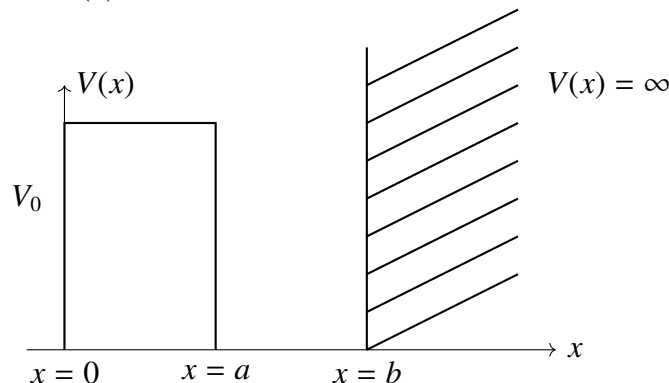


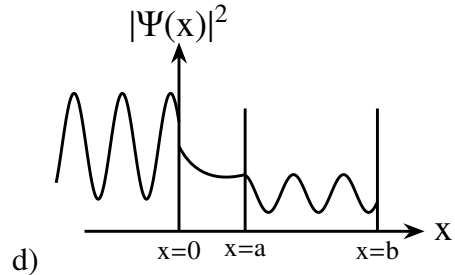
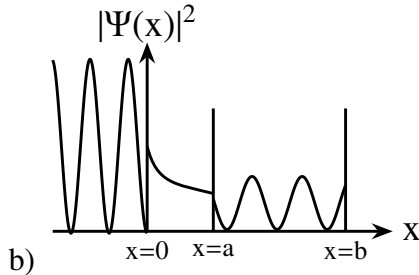
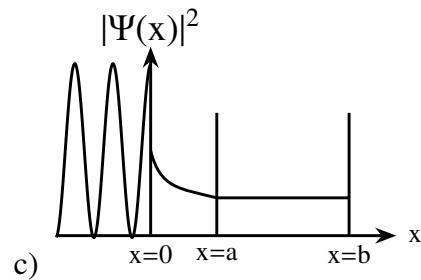
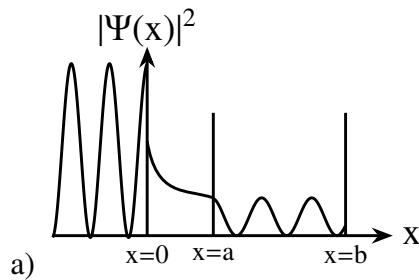
PH-2019

EE24Btech11022 - Eshan Sharma

- 1) Consider the motion of a particle along the x-axis in a potential $V(x) = F|x|$. Its ground state energy E_0 is estimated using the uncertainty principle. Then E_0 is proportional to
 - a) $F^{\frac{1}{3}}$
 - b) $F^{\frac{1}{2}}$
 - c) $F^{\frac{2}{3}}$
 - d) $F^{\frac{2}{5}}$
- 2) A 3-bit analog-to-digital converter is designed to digitize analog signals ranging from 0 V to 10 V. For this converter, the binary output corresponding to an input of 6 V is
 - a) 011
 - b) 101
 - c) 100
 - d) 010
- 3) The Hamiltonian operator for a two-level quantum system is $H = \begin{pmatrix} E_1 & 0 \\ 0 & E_2 \end{pmatrix}$. If the state of the system at $t = 0$ is given by $|\psi(0)\rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ 1 \end{pmatrix}$, then $|\langle\psi(0)|\psi(t)\rangle|^2$ at a later time t is
 - a) $\frac{1}{2} \left(1 + e^{-(E_1 - E_2)t/\hbar} \right)$
 - b) $\frac{1}{2} \left(1 - e^{-(E_1 - E_2)t/\hbar} \right)$
 - c) $\frac{1}{2} (1 + \cos[(E_1 - E_2)t/\hbar])$
 - d) $\frac{1}{2} (1 - \cos[(E_1 - E_2)t/\hbar])$
- 4) A particle of mass m moves in a lattice along the x-axis in a periodic potential $V(x) = V(x + d)$ with periodicity d . The corresponding Brillouin zone extends from $-k_0$ to k_0 , with these two k -points being equivalent. If a weak force F in the x-direction is applied to the particle, it starts a periodic motion with time period T . Using the equation of motion $F = \frac{dp_{\text{crystal}}}{dt}$ for a particle moving in a band, where p_{crystal} is the crystal momentum of the particle, the period T is found to be (\hbar is Planck constant)
 - a) $\sqrt{\frac{2md}{F}}$
 - b) $2\sqrt{\frac{2md}{F}}$
 - c) $\frac{2\hbar}{Fd}$
 - d) $\frac{\hbar}{Fd}$
- 5) Consider a potential barrier $V(x)$ of the form:



where V_0 is a constant. For particles of energy $E < V_0$ incident on this barrier from the left, which of the following schematic diagrams best represents the probability density $|\psi(x)|^2$ as a function of x .

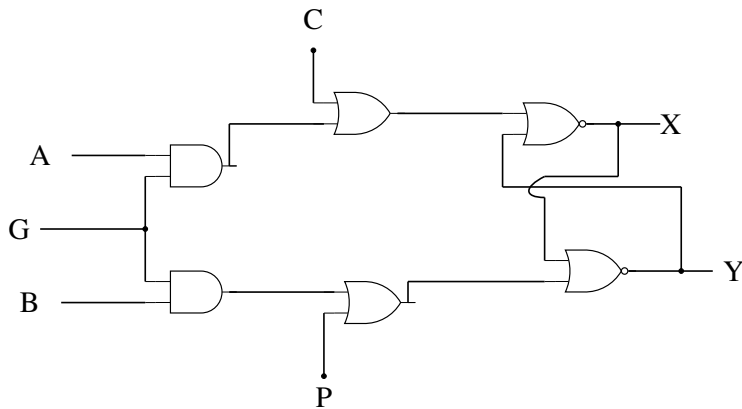


6) The spin-orbit interaction term of an electron moving in a central field is written as $f(r)\mathbf{l} \cdot \mathbf{s}$, where r is the radial distance of the electron from the origin. If an electron moves inside a uniformly charged sphere, then

- (A) $f(r) = \text{constant}$
 (B) $f(r) \propto r^{-1}$

- (C) $f(r) \propto r^{-2}$
 (D) $f(r) \propto r^{-3}$

7) For the following circuit, the correct logic values for the entries X_2 and Y_2 in the truth table are



G	A	B	P	C	X	Y
1	0	1	0	0	0	1
0	0	0	1	1	X_2	Y_2
1	0	0	0	1	0	1

- a) 1 and 0 b) 0 and 0 c) 0 and 1 d) 1 and 1

8) In a set of N successive polarizers, the m^{th} polarizer makes an angle $\left(\frac{m\pi}{2N}\right)$ with the vertical. A vertically polarized light beam of intensity I_0 is incident on two such sets with $N = N_1$ and $N = N_2$, where $N_2 > N_1$. Let the intensity of light beams coming out be $I(N_1)$ and $I(N_2)$, respectively. Which of the following statements is correct about the two outgoing beams?

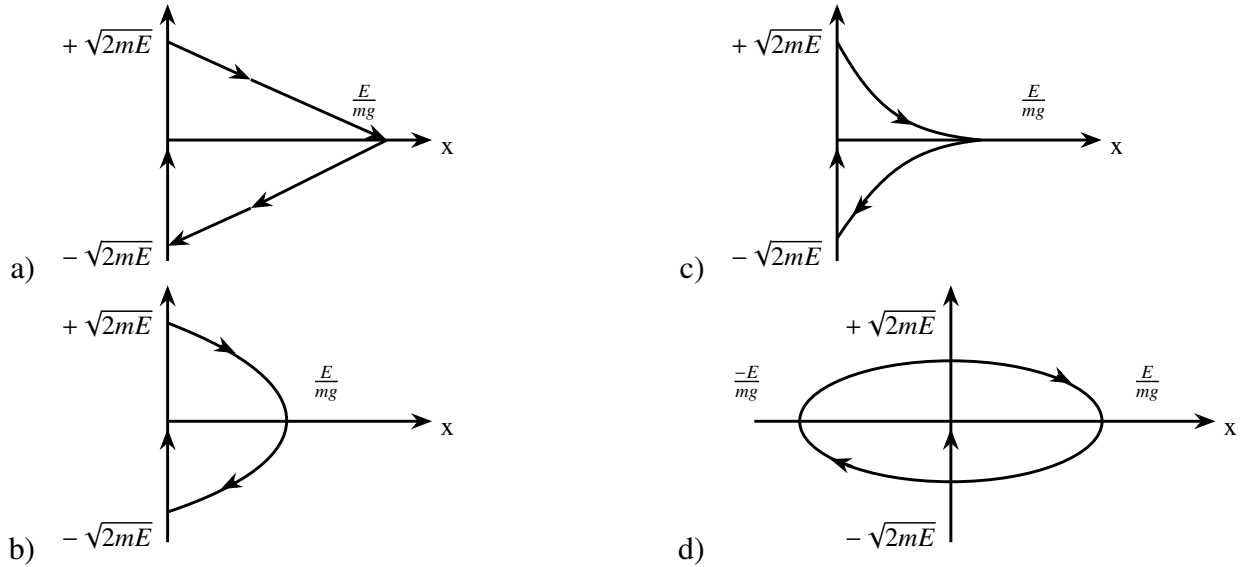
- a) $I(N_2) > I(N_1)$; the polarization in each case is vertical
 b) $I(N_2) < I(N_1)$; the polarization in each case is vertical
 c) $I(N_2) > I(N_1)$; the polarization in each case is horizontal
 d) $I(N_2) < I(N_1)$; the polarization in each case is horizontal

9) A ball bouncing off a rigid floor is described by the potential energy function

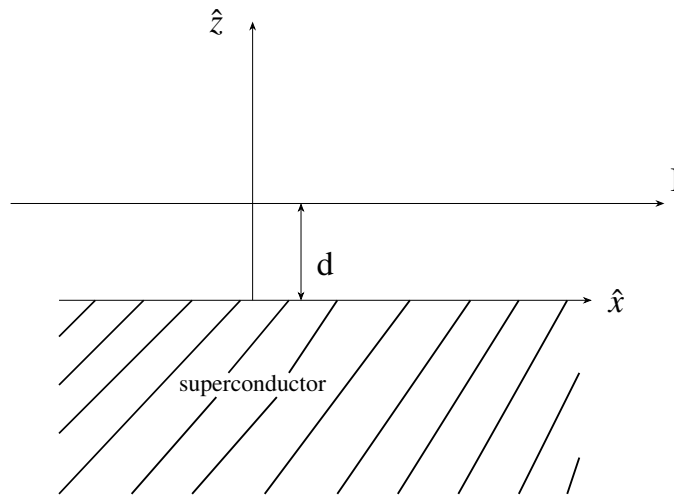
$$V(x) = mgx \text{ for } x > 0$$

$$= \infty \text{ for } x \leq 0$$

Which of the following schematic diagrams best represents the phase space plot of the ball?



- 10) An infinitely long wire parallel to the x -axis is kept at $z = d$ and carries a current I in the positive x direction above a superconductor filling the region $z \leq 0$ (see figure). The magnetic field \vec{B} inside the superconductor is zero so that the field just outside the superconductor is parallel to its surface. The magnetic field due to this configuration at a point $(x, y, z > 0)$ is



- a) $\left(\frac{\mu_0 I}{2\pi}\right) \frac{-(z-d)\hat{j}+y\hat{k}}{[y^2+(z-d)^2]}$
- b) $\left(\frac{\mu_0 I}{2\pi}\right) \left(\frac{-(z-d)\hat{j}+y\hat{k}}{[y^2+(z-d)^2]} + \frac{(z+d)\hat{j}-y\hat{k}}{[y^2+(z+d)^2]}\right)$
- c) $\left(\frac{\mu_0 I}{2\pi}\right) \left(\frac{-(z-d)\hat{j}+y\hat{k}}{[y^2+(z-d)^2]} - \frac{(z+d)\hat{j}-y\hat{k}}{[y^2+(z+d)^2]}\right)$
- d) $\left(\frac{\mu_0 I}{2\pi}\right) \left(\frac{y\hat{j}+(z-d)\hat{k}}{[y^2+(z-d)^2]} + \frac{y\hat{j}-(z+d)\hat{k}}{[y^2+(z+d)^2]}\right)$
- 11) The vector potential inside a long solenoid, with n turns per unit length and carrying current I , written in cylindrical coordinates is $\vec{A}(s, \phi, z) = \frac{\mu_0 n I}{2} s \hat{\phi}$. If the term $\frac{\mu_0 n I}{2} s (\alpha \cos \phi \hat{\phi} + \beta \sin \phi \hat{s})$, where $\alpha \neq 0$, $\beta \neq 0$, is added to $A(s, \phi, z)$, the magnetic field remains the same if

- a) $\alpha = \beta$ b) $\alpha = -\beta$ c) $\alpha = 2\beta$ d) $\alpha = \frac{\beta}{2}$

$$\left(\begin{array}{l} \text{Useful formulae: } \mathbf{v} = \frac{\partial t}{\partial s} \hat{s} + \frac{1}{s} \frac{\partial t}{\partial \phi} \hat{\phi} + \frac{\partial t}{\partial z} \hat{z}; \\ \nabla \times \mathbf{v} = \left(\frac{1}{s} \frac{\partial v_z}{\partial \phi} - \frac{\partial v_\phi}{\partial z} \right) \hat{s} + \left(\frac{\partial v_s}{\partial z} - \frac{\partial v_z}{\partial s} \right) \hat{\phi} + \frac{1}{s} \left(\frac{\partial(s v_\phi)}{\partial s} - \frac{\partial v_s}{\partial \phi} \right) \hat{z} \end{array} \right)$$

- 12) Low energy collision (s-wave scattering) of pion (π^+) with deuteron (d) results in the production of two protons ($\pi^+ + d \rightarrow p + p$). The relative orbital angular momentum (in units of \hbar) of the resulting two-proton system for this reaction is

- a) 0 b) 1 c) 2 d) 3

- 13) Consider the Hamiltonian $H(q, p) = \frac{\alpha p^2 q^4}{2} + \frac{\beta}{q^2}$, where α and β are parameters with appropriate dimensions, and q and p are the generalized coordinate and momentum, respectively. The corresponding Lagrangian $L(q, \dot{q})$ is

- a) $\frac{1}{2\alpha} \frac{\dot{q}^2}{q^4} - \frac{\beta}{q^2}$ b) $\frac{2}{\alpha} \frac{\dot{q}^2}{q^4} + \frac{\beta}{q^2}$ c) $\frac{1}{\alpha} \frac{\dot{q}^2}{q^4} + \frac{\beta}{q^2}$ d) $-\frac{1}{2\alpha} \frac{\dot{q}^2}{q^4} + \frac{\beta}{q^2}$