SECTION 1 Multiple Choice Question (MCQ)

- This section contains TEN (10) questions.
- Each question has FOUR options (A), (B), (C) and (D). ONLY ONE of these four options is the correct answer.
- For each question, darken the bubble corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:
  
  **Full Marks** : +3  If ONLY the bubble corresponding to the correct option is darkened.
  **Zero Marks** : 0  If none of the bubble is darkened (i.e., the question is unanswered).
  **Negative Marks** : −0.75  In all other cases.

Q.1 Two resistors $R_1 = 2$ ohm and $R_2 = 5$ ohm are connected in series to a 10 Volt voltage source. Let $V_1$ and $V_2$ be the voltage drop across $R_1$ and $R_2$, respectively. Then, which of the following options is true?

(A) $V_1 = V_2$  (B) $V_1 > V_2$  (C) $V_1 < V_2$  (D) The current in the circuit is 2 Ampere.

Q.2 The ideal gas law is given by $PV = nRT$, where $P$ is the pressure, $V$ is the volume, $n$ is the number of moles of gas, and $T$ is the temperature. The SI unit of the gas constant $R$ is given by_____.

(A) Joule per mole per Celsius  (B) Newton per mole per Celsius
(C) Joule per mole per Kelvin  (D) Newton per mole per Kelvin

Q.3 Two ideal monatomic gasses, $X$ and $Y$, of densities $\rho_X = \rho$ and $\rho_Y = 3\rho$, respectively, are maintained at the same temperature and pressure. If the speeds of sound in gases $X$ and $Y$ are $v_X$ and $v_Y$, respectively, then the ratio $v_X : v_Y$ is_____.

(A) 1:3  (B) 1: $\sqrt{3}$  (C) 3:1  (D) $\sqrt{3}$:1

Q.4 Consider a simple pendulum where a mass $m$ is attached to a massless, unstretchable string with one end fixed. Which of the following changes will result in the doubling of its time period?

(I) The string length increases four times.
(II) The acceleration due to gravity increases four times.
(III) The string length is halved.
(IV) The acceleration due to gravity becomes one fourth.

(A) (I) and (IV)  (B) (I) and (II)  (C) (II) and (III)  (D) (III) and (IV)
Q.5  Three spheres, each of mass $M$ and radius 1 unit, are placed in a plane as shown in the figure below:

The direction of the gravitational force on a point particle of unit mass placed at the origin $O$ is \( \hat{x} \). (Here $\hat{x}$, $\hat{y}$ are unit vectors along the $x$- and $y$-directions, respectively)

(A) $\hat{x}$  \hspace{1cm} (B) $\hat{y}$  \hspace{1cm} (C) $-\hat{x}$  \hspace{1cm} (D) $-\hat{y}$

Q.6  A particle undergoes a sinusoidal motion $x(t) = A \sin(\omega t)$ under the influence of a force $F(t)$ as shown in the figure below. At which of the points, marked as 1, 2, 3, 4 in the figure below, the magnitude of the force $F(t)$ will be the maximum?

(Here, $A$ is the amplitude, $\omega$ is the constant angular frequency, and $t$ is the time)

(A) 1  \hspace{1cm} (B) 2  \hspace{1cm} (C) 3  \hspace{1cm} (D) 4
Q.7 A particle is displaced by a distance \( x \) under the influence of a force \( F \) as per the following force-displacement graph:

![Force-displacement graph](image)

The work done \( (W) \) by the force \( F \) as a function of displacement \( x \) can be represented as:

(A) \( W \) vs. \( x \) graph (B) \( W \) vs. \( x \) graph (C) \( W \) vs. \( x \) graph (D) \( W \) vs. \( x \) graph

Q.8 The SI unit of the electromotive force (EMF) is____.

(A) Newton (N) (B) Joule (J) (C) Volt (V) (D) meter/sec² (m/s²)

Q.9 A radioactive decay process is given by \( ^{238}_{92}U \rightarrow ^{234}_{90}Th + X \). Identify \( X \).

(A) Electron (B) Proton (C) Neutron (D) Alpha particle

Q.10 A spacecraft \( S_1 \) is moving at a speed of 0.8c (c is the speed of light) with respect to another spacecraft \( S_2 \), which is at rest. After \( t_1 \) hours have passed in spacecraft \( S_1 \), the number of hours passed in spacecraft \( S_2 \) is____.

(A) 1.7 \( t_1 \) (B) 0.3 \( t_1 \) (C) \( t_1 \) (D) 0.6 \( t_1 \)
Q.11 A cylindrical resistor A of length 0.01 meter has a resistance of 2 ohm. Another resistor B of the same material and having the same cross-sectional area as A, has a length of 0.02 meter. The resistance of B is ____ ohm.

Q.12 The root mean square (rms) speed \( v_{\text{rms}} \) of the molecules of an ideal gas is equal to \( \sqrt{\frac{3RT}{M}} \). At temperature \( T = 300 \) Kelvin, and for \( M = 4 \times 10^{-3} \) Kilogram/mole, the \( v_{\text{rms}} \) is \( 1.37 \times 10^2 \) meter/sec. Then the value of \( X \) is _____. (The value of gas constant \( R = 8.31 \) Joule/(mole Kelvin))

Q.13 The force required to hold the masses using a massless and frictionless pulley-string arrangement as shown in the figure below is ____ Newton. (Take the value of the acceleration due to gravity \( g = 10 \) meter/sec\(^2\)).

Q.14 The radius and mass of a uniform solid sphere are increased by a factor of 2 and 8, respectively. The magnitude of the gravitational force on a point mass placed on the surface of the aforementioned sphere is now _____ times of the initial gravitational force.

Q.15 A metallic sphere of density \( \rho \) weighs 10 Newton in vacuum. The weight of the sphere when completely submerged in a liquid of density \( \frac{\rho}{2} \) is ____ Newton.
Q.16 A ray of light is incident normally at the interface separating two media of refractive indices $n_1$ and $n_2$, as shown in the figure below.

![Diagram of light rays](image)

The angle between the reflected ray and the transmitted ray is $\pi$ Radians.

Q.17 Unpolarized light of intensity $2 \text{ Watt/meter}^2$ is incident on an ideal polarizer. The intensity of the light emerging from the polarizer is ______ Watt/meter$^2$.

Q.18 A uniform magnetic field of magnitude $B = 0.04 \text{ Tesla}$ passes perpendicularly through a circular loop of area 100 meter$^2$. The magnetic flux through the loop is ______ Tesla-meter$^2$.

Q.19 Consider a $X$-$Y$ plane with a uniform magnetic field in the positive $Y$-direction. A charged particle of charge $+q$ is at rest at the origin. Then, the magnitude of the magnetic force on the charged particle is ______ Newton.

Q.20 Two radioactive elements $R_1$ and $R_2$ with half-lives of $2\lambda$ and $\lambda$, decay to $\frac{1}{3}$ of their initial numbers of nuclei at times $t_1$ and $t_2$, respectively. The ratio $\frac{t_1}{t_2}$ is ______.
An electron in a Hydrogen atom has a de Broglie wavelength \( \lambda \). This system can be considered to be analogous to the vibrations of a wire loop with the nucleus fixed at its center. In Bohr’s model, an electron can circle around the nucleus only if the de Broglie wavelength is \( 1\lambda \), where \( n \) is an integer.

Q.21 The potential energy of the electron in the Hydrogen atom is \( \frac{-e^2}{4 \pi \varepsilon_0 r} \), where \( e \) is the charge of the electron, \( r \) is the Bohr radius and \( \varepsilon_0 \) is the permittivity of free space. Then, the total energy of the electron is \( \underline{\text{____}} \).

(A) \( \frac{-e^2}{4 \pi \varepsilon_0 r} \) \hspace{1cm} (B) \( \frac{e^2}{4 \pi \varepsilon_0 r} \) \hspace{1cm} (C) \( \frac{e^2}{8 \pi \varepsilon_0 r} \) \hspace{1cm} (D) \( \frac{e^2}{8 \pi \varepsilon_0 r} \)

An electron in a Hydrogen atom has a de Broglie wavelength \( \lambda \). This system can be considered to be analogous to the vibrations of a wire loop with the nucleus fixed at its center. In Bohr’s model, an electron can circle around the nucleus only if the de Broglie wavelength is \( n\lambda \), where \( n \) is an integer.

Q.22 Calculate the radius of the orbit when \( n = 1 \) and de Broglie wavelength is 3.3 Angstrom. (Given \( \pi = 3.14, 1 \text{ Angstrom} = 10^{-10} \text{ meters} \))

(A) 0.53 Angstrom \hspace{1cm} (B) 2.51 Angstrom \hspace{1cm} (C) 1.25 Angstrom \hspace{1cm} (D) 3.14 Angstrom
A particle of charge $q$ moving with velocity $\vec{v}$, experiences a force $q(\vec{v} \times \vec{B})$ in a magnetic field $\vec{B}$.

Q.23 A charged particle of mass 0.003 kilograms performs a uniform circular motion with a linear speed $v = 1$ meter/sec in the X-Y plane in a uniform magnetic field $\vec{B} = 10^{-3}$ T Tesla, where $\vec{z}$ is the unit vector along z-direction. Neglecting gravity, given that the magnitude of centripetal force is $q\vec{v}\vec{B}$ and the radius of the circular trajectory is 1 meter, the magnitude of the charge in Coulomb is ____.

(A) 1  (B) 2  (C) 3  (D) 4

A particle of charge $q$ moving with velocity $\vec{v}$, experiences a force $q(\vec{v} \times \vec{B})$ in a magnetic field $\vec{B}$.

Q.24 A positively charged particle is moving in a magnetic field oriented in the positive y-direction. If at a given instant the velocity is in the positive x-direction, then the magnetic force experienced by the particle at that instant is______.

(A) in the positive x-direction
(B) in the positive z-direction
(C) in the negative z-direction
(D) in the negative x-direction
The current \( I(t) = 2 \sin(\omega t) \) Ampere is flowing with a constant angular frequency \( \omega \), through a resistor of resistance 1 ohm. This results in the energy dissipation through the resistor in the form of heat. (Here \( t \) is the time.)

Q.25 \[ \text{The rate of energy dissipation at the instant } t = \frac{2\pi}{\omega} \text{ sec is ___ Watt.} \]

(A) 3 (B) 2 (C) 1 (D) 0

The current \( I(t) = 2 \sin(\omega t) \) Ampere is flowing with a constant angular frequency \( \omega \), through a resistor of resistance 1 ohm. This results in the energy dissipation through the resistor in the form of heat. (Here \( t \) is the time.)

Q.26 \[ \text{The voltage drop across the resistor _________.} \]

(A) is in phase with the current (B) leads the current by a phase of \( \frac{\pi}{2} \) (C) lags behind the current by a phase of \( \frac{\pi}{2} \) (D) is constant in time

Solid, Liquid and Gas are the three states of matter. The following figures (I) and (II) show a few interconversions between different states of matter.

Q.27 \[ \text{In Figure (II), _________.} \]

(A) process c is sublimation; process d is vaporization (B) process c is vaporization; process d is condensation (C) process c is condensation; process d is sublimation (D) process c is condensation; process d is vaporization
Solid, Liquid and Gas are the three states of matter. Following figures (I) and (II) show a few interconversions between different states of matter.

Q.28  **In Figure (I), ____________.**

(A) process a is melting; process b is solidification  
(B) process a is sublimation; process b is melting  
(C) process a is melting; process b is vaporization  
(D) process a is vaporization; process b is sublimation

A long thread is wound around a disc of radius $R$ and mass $M$ that can rotate freely about an axis perpendicular to the disc and passing through its center. One end of the thread is pulled out at a constant linear speed $v$ without slipping.

Q.29  **The moment of inertia of the disc about an axis perpendicular to the disc and passing through its center is_____.

(A) $\frac{1}{5} MR^2$  
(B) $2MR^2$  
(C) $\frac{1}{2} MR^2$  
(D) $5MR^2$

A long thread is wound around a disc of radius $R$ and mass $M$ that can rotate freely about an axis perpendicular to the disc and passing through its center. One end of the thread is pulled out at a constant linear speed $v$ without slipping.

Q.30  **The angular velocity of the disc is given by_____.

(A) $\frac{R}{v}$  
(B) $\frac{v}{R}$  
(C) $vR$  
(D) $\frac{v^2}{R}$