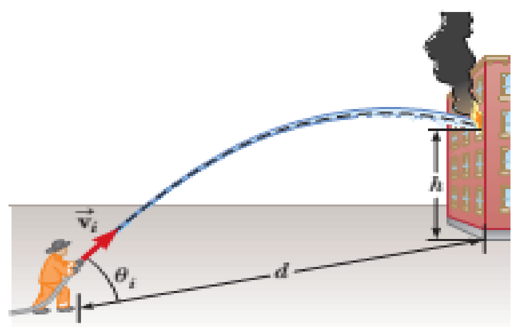
1. Two balls A and B of masses m_A and m_B are pushed horizontally from a table of height h. Ball A is pushed so that its initial velocity is v_A and ball B is pushed so that its initial velocity is v_B. Find the time it takes each ball to hit the ground. The acceleration due to gravity is g.

   (A) $\sqrt{\frac{h}{2g}}$
   (B) $\sqrt{\frac{2h}{g}}$
   (C) $\sqrt{\frac{3h}{2g}}$
   (D) $\sqrt{\frac{h}{g}}$
   (E) $\sqrt{\frac{h}{4g}}$

2. A fire fighter, distance d from a burning building, directs a stream of water from a firehouse at angle θ_i above the horizontal as shown in diagram. If the initial speed of the stream is v_i, at what height h does the water strike the building?



(A) $d \sin^2\theta_i - g/t$

(B) $gd^2/\cos \theta_i$

(C) $d \tan \theta_i - gd^2/2v_i$

(D) $d \tan \theta_i - gd^2/2v_i^2\cos^2\theta_i$

(E) None of These

3. A skater is spinning at an angular frequency of ω_1 with her arms and legs extended outward. In this position, her moment of inertia with respect to the vertical axis about which she is spinning is I_1. She pulls her arms and legs in close to her body changing her moment of inertia to $I_2 = \frac{I_1}{2}$ and angular velocity ω_2. What is her final kinetic energy?
   (A) same as the initial kinetic energy
   (B) Three times the initial kinetic energy
   (C) Half of the initial kinetic energy
   (D) Four times the initial kinetic energy
   (E) Twice the initial kinetic energy

4. Two spherical conductors of radii r_1 and r_2 are separated by a distance much greater than the radius of either sphere. The spheres are connected by a conducting wire. The charges on the spheres in equilibrium are q_1 and q_2, respectively, and they are uniformly charged. The ratio of the magnitudes of the electric fields at the surfaces of the spheres is

(A) ${}^{E_1}/_{E_2} = {}^{r_1}/_{r_2}$

(B) ${}^{E_1}/_{E_2} = 0$

(C) ${}^{E_1}/_{E_2} = {}^{r_2}/_{r_1}$

(D) ${}^{E_1}/_{E_2} = 1$

(E) ${}^{E_1}/_{E_2} = 2$

5. An electromagnetic wave propagates in the negative *y* direction. The electric field at a point in space is momentarily oriented in the positive *x* direction. In which direction is the magnetic field at that point momentarily oriented?

(A) the negative *x* direction

(B) the positive *y* direction

(C) the positive *z* direction

(D) the negative *z* direction

(E) impossible to determine.

6. Solenoid A has length *L* and *N* turns, solenoid B has length 2*L* and *N* turns and solenoid C has length *L*/2 and 2*N* turns. The fields at the centers of the solenoids A, B and C is B_A, B_B and B_C, respectively. If each solenoid carries the same current, the magnitudes of the magnetic fields at the centers of the solenoids are related as

A) $B_C = 4B_A$
B) $4B_C = B_A$
C) $B_C = B_A$
D) $B_C = 2B_A$
E) $2B_C = B_A$

7. Let S_I denote the change in entropy of a sample for an irreversible process from state A to state B. Let S_R denote the change in entropy of the same sample for a reversible process from state A to state B. Then which of the following statement is true?
   (A) $S_I > S_R$
   (B) $S_I = S_R$
   (C) $S_I < S_R$
   (D) $S_I = 2\ S_R$
   (E) $S_R = -\ S_I$

8. Suppose that each system in an ensemble is a single dice and n donates the number of dots showing upwards. Let f be the square of dots showing upwards $(f_n = n^2)$. What is the mean value of f if large number of dice are rolled?
   (A) 91/6
   (B) 7
   (C) $\frac{1}{6}$
   (D) $\frac{1}{36}$
   (E) $\frac{1}{5}$

9. The solution to the Schrodinger equation for a particle bound in a one-dimensional, infinitely deep potential well, indexed by quantum number ***n***, indicates that in the middle of the well the probability density vanishes for

   (A) The ground state (***n*** = 1) only
   (B) States of even ***n*** (***n*** = 2,4 …)
   (C) States of odd ***n*** (***n*** = 1,3 …)
   (D) All states
   (E) All states except the ground state

10. A particle of mass m has the wave function $\Psi(x, t) = e^{i\omega t}[\alpha \cos kx + \beta \sin kx]$, where α and β are complex constants and ω and k are real constants. The probability current density will be given by which of the following? (Note α* denotes the complex conjugate of α)
    A) 0
    B) $\frac{\hbar k}{m}$
    C) $\frac{\hbar k}{2m}(|\alpha|^2 + |\beta|^2)$
    D) $\frac{\hbar k}{2m}(|\alpha|^2 - |\beta|^2)$
    E) $\frac{\hbar k}{2mi}(\alpha^*\beta - \beta^*\alpha)$

11. If **A** and **B** are Hermitian operators, each of which possesses a complete set of eigenfunctions, and if **AB = BA**, then
    (A) **A** and **B** both represent the same observables
    (B) **A** and **B** both commute with the Hamiltonian
    (C) Observation of either one alters the result of the other
    (D) There exists a complete set of functions which are eigenfunctions of A and B
    (E) Neither **A** nor **B** represents an observable

12. For an energy level of Hydrogen atom having principal quantum number ***n*** and angular quantum number ***l***, how many orbitals share the same angular momentum?
    (A) n
    (B) n^2
    (C) l
    (D) $l(l+1)$
    (E) $2l+1$

13. A three level system is found to be in the state: $|\Phi\rangle = 2|E_1\rangle + 3|E_2\rangle + |E_3\rangle$, which is a linear combination of orthonormal energy states with corresponding energyE_1, E_2, E_3. What is the probability of obtaining the energy E_2?
    (A) 1/2
    (B) 3/11
    (C) 9/14
    (D) 3/14
    (E) 1/12

14. Suppose that $|\phi_1 >$ and $|\phi_2 >$ form an orthonormal basis. Working in the ϕ basis, a 2x2 matrix whose action on any state is to project out the ϕ_2 part is
    (A) $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$
    (B) $\begin{pmatrix} 0 & 1 \\ 0 & 1 \end{pmatrix}$
    (C) $\begin{pmatrix} 0 & 0 \\ 1 & 1 \end{pmatrix}$
    (D) $\begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$
    (E) $\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$

15. For a certain system there is only one accessible state and it has energy $E = -NkTln\left(\frac{V}{V_0}\right)$, where V_0 is a constant. The partition function of the system in terms of T, V and N is

    A) $\left(\frac{V}{V_0}\right)^N$
    B) $\left(\frac{V_0}{V}\right)^N$
    C) $ln(\frac{V}{V_0})$
    D) $ln\left(\frac{V_0}{V}\right)$
    E) $N\left(\frac{V_0}{V}\right)$

16. Consider an ideal gas that is compressed slowly from an initial volume V_i to a final volume V_f as it is kept thermally insulated. In this case its pressure is found to depend on the volume as $P = \alpha V^{-5/3}$ where α is independent of V. What is the work done on the gas in this process?

A) $\frac{3\alpha}{2}\left(V_f^{-1/3} - V_i^{-1/3}\right)$
B) $\alpha\left(V_f^{-2/3} - V_i^{-2/3}\right)$
C) $\frac{3\alpha}{2}\left(V_f^{-2/3} - V_i^{-2/3}\right)$
D) $\frac{2\alpha}{3}\left(V_f^{-2/3} - V_i^{-2/3}\right)$
E) $-\frac{3\alpha}{2}\left(V_f^{-2/3} - V_i^{-2/3}\right)$

17. Suppose a scalar field $X(x, y, z)$ is related to a vector field $\vec{Y}(x, y, z)$ such that $X = \vec{\nabla}.\vec{Y}$. If $X(x, y, z) = 1$ inside a cube of edge length a, evaluate the following integral over the surface of this cube: $I = \oint_{cube\ surface} \vec{Y}.d\vec{a}$, where $d\vec{a}$ is an infinitesimal area element on the surface of the cube.
(A) 0
(B) a^3
(C) $6a^2|\vec{Y}|$
(D) 1
(E) 2

18. Consider the position vector of a point $P(x, y, z)$ in Cartesian coordinates, $\vec{p} = x\hat{x} + y\hat{y} + z\hat{z}$. What are the components of this vector along the basis vectors $\hat{r}$, $\hat{\theta}$, and $\hat{\varphi}$ of spherical polar coordinate system.
A) $\sqrt{x^2 + y^2 + z^2}$, 0, 0
(B) 0, 0, 0
(C) $\sqrt{x^2 + y^2 + z^2}$, $\tan^{-1}\frac{\sqrt{x^2+y^2}}{z}$, $\tan^{-1}\frac{y}{x}$
(D) $\sqrt{x^2 + y^2}$, $\tan^{-1}\frac{\sqrt{x^2+y^2}}{z}$, z
(E) 1,1,1

19. The Fourier coefficients of complex Fourier series of the function $f(x) = 2\sin(x) - 3e^{-ix}$ are

    (A) $c_1 = 2, c_{-1} = -3$, $c_n = 0$ for $n \neq \pm 1$
    (B) $c_1 = -i, c_{-1} = (i - 3)$, $c_n = 0$ for $n \neq \pm 1$
    (C) $c_0 = 1$, $c_n = 0$ for $n \neq 0$
    (D) $f(x)$ is a complicated function, the Fourier series cannot be written.
    (E) $c_1 = 1, c_{-1} = -1$, $c_n = 0$ for $n \neq \pm 1$

20. What happens to the position vector $\vec{p}$ of complex variable $z = x + iy$ in the complex plane when z is multiplied by i.
    (A) $\vec{p}$ changes to $-\vec{p}$
    (B) $\vec{p}$ becomes a scalar q
    (C) $\vec{p}$ rotates by 90^o counter-clockwise
    (D) $\vec{p}$ rotates by 90^o clockwise
    (E) Nothing happens to $\vec{p}$

21. The general solution to the differential equation $\frac{dy}{dx} = \frac{y}{e^x lny}$ $(y > 0)$ is

    A) $y = e^{\pm\sqrt{e^{-x}+C}}$

    B) $y = e^{\pm\sqrt{-2e^{-2x}+C}}$

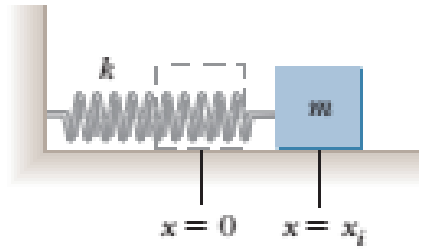
    C) $y = e^{\pm\sqrt{-2e^{-3x}+C}}$

    D) $y = e^{\pm\sqrt{-2e^{-x}+C}}$

    E) $y = e^{\pm x} + C$

22. A block of mass m is attached to a spring of force constant k . The block is pulled to a position x_i to the right of equilibrium and released from rest. What is the speed of the

block when it passes through the equilibrium point $x = 0$ on a frictionless horizontal surface ?



A) $\sqrt{\frac{k}{m}}\ x_i$

B) 0

C) $\sqrt{\frac{k}{m}}$

D) $\sqrt{\frac{k}{m}}\ x_i^2$

E) $\sqrt{\frac{m}{k}}\ x_i$

23. A particle with charge q is located a distance d from an infinite plane. The electric flux through the plane due to the charged particle is

A) $\frac{q}{\varepsilon_0}$

B) $\frac{q}{2\varepsilon_0}$

C) 0

D) ∞

E) $\frac{qd}{\varepsilon_0}$

24. A bullet of mass m is fired into a stationary block of wood having mass M suspended like a pendulum and makes a completely inelastic collision with it. After the impact, the block swings up to a maximum height h. What is the initial speed of the bullet?

A) $\frac{M}{m}\sqrt{2gh}$

B) $\frac{m}{M}\sqrt{2gh}$

C) $\frac{m+M}{m}\sqrt{2gh}$

D) $\sqrt{2mgh}$

E) $\sqrt{2gh}$

25. Two charges are placed on the x-axis. The positive charge $+8q$ at the origin and a negative charge $-2q$ at $x = L$. At which point on the x-axis is the net electric field due to these two charges zero?

A) $x = 0$

B) $x = 2L$

C) $x = L$
D) $x = L/2$
E) $x = -L$