JEE Main Physics
Sample Paper – 16

Duration: 60 Minutes | Maximum Marks: 100

Instructions

- **Section A** contains **20 Multiple Choice Questions (MCQ)**. Each correct answer carries **+4 marks**; each wrong answer carries -1 **mark**. Unattempted questions carry **0 marks**.
- **Section B** contains **10 Numerical Value Questions (NVQ)**. Attempt **any 5**. Each correct answer carries **+4 marks**. There is **no negative marking** in Section B.
- The syllabus is based on **NCERT Physics (Class XI & XII)**.
- **No personal calculators** are allowed. An on-screen virtual calculator is provided.

SECTION A – Multiple Choice Questions (Q1–Q20)

Q1. The displacement-time (s-t) graph of a particle is a parabola (opening upward). What can be correctly concluded about the motion?

(A) The velocity is constant throughout.

(B) The acceleration is zero.

(C) The velocity decreases uniformly.

(D) The acceleration is constant (uniformly accelerated motion).

Q2. A block of mass $m = 5$ kg rests on the floor of a car. The car accelerates forward at $a = 2\ \mathrm{m/s^2}$. In the reference frame of the car (non-inertial), the magnitude of the pseudo force (fictitious force) acting on the block is:

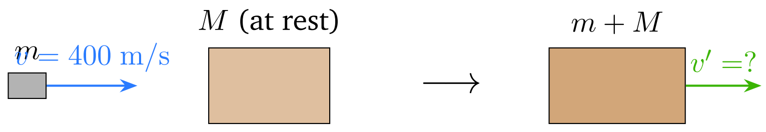
(A) 5 N

(B) 10 N

(C) 20 N

(D) 2 N

Q3. A bullet of mass $m = 10$ g $= 0.01$ kg moves at $v = 400$ m/s and embeds itself in a stationary wooden block of mass $M = 390$ g $= 0.39$ kg, as shown below. By conservation of momentum, the velocity of the combined block-bullet system just after the collision is:



Before collision

After collision

(A) 400 m/s

(B) 40 m/s

(C) 10 m/s

(D) 4 m/s

Q4. A solid cylinder (moment of inertia $I = MR^2/2$) rolls without slipping down a rough incline. For a solid cylinder, the fraction of total kinetic energy that is **rotational** is:

(A) $\frac{1}{3}$

(B) $\frac{1}{2}$

(C) $\frac{2}{3}$

(D) $\frac{1}{4}$

Q5. In which of the following situations does a person experience **weightlessness** (apparent weight $= 0$)?

(A) Standing on the surface of the Moon.

(B) In an elevator moving upward at constant velocity.

(C) In an elevator accelerating downward at $g/2$.

(D) In a spacecraft moving in a stable circular orbit around Earth (free-fall condition).

Q6. A simple pendulum has time period T_1 on Earth ($g_E = 10\ \mathrm{m/s^2}$). On a planet where $g_P = 2.5\ \mathrm{m/s^2}$, the period of the same pendulum T_2 is:

(A) $T_1/2$

(B) $2T_1$

(C) T_1

(D) $4T_1$

Q7. A small sphere of radius r and density ρ_s falls through a viscous fluid of viscosity η and density ρ_f. By Stokes' Law, the terminal velocity v_t is:

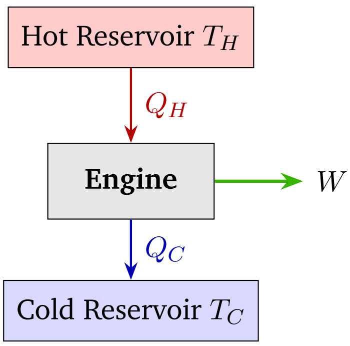
(A) $v_t = \dfrac{r(\rho_s - \rho_f)g}{9\eta}$

(B) $v_t = \dfrac{2r(\rho_s - \rho_f)g}{9\eta}$

(C) $v_t = \dfrac{2r^2(\rho_s - \rho_f)g}{9\eta}$

(D) $v_t = \dfrac{r^2(\rho_s - \rho_f)g}{9\eta}$

Q8. Which of the following correctly states the Second Law of Thermodynamics?



(A) Heat cannot spontaneously flow from a cooler body to a hotter body without an external agent doing work.

(B) The total energy of the universe is constant.

(C) A process that absorbs heat and converts it entirely into work is always possible.

(D) Both work-to-heat and heat-to-work conversions are equally possible with 100% efficiency.

Q9. The van der Waals equation of state for n moles of a real gas is written correctly as:

(A) $\left(P + \frac{a}{V}\right)(V - b) = RT$

(B) $\left(P - \frac{a}{V^2}\right)(V + b) = RT$

(C) $\left(P + \frac{a}{V^2}\right)(V - b) = nRT$

(D) $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$

Q10. Two tuning forks have frequencies $f_1 = 512$ Hz and $f_2 = 516$ Hz. When both are sounded simultaneously, the beat frequency heard is:

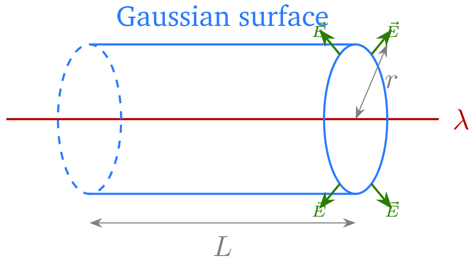
(A) 1028 Hz

(B) 4 Hz

(C) 2 Hz

(D) 514 Hz

Q11. A very long straight rod has a uniform linear charge density λ C/m. A coaxial cylindrical Gaussian surface of radius r and length L is drawn around it, as shown. The total electric flux Φ_E through this closed Gaussian surface is:



(A) $\frac{\lambda}{\varepsilon_0 L}$

(B) $\frac{\lambda L^2}{\varepsilon_0}$

(C) $\dfrac{\lambda L}{\varepsilon_0}$

(D) $\dfrac{\lambda}{2\pi\varepsilon_0 r L}$

Q12. In a potentiometer circuit, a standard cell of EMF $\varepsilon_s = 1.5$ V gives a balance length of $\ell_s = 50$ cm. An unknown battery balances at $\ell_x = 75$ cm. The EMF of the unknown battery is:

(A) 2.25 V

(B) 1 V

(C) 3 V

(D) 1.5 V

Q13. A solenoid has $N = 1000$ turns, length $L = 0.5$ m, and carries current $I = 2$ A ($\mu_0 = 4\pi \times 10^{-7}$ T $\cdot$ m/A). The magnetic field inside the solenoid is:

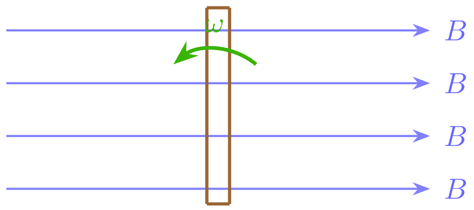
(A) 10 mT

(B) 2 mT

(C) 1 mT

(D) 5 mT

Q14. An AC generator coil has $N = 100$ turns, each of area $A = 0.02$ m^2, rotating at angular velocity $\omega = 50\pi$ rad/s in a uniform magnetic field $B = 0.4$ T, as illustrated. The peak (maximum) EMF generated is:



Coil in uniform magnetic field B

(A) 200 V

(B) 40π V

(C) 80π V

(D) 40 V

Q15. In a purely capacitive AC circuit, the phase relationship between the voltage across the capacitor V_C and the current I is:

(A) Current and voltage are in phase ($\phi = 0$).

(B) Voltage leads current by 90.

(C) Current leads voltage by 90 (i.e., voltage lags behind the current by 90).

(D) Current leads voltage by 45.

Q16. A short-sighted (myopic) person cannot see objects beyond 50 cm from their eye. The far point is 50 cm. To correct this defect, the person should use a lens of power:

(A) -2 D

(B) $+2$ D

(C) -4 D

(D) $+4$ D

Q17. Which of the following statements correctly describes the resolving power of an optical instrument?

(A) Using light of longer wavelength increases the resolving power.

(B) Resolving power depends only on the size of the object being viewed.

(C) The limit of resolution of a telescope is $D/(1.22\lambda)$ (where D is the aperture).

(D) Shorter wavelength of light gives better (higher) resolving power and finer detail.

Q18. The Compton wavelength of the electron is defined as $\lambda_C = h/(m_e c)$. Using $h = 6.63 \times 10^{-34}$ J $\cdot$ s, $m_e = 9.1 \times 10^{-31}$ kg, $c = 3 \times 10^8$ m/s, its value is approximately:

(A) 0.24 nm

(B) 2.43 pm

(C) 24 pm

(D) 0.243 nm

Q19. Among the following nuclei, which has the **highest** binding energy per nucleon?

(A) Deuterium ($^{2}_{1}$H)

(B) Carbon-12 ($^{12}_{6}$C)

(C) Iron-56 ($^{56}_{26}$Fe)

(D) Uranium-235 ($^{235}_{92}$U)

Q20. The Boolean expression that correctly represents the output Y of a NAND gate with inputs A and B is:

(A) $Y = \overline{A \cdot B}$

(B) $Y = A \cdot B$

(C) $Y = \overline{A + B}$

(D) $Y = \overline{A} \cdot \overline{B}$

SECTION B – Numerical Value Questions (Q21–Q30)

Attempt any 5

Q21. A particle moves in a circle of radius $r = 2$ m at constant angular speed $\omega = 3$ rad/s. The centripetal acceleration (in $\mathrm{m/s^2}$) is ______.

Q22. In the Bohr model of hydrogen, the energy of the electron in the $n = 3$ orbit is given by $E_3 = -13.6/n^2$ eV. The magnitude $|E_3|$ (in eV, correct to 2 decimal places) is ______.

Q23. Three capacitors $C_1 = 2\ \mu\text{F}$ and $C_2 = 3\ \mu\text{F}$ are in parallel; this combination is in series with $C_3 = 5\ \mu\text{F}$. The combination is connected to a $20\ \text{V}$ battery. The total energy stored (in mJ) is ______.

Q24. The magnetic flux through a single-turn coil changes from $0.01\ \text{Wb}$ to $0.05\ \text{Wb}$ in $0.01\ \text{s}$. The magnitude of the induced EMF (in V) is ______.

Q25. Two point charges $+4\ \mu\text{C}$ and $+9\ \mu\text{C}$ are placed $5\ \text{cm}$ apart on the x-axis. The electric field is zero at a point between the charges at distance d (in cm) from the $+4\ \mu\text{C}$ charge. The value of d is ______.

Q26. A straight wire of length $1\ \text{m}$ carrying current $I = 2\ \text{A}$ is placed perpendicular to a uniform magnetic field $B = 3\ \text{T}$. The force on the wire (in N) is ______.

Q27. In the nuclear fusion reaction ${}^2_1\text{H} + {}^3_1\text{H} \to {}^4_2\text{He} + {}^1_0\text{n}$, the mass defect is $\Delta m = 0.0188\ \text{u}$ (using $m_{^2\text{H}} = 2.0141\ \text{u}$, $m_{^3\text{H}} = 3.0160\ \text{u}$, $m_{^4\text{He}} = 4.0026\ \text{u}$, $m_n = 1.0087\ \text{u}$). The energy released (in MeV, using $1\ \text{u} = 931.5\ \text{MeV}/c^2$) is ______.

Q28. A Geiger counter records 6400 counts during the first hour and 1600 counts during the second hour. The half-life of the radioactive sample (in minutes) is ______.

Q29. A proton and an alpha particle are each accelerated from rest through the same potential difference V. Using $\lambda = h/\sqrt{2mqV}$ and the relations $m_\alpha = 4m_p$, $q_\alpha = 2q_p$, the ratio of their de Broglie wavelengths λ_p/λ_α is ______.

Q30. A Carnot engine has efficiency 40% when its heat source is at temperature $T_H = 600\ \text{K}$. To increase the efficiency to 50% while keeping the cold reservoir temperature T_C unchanged, the required new source temperature T'_H (in K) is ______.

SOLUTIONS

Sol. 1.

Solution

A **parabolic** s-t graph of the form $s = ut + \frac{1}{2}at^2$ means that displacement is a quadratic function of time.

- Velocity $v = ds/dt = u + at$ — a linear (not constant) function of time.
- Acceleration $a = d^2s/dt^2 = \text{const}$ — the acceleration is **uniform (constant)**.
- The upward-opening parabola confirms $a > 0$ (positive, constant).

Options (A), (B), and (C) are incorrect. A parabolic s-t graph is the hallmark of **uniformly accelerated motion**.

Answer: (D)

Sol. 2.

Solution

In a non-inertial (accelerating) reference frame, a **pseudo force** is introduced to apply Newton's second law. Its magnitude equals the product of the mass and the frame's acceleration, and it acts *opposite* to the direction of the frame's acceleration.

$$F_{\text{pseudo}} = m \times a = 5 \text{ kg} \times 2 \text{ m/s}^2 = \boxed{10 \text{ N}}$$

The pseudo force acts *backward* in the car's reference frame (opposite to the car's forward acceleration).

Answer: (B)

Sol. 3.

Solution

This is a **perfectly inelastic collision** (bullet embeds in block). By the **law of conservation of linear momentum**:

$$mv + M \times 0 = (m + M)\,v'$$

$$v' = \frac{mv}{m+M} = \frac{0.01 \times 400}{0.01 + 0.39} = \frac{4}{0.40} = \boxed{10 \text{ m/s}}$$

Note that a large fraction of kinetic energy is lost as heat/sound/deformation, but momentum is conserved.

Answer: (C)

Sol. 4.

Solution

For a solid cylinder of mass M and radius R rolling without slipping with centre-of-mass speed v:

$$KE_{\text{trans}} = \tfrac{1}{2}Mv^2$$
$$KE_{\text{rot}} = \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}\cdot\tfrac{MR^2}{2}\cdot\frac{v^2}{R^2} = \tfrac{1}{4}Mv^2$$
$$KE_{\text{total}} = \tfrac{1}{2}Mv^2 + \tfrac{1}{4}Mv^2 = \tfrac{3}{4}Mv^2$$

$$\text{Fraction rotational} = \frac{KE_{\text{rot}}}{KE_{\text{total}}} = \frac{\frac{1}{4}Mv^2}{\frac{3}{4}Mv^2} = \boxed{\frac{1}{3}}$$

Answer: (A)

Sol. 5.

Solution

Apparent weight $= m(g - a_{\text{downward}})$, where a_{downward} is the downward acceleration of the reference frame.

- **(A) Moon surface**: There is still gravitational pull ($g_{\text{moon}} \approx 1.6\ \text{m/s}^2$), so apparent weight $\neq 0$.
- **(B) Elevator moving up at constant velocity**: $a = 0$; apparent weight $= mg \neq 0$.
- **(C) Elevator accelerating down at $g/2$**: Apparent weight $= m(g - g/2) = mg/2 \neq 0$.
- **(D) Stable circular orbit**: The spacecraft (and person) are in continuous *free fall* toward Earth. Apparent weight $= m(g - g) = 0$. ✓

Answer: (D)

Sol. 6.

Solution

The time period of a simple pendulum of length ℓ is $T = 2\pi\sqrt{\ell/g}$, so $T \propto 1/\sqrt{g}$.

$$\frac{T_2}{T_1} = \sqrt{\frac{g_E}{g_P}} = \sqrt{\frac{10}{2.5}} = \sqrt{4} = 2$$

$$\therefore \quad T_2 = \boxed{2T_1}$$

Since $g_P < g_E$, the pendulum swings more slowly on the new planet, giving a longer period.

Answer: (B)

Sol. 7.

Solution

At terminal velocity, the net downward force equals Stokes' drag:

$$\underbrace{\tfrac{4}{3}\pi r^3(\rho_s - \rho_f)g}_{\text{effective weight}} = \underbrace{6\pi\eta r\, v_t}_{\text{Stokes drag}}$$

Solving for v_t:

$$v_t = \frac{2r^2(\rho_s - \rho_f)g}{9\eta}$$

This is **option (C)**. Note the dependence on r^2 — doubling the radius quadruples the terminal speed.

Answer: (C)

Sol. 8.

Solution

The **Second Law of Thermodynamics** has two classical statements:

- **Clausius statement**: Heat cannot spontaneously flow from a colder body to a hotter body; an external agent (work) is required. $\Rightarrow$ **Option (A) — correct.**
- **Kelvin-Planck statement**: No cyclic process can convert heat from a single reservoir entirely into work with no other effect.

- (B) describes the First Law (conservation of energy) — *wrong*.
- (C) violates the Kelvin-Planck statement — *wrong*.

- (D) is incorrect; converting work to heat can be 100% efficient, but the reverse cannot.

$\boxed{\textbf{Answer: (A)}}$

Sol. 9.

Solution

The van der Waals equation for n moles accounts for:

- **Intermolecular attraction**: adds pressure correction an^2/V^2 (increases effective pressure).
- **Finite molecular volume**: subtracts volume correction nb (reduces available volume).

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

This is **option (D)**. Option (C) uses a/V^2 without n^2, which is only valid for 1 mole.

$\boxed{\textbf{Answer: (D)}}$

Sol. 10.

Solution

When two sound waves of slightly different frequencies are superposed, **beats** are produced. The beat frequency is the absolute difference of the two frequencies:

$$f_{\text{beats}} = |f_2 - f_1| = |516 - 512| = \boxed{4\text{ Hz}}$$

The listener hears 4 loud-soft cycles per second. This phenomenon is used to tune musical instruments.

$\boxed{\textbf{Answer: (B)}}$

Sol. 11.

Solution

By **Gauss's Law**:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$$

The enclosed charge within the cylindrical Gaussian surface of length L is:

$$Q_{\text{enc}} = \lambda L$$

Therefore:

$$\Phi_E = \frac{\lambda L}{\varepsilon_0}$$

This is **option (C)**. (The flux through the two flat end-caps is zero because $\vec{E}$ is radial and perpendicular to the axial end-cap normals.)

Answer: (C)

Sol. 12.

Solution

In a potentiometer, the EMF is proportional to the balance length (potential gradient is constant):

$$\frac{\varepsilon_x}{\varepsilon_s} = \frac{\ell_x}{\ell_s}$$

$$\varepsilon_x = \varepsilon_s \times \frac{\ell_x}{\ell_s} = 1.5 \times \frac{75}{50} = 1.5 \times 1.5 = \boxed{2.25 \text{ V}}$$

The potentiometer is preferred over a voltmeter for accurate EMF measurement because it draws no current from the cell at balance.

Answer: (A)

Sol. 13.

Solution

The magnetic field inside a long solenoid is:

$$B = \mu_0 n I, \quad n = \frac{N}{L} = \frac{1000}{0.5} = 2000 \text{ turns/m}$$

$$B = 4\pi \times 10^{-7} \times 2000 \times 2 = 16\pi \times 10^{-4} \text{ T}$$

$$B = 16 \times 3.1416 \times 10^{-4} \approx 50.27 \times 10^{-4}\ \mathrm{T} \approx \boxed{5\ \mathrm{mT}}$$

The field is uniform and parallel to the axis inside; outside it is approximately zero.

Answer: (D)

Sol. 14.

Solution

The peak (maximum) EMF of an AC generator is:

$$\varepsilon_0 = NBA\omega$$

Substituting values:

$$\varepsilon_0 = 100 \times 0.4 \times 0.02 \times 50\pi = 100 \times 0.4 \times 0.02 \times 50\pi$$

$$= 100 \times 0.4 \times 1\pi = \boxed{40\pi\ \mathrm{V}} \approx 125.7\ \mathrm{V}$$

Step-by-step: $NBA = 100\times0.4\times0.02 = 0.8\ \mathrm{V\cdot s/rad}$; then $\varepsilon_0 = 0.8\times50\pi = 40\pi\ \mathrm{V}$.

Answer: (B)

Sol. 15.

Solution

For a capacitor C connected to $V = V_0 \sin(\omega t)$:

$$Q = CV \implies I = C\frac{dV}{dt} = CV_0\omega\cos(\omega t) = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

The current is $\pi/2 = 90$ *ahead* of the voltage. Equivalently, the **voltage lags the current by** 90.

- (A) incorrect — there is a 90 phase difference.
- (B) incorrect — it is current, not voltage, that leads.
- **(C) correct**: current leads voltage by 90.
- (D) incorrect — the angle is 90, not 45.

Answer: (C)

Sol. 16.

Solution

A myopic eye has a **far point** at $50 \text{ cm} = 0.50 \text{ m}$ (instead of infinity). The corrective lens must form a virtual image of a distant object (object at ∞) at the far point ($v = -50$ cm, using sign convention):

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-0.50} - \frac{1}{\infty} = -2 \text{ D}$$

$$P = \frac{1}{f} = \boxed{-2 \text{ D}}$$

A **concave (diverging) lens** of power -2 D is required. This is **option (A)**.

Answer: (A)

Sol. 17.

Solution

The **Rayleigh criterion** gives the minimum angular separation (limit of resolution) for a circular aperture of diameter D:

$$\theta_{\text{min}} = \frac{1.22\lambda}{D}$$

Resolving power $\propto 1/\theta_{\text{min}} \propto D/\lambda$.

- (A) Longer λ *decreases* resolving power — *wrong*.
- (B) Resolving power depends on λ and D, not just object size — *wrong*.
- (C) The limit of resolution is $1.22\lambda/D$ (not $D/1.22\lambda$) — *wrong*.
- **(D)** Shorter $\lambda \Rightarrow$ smaller $\theta_{\text{min}} \Rightarrow$ finer detail — **correct**.

Answer: (D)

Sol. 18.

Solution

The **Compton wavelength** of the electron:

$$\lambda_C = \frac{h}{m_e c} = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^{8}}$$

$$= \frac{6.63 \times 10^{-34}}{27.3 \times 10^{-23}} = \frac{6.63}{27.3} \times 10^{-11} \text{ m}$$

$$\approx 0.2429 \times 10^{-11}\text{ m} = 2.43 \times 10^{-12}\text{ m} = \boxed{2.43\text{ pm}}$$

This is **option (B)**. Note: 1 pm $= 10^{-12}$ m; 1 nm $= 10^{-9}$ m.

Answer: (B)

Solution

The **binding energy per nucleon** (BE/A) curve peaks at **iron-56** ($^{56}_{26}\text{Fe}$) with approximately 8.8 MeV/nucleon.

Sol. 19.

- $^{2}_{1}\text{H}$: BE/A ≈ 1.1 MeV — very low (lightest nucleus).
- $^{12}_{6}\text{C}$: BE/A ≈ 7.7 MeV — moderate.
- $^{56}_{26}\text{Fe}$: BE/A ≈ 8.8 MeV — **maximum.** ✓
- $^{235}_{92}\text{U}$: BE/A ≈ 7.6 MeV — lower than iron (heavier nucleus).

Nuclei lighter than Fe release energy by *fusion*; heavier nuclei release energy by *fission*.

Answer: (C)

Solution

A **NAND gate** is a NOT-AND gate. Its output is the complement of the AND operation:

$$Y = \overline{A \cdot B}$$

Truth table for NAND:

Sol. 20.

A	B	$Y = \overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

Option (A) is the primary definition. (Option D, $\bar{A} \cdot \bar{B}$, equals NOR by De Morgan — not NAND.)

Answer: (A)

SECTION B SOLUTIONS – Numerical Value Questions

Sol. 21.

Solution

For uniform circular motion, the **centripetal acceleration** is:

$$a_c = \omega^2 r = (3)^2 \times 2 = 9 \times 2 = \boxed{18 \text{ m/s}^2}$$

Alternatively, $v = \omega r = 6$ m/s, and $a_c = v^2/r = 36/2 = 18$ m/s^2.

Answer: (18)

Sol. 22.

Solution

In the Bohr model, the energy of the electron in orbit n is:

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

For $n = 3$:

$$E_3 = -\frac{13.6}{9} = -1.5\overline{1} \text{ eV}$$

$$|E_3| = \frac{13.6}{9} \approx \boxed{1.51 \text{ eV}}$$

(exact: $13.6/9 = 1.5111\ldots \approx 1.51$ eV to 2 decimal places)

Answer: (1.51)

Sol. 23.

Solution

Step 1: C_1 and C_2 in parallel:

$$C_{12} = C_1 + C_2 = 2 + 3 = 5\ \mu\text{F}$$

Step 2: C_{12} in series with $C_3 = 5\ \mu\text{F}$:

$$\frac{1}{C_{\text{eff}}} = \frac{1}{5} + \frac{1}{5} = \frac{2}{5} \implies C_{\text{eff}} = 2.5\ \mu\text{F}$$

Step 3: Energy stored with $V = 20$ V:

$$U = \frac{1}{2}C_{\text{eff}}V^2 = \frac{1}{2} \times 2.5 \times 10^{-6} \times 400 = 500 \times 10^{-6}\ \text{J} = \boxed{0.5\ \text{mJ}}$$

Answer: (0.5)

Sol. 24.

Solution

By **Faraday's Law of Electromagnetic Induction** (for a single-turn coil):

$$|\varepsilon| = \left|\frac{\Delta\Phi}{\Delta t}\right| = \frac{0.05 - 0.01}{0.01} = \frac{0.04}{0.01} = \boxed{4\ \text{V}}$$

The induced EMF is 4 V. The direction (Lenz's law) would oppose the increasing flux.

Answer: (4)

Sol. 25.

Solution

Let the null point be at distance d (cm) from the $+4\ \mu$C charge, so it is $(5-d)$ cm from the $+9\ \mu$C charge. Setting magnitudes of electric fields equal:

$$\frac{k \times 4 \times 10^{-6}}{d^2} = \frac{k \times 9 \times 10^{-6}}{(5-d)^2}$$

$$\frac{4}{d^2} = \frac{9}{(5-d)^2} \implies \frac{2}{d} = \frac{3}{5-d}$$

$$2(5-d) = 3d \implies 10 = 5d \implies d = \boxed{2 \text{ cm}}$$

Answer: (2)

Sol. 26.

Solution

The force on a current-carrying conductor in a magnetic field:

$$F = BIL\sin\theta$$

The wire is perpendicular to $\vec{B}$, so $\theta = 90$ and $\sin 90 = 1$:

$$F = 3\text{ T} \times 2\text{ A} \times 1\text{ m} \times 1 = \boxed{6\text{ N}}$$

The direction is given by the right-hand rule (or $\vec{F} = I\vec{L} \times \vec{B}$).

Answer: (6)

Sol. 27.

Solution

Mass defect verification:

$$\Delta m = (m_{^2\text{H}} + m_{^3\text{H}}) - (m_{^4\text{He}} + m_n) = (2.0141 + 3.0160) - (4.0026 + 1.0087)$$

$$= 5.0301 - 5.0113 = 0.0188\text{ u}$$

Energy released using $1\text{ u} = 931.5\text{ MeV}/c^2$:

$$E = 0.0188 \times 931.5 = \boxed{17.5\text{ MeV}}$$

This D-T fusion reaction releases the highest energy per unit mass among practical fusion fuels.

Answer: (17.5)

Sol. 28.

Solution

Activity is proportional to the number of undecayed nuclei: $A(t) \propto N_0(1/2)^{t/t_{1/2}}$.

The counts in each hour represent the average activity during that hour. The ratio of activities:

$$\frac{A_1}{A_2} = \frac{6400}{1600} = 4 = 2^2$$

This means the activity halved **twice** in 1 hour (2 half-lives elapsed in 60 minutes):

$$2 \times t_{1/2} = 60 \text{ min} \implies t_{1/2} = \boxed{30 \text{ min}}$$

Answer: (30)

Sol. 29.

Solution

The de Broglie wavelength after acceleration through potential difference V is:

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

For a proton (mass m_p, charge q_p) and an alpha particle (mass $4m_p$, charge $2q_p$):

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4m_p \times 2q_p}{m_p \times q_p}} = \sqrt{8} = 2\sqrt{2}$$

$$2\sqrt{2} = 2 \times 1.4142 \approx \boxed{2.83}$$

Answer: (2.83)

Sol. 30.

Solution

Step 1: Find T_C from original conditions ($\eta = 40\%$, $T_H = 600$ K):

$$\eta = 1 - \frac{T_C}{T_H} \implies 0.40 = 1 - \frac{T_C}{600} \implies T_C = 600 \times 0.60 = 360 \text{ K}$$

Step 2: Find new T'_H for $\eta' = 50\%$ with $T_C = 360$ K unchanged:

$$0.50 = 1 - \frac{360}{T'_H} \implies \frac{360}{T'_H} = 0.50 \implies T'_H = \frac{360}{0.50} = \boxed{720 \text{ K}}$$

Answer: (720)

1	D	2	B	3	C	4	A	5	D
6	B	7	C	8	A	9	D	10	B
11	C	12	A	13	D	14	B	15	C
16	A	17	D	18	B	19	C	20	A

21	18	22	1.51
23	0.5	24	4
25	2	26	6
27	17.5	28	30
29	2.83	30	720