VITEEE 2019 Question Paper with Solutions for Physics

Time Allowed : 90 Minutes	Maximum Marks : 80	Total Questions : 80

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The question paper contains a total of 80 questions divided into four parts:
   - Part I: Physics (Questions 1 to 25)
   - Part II: Chemistry (Questions 26 to 50)
   - Part III: Mathematics (Questions 51 to 75)
   - Part IV: English & Logical Reasoning (Questions 76 to 80)
2. All questions are multiple-choice with four options, and only one of them is correct.
3. For each correct answer, the candidate will earn 1 mark.
4. There is no negative marking for incorrect answers.
5. The test duration is 12 hours.

1. A mass m rotates in a vertical circle of radius R and has a circular speed v_c at the top. If the radius of the circle is increased by a factor of 4, circular speed at the top will be
(A) decreased by a factor of 2
(B) decreased by a factor of 4
(C) increased by a factor of 2
(D) increased by a factor of 4
Correct Answer: (C) increased by a factor of 2

Solution:
The critical minimum speed (v_c) required for a mass m to complete a vertical circle of radius R is given by the equation:
$v_c = \sqrt{gR}$.

We are given the initial critical speed $v_{c1} = \sqrt{gR}$.

The radius is increased by a factor of 4, so the new radius is $R' = 4R$.

The new critical speed v_c' is:
$v_c' = \sqrt{gR'} = \sqrt{g(4R)}$.

$v_c' = 2\sqrt{gR}$.

Since $v_c = \sqrt{gR}$, we have $v'_c = 2v_c$.

The circular speed at the top is increased by a factor of 2.

Quick Tip

The critical speed required to complete a vertical loop depends only on the radius of the loop and the gravitational acceleration ($v_c = \sqrt{gR}$), independent of the mass m.

---

2. A vessel contains 1 mol of O_2 and 2 mol of He. What is the value of 'C_p/C_v' of the mixture?
(A) 17/11
(B) 71/65
(C) 38/15
(D) 46/15
Correct Answer: (A) 17/11

Solution:
O_2 is a diatomic gas ($n_1 = 1$ mol): $C_{v1} = 5R/2$.
He is a monoatomic gas ($n_2 = 2$ mol): $C_{v2} = 3R/2$.

The molar specific heat capacity at constant volume for the mixture ($C_{v,mix}$) is:
$C_{v,mix} = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2}$.

$C_{v,mix} = \frac{(1)(\frac{5R}{2}) + (2)(\frac{3R}{2})}{1+2}$.

$C_{v,mix} = \frac{5R/2 + 3R}{3} = \frac{11R/2}{3} = \frac{11R}{6}$.

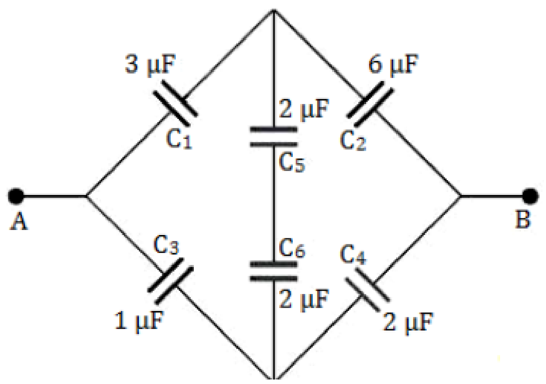
The molar specific heat capacity at constant pressure for the mixture ($C_{p,mix}$) is derived using Mayer's relation $C_p = C_v + R$:
$C_{p,mix} = C_{v,mix} + R = \frac{11R}{6} + R = \frac{17R}{6}$.

The required ratio $\gamma_{mix} = C_p/C_v$ is:
$\gamma_{mix} = \frac{17R/6}{11R/6} = \frac{17}{11}$.

Quick Tip

The specific heat ratio $\gamma = C_p/C_v$ for a mixture depends on the weighted average of C_v values of the components. Remember $C_v = fR/2$, where f is the degrees of freedom (3 for monoatomic, 5 for diatomic).

3. The effective capacitance between terminals A and B (as shown in the figure) is



(A) 16 μF
(B) 8 μF
(C) 6 μF
(D) 8/3 μF
Correct Answer: (D) 8/3 μF

Solution:
The circuit is a Wheatstone bridge configuration. Let $C_1 = 3\mu$F, $C_2 = 6\mu$F, $C_3 = 1\mu$F, $C_4 = 2\mu$F.

We check the balance condition: C_1/C_3 versus C_2/C_4.
$C_1/C_3 = 3/1 = 3$.
$C_2/C_4 = 6/2 = 3$.

Since $C_1/C_3 = C_2/C_4$, the bridge is balanced.

Capacitors C_5 (2 μF) and C_6 (2 μF) are connected between points of equal potential, so they carry no charge and can be ignored.

The equivalent capacitance is calculated by treating the upper branch (C_1 and C_2 in series) and the lower branch (C_3 and C_4 in series) as being in parallel.

Upper branch equivalent capacitance (C_{upper}):
$C_{upper} = \frac{C_1 C_2}{C_1+C_2} = \frac{3\times6}{3+6} = \frac{18}{9} = 2\mu$F.

Lower branch equivalent capacitance (C_{lower}):
$C_{lower} = \frac{C_3 C_4}{C_3+C_4} = \frac{1\times2}{1+2} = \frac{2}{3}\mu$F.

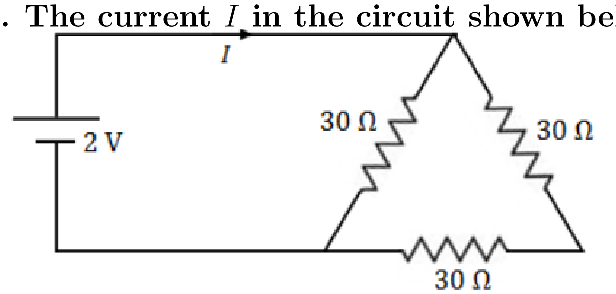
Total effective capacitance (C_{eq}):
$C_{eq} = C_{upper} + C_{lower} = 2 + \frac{2}{3}$.

$C_{eq} = \frac{6}{3} + \frac{2}{3} = \frac{8}{3}\mu$F.

> **Quick Tip**
>
> In a balanced capacitive Wheatstone bridge, the central connection (between the intermediate points) does not affect the overall capacitance and can be disregarded for simplification.

---

4. The current I in the circuit shown below is



(A) $\frac{1}{45}$ A
(B) $\frac{1}{15}$ A
(C) $\frac{1}{10}$ A
(D) $\frac{1}{5}$ A
Correct Answer: (C) $\frac{1}{10}$ A

Solution:
The circuit consists of a 2 V voltage source connected across two vertices of a delta (Δ) configuration of three identical 30Ω resistors.

Let the terminals be connected across resistor $R_1 = 30\Omega$.

The remaining two resistors, $R_2 = 30\Omega$ and $R_3 = 30\Omega$, are connected in series between the same two vertices.
$R_{series} = R_2 + R_3 = 30\Omega + 30\Omega = 60\Omega$.

The equivalent resistance (R_{eq}) is found by combining R_1 and R_{series} in parallel:
$R_{eq} = \frac{R_1 \times R_{series}}{R_1 + R_{series}} = \frac{30 \times 60}{30+60}$.

$R_{eq} = \frac{1800}{90} = 20\Omega$.

The total current I drawn from the source is calculated using Ohm's Law:
$I = \frac{V}{R_{eq}} = \frac{2 \text{ V}}{20\Omega}$.

$I = \frac{1}{10}$ A.

Quick Tip

When calculating the equivalent resistance of a symmetrical Δ network connected across two terminals, the resistance across the terminals is parallel to the series combination of the other two resistances.

---

5. An electric wire in the wall of a building carries a DC current of 25 A vertically upward. What is the magnetic field due to this current at a point which is 10 cm to the right of the wire?
(A) 3.1×10^{-4} T
(B) 5.0×10^{-5} T
(C) 4.23×10^{-4} T
(D) 5.11×10^{-3} T
Correct Answer: (B) 5.0×10^{-5} T

Solution:
The magnetic field B due to an infinitely long straight conductor carrying current I at a perpendicular distance r is given by:
$B = \frac{\mu_0 I}{2\pi r}$.

Given values: $I = 25$ A.
Distance $r = 10$ cm $= 0.10$ m.
Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ T $\cdot$ m/A.

Substitute the values:
$B = \frac{(4\pi \times 10^{-7}) \times 25}{2\pi \times 0.10}$.

Simplify the constants: $\frac{4\pi}{2\pi} = 2$.
$B = \frac{2 \times 10^{-7} \times 25}{0.10}$.

$B = \frac{50 \times 10^{-7}}{0.1}$.

$B = 500 \times 10^{-7}$ T.

$B = 5.0 \times 10^{-5}$ T.

Quick Tip

The direction of the magnetic field can be found using the Right-Hand Thumb Rule. If the current is upward, the field lines circulate counterclockwise. At a point to the right, the magnetic field points into the page.

6. In an electric circuit, R, C, L and AC voltage are all connected in series. When L is removed from the LCR circuit, the phase difference between the voltage and the current in the circuit is $\pi/3$. If instead, C is removed from the LCR circuit, the phase difference is again $\pi/3$. Determine the power factor of the circuit.
(A) $\frac{1}{2}$
(B) $\frac{1}{\sqrt{2}}$
(C) 1
(D) $\frac{\sqrt{3}}{2}$
Correct Answer: (C) 1

Solution:
The phase difference ϕ in an AC circuit is given by $\tan\phi = \frac{X_L - X_C}{R}$.

Case 1: L is removed (RC circuit). $X_L = 0$. Phase difference $\phi_1 = \pi/3$.
$\tan(\pi/3) = \left|\frac{0 - X_C}{R}\right| = \frac{X_C}{R}$.
$X_C/R = \sqrt{3}$. (1)

Case 2: C is removed (RL circuit). $X_C = 0$. Phase difference $\phi_2 = \pi/3$.
$\tan(\pi/3) = \left|\frac{X_L - 0}{R}\right| = \frac{X_L}{R}$.
$X_L/R = \sqrt{3}$. (2)

From equations (1) and (2), we deduce $X_C = R\sqrt{3}$ and $X_L = R\sqrt{3}$.
Thus, $X_L = X_C$.

For the original LCR circuit, the net reactance is zero, $X_{net} = X_L - X_C = 0$.
The phase difference ϕ of the LCR circuit is:
$\tan\phi = \frac{X_L - X_C}{R} = \frac{0}{R} = 0$.
This implies $\phi = 0$. The circuit is in resonance.

The power factor is given by $\cos\phi$:
Power factor $= \cos(0) = 1$.

Quick Tip

If removing L results in the same phase shift as removing C, the capacitive reactance (X_C) must equal the inductive reactance (X_L). This means the original LCR circuit is operating at resonance, where the impedance $Z = R$ and the power factor is $\cos(0) = 1$.

---

7. A short object of length l is placed along the principal axis of a concave mirror away from focus. The object distance is x. If the mirror has a focal length f what

will be the length of the image? ($l \ll |v - f|$, where v is the image distance)
(A) $\frac{(x-f)^2}{f^2 l}$
(B) $\frac{f^2 l}{(x-f)^2}$
(C) $\frac{fl}{(x-f)}$
(D) $\frac{(x-f)}{fl}$
Correct Answer: (B) $\frac{f^2 l}{(x-f)^2}$

Solution:

Since the object is short and placed along the principal axis, the image length is determined using **longitudinal magnification**.
Step 1: Longitudinal magnification relation
For mirrors,

$$m_L = \frac{l'}{l} = m_T^2$$

where m_T is the transverse magnification.
Step 2: Transverse magnification for mirror

$$m_T = -\frac{v}{u}$$

Using the mirror formula:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Solving for v:

$$v = \frac{uf}{u - f}$$

Step 3: Substitute in magnification

$$m_T = -\frac{v}{u} = -\frac{f}{u - f}$$

Given object distance $u = -x$ (sign convention),

$$|m_T| = \frac{f}{x - f}$$

Step 4: Image length

$$l' = l\, m_T^2 = l \left(\frac{f}{x - f} \right)^2$$

$$\boxed{l' = \frac{f^2 l}{(x - f)^2}}$$

💡 Quick Tip

For small objects placed axially along the principal axis, the longitudinal magnification m_L is approximated by the square of the transverse magnification m_T: $m_L = m_T^2$. Also remember the useful forms of transverse magnification: $m_T = \frac{f}{f-u} = \frac{v-f}{f}$.

---

8. The wavelength of the characteristic X-ray K_α line emitted by a hydrogen like element is 0.32 Å. The wavelength of K_β line emitted by the same element will be

(A) 0.21 Å
(B) 0.27 Å
(C) 0.34 Å
(D) 0.40 Å

Correct Answer: (B) 0.27 **Å**

Solution:

Characteristic X-ray wavelengths follow Moseley's law:

$$\frac{1}{\lambda} \propto (Z-b)^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Since the element is the same, the factor $(Z-b)^2$ is constant. Hence,

$$\frac{1}{\lambda} \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For K_α line:
Transition: $n_2 = 2 \to n_1 = 1$

$$\frac{1}{\lambda_\alpha} \propto \left(1 - \frac{1}{4}\right) = \frac{3}{4}$$

For K_β line:
Transition: $n_2 = 3 \to n_1 = 1$

$$\frac{1}{\lambda_\beta} \propto \left(1 - \frac{1}{9}\right) = \frac{8}{9}$$

Taking ratio:

$$\frac{\lambda_\alpha}{\lambda_\beta} = \frac{8/9}{3/4} = \frac{32}{27}$$

Given: $\lambda_\alpha = 0.32\,\text{Å}$

$$\lambda_\beta = 0.32 \times \frac{27}{32} = 0.27\,\text{Å}$$

💡 Quick Tip

Remember the transitions for K series X-rays: K_α is $n = 2 \rightarrow n = 1$, K_β is $n = 3 \rightarrow n = 1$. Since $1/\lambda$ is proportional to the difference of inverse squares, the wavelengths are inversely proportional to this difference ratio.

---

9. The number of alpha-particles scattered at 60° is 100 per minute in an alpha-scattering experiment on gold foil. The number of alpha-particles scattered per minute at 90° will be

(A) 25

(B) 50

(C) 16

(D) 32

Correct Answer: (A) 25

Solution:

According to Rutherford's scattering formula, the number of alpha particles scattered (N) through an angle θ is inversely proportional to the fourth power of the sine of half the scattering angle.

$N \propto \frac{1}{\sin^4(\theta/2)}$.

We compare the counts at two different angles $\theta_1 = 60^\circ$ and $\theta_2 = 90^\circ$.
Given $N_1 = 100$ per minute at $\theta_1 = 60^\circ$. Find N_2 at $\theta_2 = 90^\circ$.

$\frac{N_2}{N_1} = \frac{\sin^4(\theta_1/2)}{\sin^4(\theta_2/2)}$.

Calculate half-angles and sine values:
$\theta_1/2 = 60^\circ/2 = 30^\circ$. $\sin(30^\circ) = 1/2$.
$\theta_2/2 = 90^\circ/2 = 45^\circ$. $\sin(45^\circ) = 1/\sqrt{2}$.

Substitute these values:
$\frac{N_2}{100} = \frac{(1/2)^4}{(1/\sqrt{2})^4}$.

$\frac{N_2}{100} = \frac{1/16}{1/4}$.

$\frac{N_2}{100} = \frac{4}{16} = \frac{1}{4}$.

$N_2 = 100/4 = 25$.
The number of alpha-particles scattered per minute at 90° is 25.

Quick Tip

The highly sensitive dependence on the scattering angle ($\propto\ 1/\sin^4(\theta/2)$) is the key result of the Rutherford model, demonstrating that large angle scattering requires interaction with a concentrated, massive nucleus.

---

10. A p-n junction diode connected in series with a resistor of $200\ \Omega$ is forward biased so that a current of 200 mA flows. If the voltage across this combination is instantaneously reversed at $t = 0$, the current through diode is approximately,
(A) 400 mA
(B) 200 mA
(C) 100 mA
(D) 0 mA
Correct Answer: (B) 200 mA

Solution:

Initially, the diode is forward biased and a steady current of

$$I_F = 200\,\text{mA} = 0.2\,\text{A}$$

flows through the resistor $R = 200\,\Omega$.

The corresponding applied voltage is approximately

$$V \approx I_F R = (0.2)(200) = 40\,\text{V}$$

(neglecting the small diode forward drop).

At time $t = 0$, the applied voltage is instantaneously reversed. However, the current through the diode does **not** drop to zero immediately due to the presence of stored minority charge carriers in the diode (reverse recovery effect).

Just after reversal ($t = 0^+$):
The diode behaves momentarily like a short circuit, and the reverse current is limited only by the external resistor.

$$I(0^+) = \frac{V}{R} = \frac{40}{200} = 0.2\,\text{A} = 200\,\text{mA}$$

Thus, the magnitude of the instantaneous current just after reversal is equal to the initial forward current.

Quick Tip

When a diode transitions instantaneously from forward bias to reverse bias, the reverse current initially matches the forward current magnitude ($I_R \approx I_{FB}$), limited only by the external circuit resistance, before the diode fully blocks the flow during the reverse recovery time (t_{rr}).