JEE (Main) 2020

COMPUTER BASED TEST (CBT)

Questions & Solutions

Date: 09 January, 2020 (SHIFT-1) | TIME: (9.30 am to 12.30 pm)

Duration: 3 Hours | Max. Marks: 300

SUBJECT: PHYSICS
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### Single Choice Type (एकल विकल्पीय प्रकार)

This section contains 20 Single choice questions. Each question has 4 choices (1), (2), (3) and (4) for its answer, out of which Only One is correct.

**инфек्रिय एकल विकल्पीय प्रश्न हैं। प्रत्येक प्रश्न के 4 विकल्प (1), (2), (3) तथा (4) हैं, जिनमें से सिर्फ एक सही हैं।**

1. Radiation, with wavelength 6561 Å falls on a metal surface to produce photoelectrons. The electrons are made to enter a uniform magnetic field of $3 \times 10^{-4}$ T. If the radius of the largest circular path followed by the electrons is 10 mm, the work function of the metal is close to:

<table>
<thead>
<tr>
<th>(1) 1.8 eV</th>
<th>(2) 0.8 eV</th>
<th>(3) 1.6 eV</th>
<th>(4) 1.1 eV</th>
</tr>
</thead>
</table>

**Ans. (2)**

**Sol.**

$KE_{\text{max}} = E - \phi$

$= \frac{12400}{\lambda (\text{in Å})} - \phi$ (in eV)

$\therefore r = \frac{\sqrt{2mKE}}{eB}$

$KE_{\text{max}} = \frac{r^2e^2B^2}{2m}$ (in J)

$= \frac{r^2e^2B^2}{2m}$ (in eV)

$\therefore \phi = \frac{12400}{6561} - \frac{r^2e^2B^2}{2m} = 1.1$ eV

2. An electric dipole of moment $\vec{p} = (-i - 3j + 2k) \times 10^{-29}$ C.m. is at the origin (0, 0, 0). The electric field due to this dipole at $\vec{r} = (+i + 3j + 5k)$ (note that $\vec{r} \cdot \vec{p} = 0$) is parallel to:

(1) (+i + 3j - 2k)  
(2) (-i + 3j - 2k)  
(3) (+i - 3j - 2k)  
(4) (-i - 3j + 2k)

**Ans. (1)**
Since \( \hat{p} \cdot \hat{f} = 0 \)

\( \vec{E} \) must be antiparallel to \( \hat{p} \)

\( \vec{E} \), \( \hat{p} \) के प्रतिपादनात्मक होता है

So, \( \vec{E} = -\lambda \hat{p} \)

where \( \lambda \) is a arbitrary positive constant

जहाँ \( \lambda \) कोई एक धनात्मक नियतांक है

Now \( \hat{A} = a \hat{i} + b \hat{j} + c \hat{k} \)

\[ \hat{A} = a \hat{i} + b \hat{j} + c \hat{k} \]

\[ \hat{A} \parallel \vec{E} \]

\[ \frac{a}{\lambda} = \frac{b}{-2\lambda} = \frac{c}{k} \]

so इसलिए \( \hat{A} = \lambda (\hat{i} + 3\hat{j} - 2\hat{k}) \)

3. The aperture diameter of a telescope is 5 m. The separation between the moon and the earth is \( 4 \times 10^5 \) km. With light of wavelength of 5500 Å, the minimum separation between objects on the surface of moon, so that they are just resolved, is close to:

एक टेलीस्कोप के छाया का व्यास 5 मी है। चंद्रमा और भूमि के बीच की दूरी 4 \times 10^5 km है। यदि प्रकाश का तरंगांश 5500 Å लिया जाये तो चंद्रमा पर दो वस्तुओं के बीच की सीमांत दूरी कितनी होगी जिससे उनमें किस्मत करा जा सके:

(1) 600 m  (2) 20 m  (3) 200 m  (4) 60 m

Ans. (4)

Sol.

\[ \theta = 1.22 \frac{\lambda}{a} \]
distance \( O_1O_2 = d \theta = 1.22 \frac{\lambda}{a} \)

distance \( O_1O_2 = \frac{1.22 \times 5893 \times 10^{-10} \times 4 \times 10^8}{5} \approx 57.5 \text{ m} \)

\[ \therefore \text{ answer from options विकल्पों के आधार पर उत्तर } = 60\text{m} \]

(minimum distance न्यूनतम दूरी)

4. A charged particle of mass 'm' and charge 'q' moving under the influence of uniform electric field \( \vec{E} \) and a uniform magnetic field \( \vec{B} \) follows a trajectory from point P to Q as shown in figure. The velocities at P and Q are respectively, \( \vec{v}_1 \) and \( -2\vec{v}_2 \). Then which of the following statements (A, B, C, D) are the correct? (Trajectory shown is schematic and not to scale)

\[ \text{द्रव्यमान 'm' और आवेश 'q' का एक कण एक समानांतर क्षेत्र } \vec{E} \text{ तथा एकसमान चुम्बकीय क्षेत्र } \vec{B} \text{ में चलता हुआ किन्द्र } P \text{ से चित्र में दिखाये गये पथ पर चलकर किन्द्र } Q \text{ तक पहुँचता है। कण का किन्द्रों } P \\text{ और } Q \text{ पर वेग क्रमशः } \vec{v}_1 \text{ तथा } -2\vec{v}_2 \text{ है। ऐसे में नीचे दिये गये कथनों (A, B, C, D) में से कोन-कोन से कथन सही हैं? (दिखाया गया पथ सांकेतिक है) } \]

(A) \( E = \frac{3}{4} \left( m \frac{v^2}{qa} \right) \)

(B) Rate of work done by the electric field at P is \( \frac{3}{4} \left( m \frac{v^3}{a} \right) \)

(C) Rate of work done by both the fields at Q is zero

(D) The difference between the magnitude of angular momentum of the particle at P and Q is 2mav.
5. Three harmonic waves having equal frequency \( v \) and same intensity \( I_0 \), have phase angles \( 0, \frac{\pi}{4} \) and \( -\frac{\pi}{4} \) respectively. When they are superimposed the intensity of the resultant wave is close to:

एक समान आवृत्ति \( v \) तथा \( I_0 \) की सीन हरतमक तरंगों के कालाकांक क्रमशः \( 0, \frac{\pi}{4} \) तथा \( -\frac{\pi}{4} \) हैं। जब इन तरंगों के अध्यायरोपित (superimposed) करा जाता है तो परिणामी तरंग की तीव्रता होगी:

(1) 5.8 \( I_0 \)  
(2) 3 \( I_0 \)  
(3) \( 0.2 I_0 \)  
(4) \( I_0 \)  

Ans. (1)
Sol. \[
A_{\text{res}} = \left(\sqrt{2} + 1\right)A
\]
\[
I_{\text{res}} = \left(\sqrt{2} + 1\right)^2 I_0
\]
\[
= \left(3 + 2\sqrt{2}\right)I_0 = 5.8 I_0
\]

6. Consider a force \( \mathbf{F} = -x \hat{i} + y \hat{j} \). The work done by this force in moving a particle from point A(1, 0) to B(0, 1) along the line segment is:

(All quantities are in SI units)

\[W = \int \mathbf{F} \cdot d\mathbf{s} = \int (-x \hat{i} + y \hat{j}) \cdot (dx \hat{i} + dy \hat{j})\]
\[= \int_{1}^{0} -xdx + \int_{0}^{1} ydy\]
\[= -\frac{x^2}{2}\bigg|_{1}^{0} + \frac{y^2}{2}\bigg|_{0}^{1} = \left(0 + \frac{1}{2}\right) + \left(\frac{1}{2}\right) = 1\text{J}\]
7. Three solid spheres each of mass \( m \) and diameter \( d \) are stuck together such that the lines connecting the centres form an equilateral triangle of side of length \( d \). The ratio \( I_0/I_A \) of moment of inertia \( I_0 \) of the system about an axis passing the centroid and about center of any of the spheres \( I_A \) and perpendicular to the plane of the triangle is:

\[
\frac{I_0}{I_A} = \frac{13}{23}
\]

\[\text{(3)}\]

**Ans.** (3)

**Sol.**

M.I about P के परिक जड़त्व आपूर्ण =

\[
3 \left[ \frac{2}{5} M \left( \frac{d}{2} \right)^2 + \frac{M}{\sqrt{3}} \left( \frac{d}{\sqrt{3}} \right)^2 \right] = \frac{13}{10} M d^2
\]

M.I about B के परिक जड़त्व आपूर्ण =

\[
2 \left[ \frac{2}{5} M \left( \frac{d}{2} \right)^2 + \frac{M}{\sqrt{3}} \left( \frac{d}{\sqrt{3}} \right)^2 \right] + \frac{2}{5} M \left( \frac{d}{2} \right)^2 = \frac{23}{10} M d^2
\]

Now ratio (अब अनुपात) = \( \frac{13}{23} \)
8. A vessel of depth 2h is half filled with a liquid of refractive index $2\sqrt{2}$ and the upper half with another liquid of refractive index $\sqrt{2}$. The liquids are immiscible. The apparent depth of the inner surface of the bottom of vessel will be:

\[ \frac{h}{3\sqrt{2}} \quad \frac{3}{4}h\sqrt{2} \quad \frac{h}{\sqrt{2}} \quad \frac{h}{2(\sqrt{2}+1)} \]

Ans. (2)

Sol.

\[
\begin{align*}
\text{d} &= \frac{h}{\sqrt{2}} + \frac{h}{2\sqrt{2}} \\
\Rightarrow \text{d} &= \frac{h}{\sqrt{2}} \times \frac{3}{2} = \frac{3\sqrt{2}h}{4}
\end{align*}
\]

9. A long, straight wire of radius $a$ carries a current distributed uniformly over its cross-section. The ratio of the magnetic fields due to the wire at distance $\frac{a}{3}$ and $2a$, respectively from the axis of the wire is:

\[ \frac{1}{2} \quad 2 \quad \frac{3}{2} \quad \frac{2}{3} \]

Ans. (4)

Sol.

\[
\begin{align*}
B_A &= \frac{\mu_0 i r}{2\pi a^2} = \frac{\mu_0 \frac{a}{3}}{2\pi a^2} = \frac{\mu_0 a}{6\pi a} = \frac{\mu_0 i}{6\pi} \\
B_B &= \frac{\mu_0 i}{2\pi(2a)} \\
\frac{B_A}{B_B} &= \frac{4}{6} = \frac{2}{3}
\end{align*}
\]
10. A body A of mass \( m \) is moving in a circular orbit of radius \( R \) about a planet. Another body B of mass \( \frac{m}{2} \) collides with A with a velocity which is half \( \frac{v}{2} \) the instantaneous velocity \( v \) of A. The collision is completely inelastic. Then, the combined body:

1. Escapes from the planet’s gravitational field
2. Continues to move in a circular orbit
3. Falls vertically downwards towards the planet
4. Starts moving in an elliptical orbit around the planet

\[ \text{Ans. (4)} \]

\[ \text{Sol.} \]

Conserving momentum:

\[ \frac{m}{2} \frac{v}{2} + mv = \left( \frac{m + \frac{m}{2}}{2} \right) v_f \]

\[ v_f = \frac{5mv}{4 \times \frac{3m}{2}} = \frac{5v}{6} \]

\[ v_f < v_{orb} (= v) \] thus the combined mass will go on to an elliptical path

\[ v_f < v_{orb} (= v) \] \text{after partially moving a circular path before getting into an elliptical path}.

11. A particle moving with kinetic energy \( E \) has de Broglie wavelength \( \lambda \). If energy \( \Delta E \) is added to its energy, the wavelength becomes \( \lambda/2 \). Value of \( \Delta E \), is:

\[ \text{Ans. (2)} \]

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The electric fields of two plane electromagnetic plane waves in vacuum are given by:
\[ \vec{E}_1 = \hat{E}_0 \hat{i} \cos(\omega t - kx), \quad \vec{E}_2 = \hat{E}_0 \hat{k} \cos(\omega t - ky) \]

At \( t = 0 \), a particle of charge \( q \) is at origin with a velocity \( \vec{v} = 0.8\hat{c}\hat{j} \) (\( c \) is the speed of the light in vacuum). The instantaneous force experienced by the particle is:

\[ \vec{F} = q \vec{E}_1 + q \vec{E}_2 \]

The net Lorentz force on the charged particle is \( \vec{F} \) on the charged particle is:

\[ \vec{F} = q \vec{E}_0 [0.8\cos(kx - \omega t)\hat{i} + \cos(kx - \omega t)\hat{j} + 0.2\cos(ky - \omega t)\hat{k}] \]

at \( t = 0 \) and \( x = y = 0 \)

\[ \vec{F} = q \vec{E}_0 [0.8\hat{i} + \hat{j} + 0.2\hat{k}] \]
13. In the given circuit diagram, a wire is joining points B and D. The current in this wire is:

In the circuit diagram, a wire is joining points B and D. The current in this wire is:

\[ R_{\text{eff}} = \frac{4}{5} + \frac{6}{5} = 2 \Omega \]

\[ i = \frac{20}{2} = 10 \text{A} \]

\[ I = \frac{4i}{5} - \frac{3i}{5} = \frac{i}{5} = 2 \text{A} \]
14. Consider a sphere of radius \( R \) which carries a uniform charge density \( \rho \). If a sphere of radius \( \frac{R}{2} \) is carved out of it, as shown, the ratio \( \frac{E_A}{E_B} \) of magnitude of electric field \( E_A \) and \( E_B \), respectively, at points A and B due to the remaining portion is:

\[ \frac{E_A}{E_B} \]

Answer: (1)

Solution:

For a solid sphere, the electric field at a point is given by:

\[ E = \frac{\rho r}{3\epsilon_0} \]

For point A:

\[ E_A = \frac{-\rho R}{2(3\epsilon_0)} \]

For point B:

\[ E_B = \frac{\rho R}{6\epsilon_0} \]

Electric field at point B (where \( B \) is the remaining portion):

\[ E_B = E_{1A} + E_{2A} \]

\[ E_{1A} = \text{Electric Field Due to solid sphere of radius } R \text{ at point } B = \frac{\rho R}{3\epsilon_0} \]

\[ E_{2A} = \text{Electric Field Due to solid sphere of radius } \frac{R}{2} \text{ (which having charge density } -\rho \text{)} \]

\[ E_{2A} = \frac{\rho R}{54\epsilon_0} \]

\[ \left| \frac{E_A}{E_B} \right| = \frac{9}{17} \]
15. Consider two ideal diatomic gases A and B at some temperature T. Molecules of the gas A are rigid, and have a mass $m$. Molecules of the gas B have an additional vibrational mode, and have a mass $\frac{m}{4}$.

The ratio of the specific heats $\left( C_V^A \text{ and } C_V^B \right)$ of gas A and B, respectively is:

(1) $3 : 5$  
(2) $5 : 9$  
(3) $7 : 9$  
(4) $5 : 7$

Ans. (4)

Sol. Molar heat capacity of A at constant volume $= \frac{5R}{2}$

A की मोलर विशिष्ट ऊष्मा धारिता नियत आयातन पर $= \frac{5R}{2}$

Molar heat capacity of B at constant volume $= \frac{7R}{2}$

B की मोलर विशिष्ट ऊष्मा धारिता नियत आयातन पर $= \frac{7R}{2}$

Dividing both मान देने पर,

$$\frac{C_V^A}{C_V^B} = \frac{5}{7}$$

16. Two particles of equal mass $m$ have respective initial velocities $\mathbf{u}$ and $\mathbf{u} + \left( \frac{\mathbf{i} + \mathbf{j}}{2} \right)$. They collide completely inelastically. The energy lost in the process is:

(1) $\frac{3}{4}mu^2$  
(2) $\sqrt{\frac{2}{3}}mu^2$  
(3) $\frac{1}{3}mu^2$  
(4) $\frac{1}{8}mu^2$

Ans. (4)
Conserving momentum संरक्षण से

\[ mv_i + m \left( \frac{v_i + v_j}{2} \right) = 2m(v_i + v_j) \]

on solving हल करने पर

\[ v_1 = \frac{3v}{4} \text{ and } v_2 = \frac{v}{4} \]

Change in K.E. गतिज ऊर्जा में परिवर्तन

\[
\left[ \frac{1}{2}mv^2 + \frac{1}{2}m\left(\frac{v}{2}\right)^2 \right] - \left[ \frac{1}{2}(2m)\left(\frac{9v^2}{16} + \frac{v^2}{16}\right) \right]
\]

\[ = \frac{3mv^2}{4} - \frac{5mv^2}{8} = \frac{mv^2}{8} \]

17. If the screw on a screw-gauge is given six rotations, it moves by 3mm on the main scale. If there are 50 divisions on the circular scale the least count of the screw gauge is:

एक स्क्रू गेज में यदि पेच को छः बार घुमाया जाये तो यह मुख्य पैमाने पर 3mm की दूरी तय करता है। यदि वृत्तीय पैमाने पर 50 भाग हों तो स्क्रू गेज का अन्तपत्तांक कितना होगा?

(1) 0.01 cm  (2) 0.02 mm  (3) 0.001 mm  (4) 0.001 cm

Ans. (4)

Sol. Pitch फिच = \( \frac{3}{6} \) = 0.5 mm

L.C. = \( \frac{0.5 \text{ mm}}{50} \) = \( \frac{1}{100} \) mm = 0.01 mm

= 0.001 cm
18. Which of the following is an equivalent cyclic process corresponding to the thermodynamic cyclic given in the figure? where, 1 → 2 is adiabatic. (Graphs are schematic and are not to scale)

नीचे दिये गये ग्राफों में से कौन सा ग्राफ चित्र में दिखायी गयी ऊथागातिज चक्रीय प्रक्रिया के समतुल्य चक्रीय प्रक्रिया दर्शाता है? चित्र में 1 → 2 एक सन्दर्भ प्रक्रिया है। (चित्र सांकेतिक है।)

![Diagram](image_url)

**Ans.** (1)

**Sol.** For process A – B प्रक्रिया के लिए; Volume is constant आयतन निर्धारित है;  
\[ PV = nRT \]

as P increases वाक्य से प्रकट है; T increases वाक्य से प्रकट है

For process B – C प्रक्रिया के लिए;
\[ PV = \text{Constant} \]

\[ \Rightarrow TV^{-1} = \text{Constant} \]

For process C – A प्रक्रिया के लिए; pressure is constant दाब निर्धारित है
\[ V = kT \]
19. Water flows in a horizontal tube (see figure). The pressure of water changes by 700 Nm\(^{-2}\) between A and B where the area of cross section are 40 cm\(^2\) and 20 cm\(^2\), respectively. Find the rate of flow of water through the tube.

(density of water = 1000 kgm\(^{-3}\))

एक क्षेत्रिय नली में पानी बह रहा है (चित्र देखें)। इस नली में A से Bके बीच पानी के दबाव में 700 Nm\(^{-2}\) का अंतर है। A और B पर नली की अनुप्रस्ताव काटा का क्षेत्रफल क्रमशः 40 cm\(^2\) और 20 cm\(^2\) है। नली में पानी के बहाव की दर है

(पानी का घनत्व = 1000 kgm\(^{-3}\))

\[
(\text{1) } 2720 \text{ cm}^3/\text{s} \quad (\text{2) } 2420 \text{ cm}^3/\text{s} \quad (\text{3) } 3020 \text{ cm}^3/\text{s} \quad (\text{4) } 1810 \text{ cm}^3/\text{s}
\]

Ans. (1)

Sol. using equation of continuity सांत्यता की समीकरण से

\[
40 V_A = 20 V_B
\]

\[
\Rightarrow 2V_A = V_B
\]

Using Bernoullies equation कर्नोली समीकरण से

\[
P_A + \frac{1}{2} \rho V_A^2 = P_B + \frac{1}{2} \rho V_B^2
\]

\[
\Rightarrow P_A - P_B = \frac{1}{2} \rho (V_B^2 - V_A^2)
\]

\[
\Rightarrow \Delta P = \frac{1}{2} \cdot 1000 \left( V_B^2 - \frac{V_B^2}{4} \right)
\]

\[
\Rightarrow \Delta P = 500 \times \frac{3}{4} V_B^2
\]

\[
\Rightarrow V_B = \sqrt{\frac{(\Delta P) \times 4}{1500}} = \sqrt{\frac{(700) \times 4}{1500}} \text{ m/s}
\]

Volume flow rate आयतन प्रवाह दर = \(20 \times 100 \times V_B = 2732 \text{ cm}^3/\text{s}\)

20. A quantity \(f\) is given by \(f = \sqrt{\frac{hc^5}{G}}\) where \(c\) is speed of light, \(G\) universal gravitational constant and \(h\) is the Planck’s constant. Dimension of \(f\) is that of:

एक राशि \(f\) का सूत्र \(f = \sqrt{\frac{hc^5}{G}}\) है। यहाँ \(c\) प्रकाश की गति, \(G\) सर्वक्षणीय गुरुत्वाकर्षण स्थिरांक तथा \(h\) प्लांक का स्थिरांक है। \(f\) की निम्न में से किसके समान है?

(1) volume  (2) energy  (3) momentum  (4) area

(1) आयतन  (2) ऊर्जा  (3) संरचना  (4) क्षेत्रफल

Ans. (2)
Sol.  
\[ [ML^2T^{-2}] \]
\[ [hc] = [ML^3T^{-2}] \]
\[ [c] = [LT^{-1}] \]
\[ [G] = [M^{-1}L^2T^{-2}] \]

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**Numerical Value Type (संख्यात्मक प्रकार)**

This section contains **5 Numerical value type questions**.

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**21.** The distance \( x \) covered by a particle in one dimensional motion varies with time \( t \) as \( x^2 = at^2 + 2bt + c \). If the acceleration of the particle depends on \( x \) as \( x^{-n} \), where \( n \) is an integer, the value of \( n \) is .......

एक दिशा में चलते हुए एक कण द्वारा \( t \) समय में तय की गयी दूरी \( x \) प्रति \( x^2 = at^2 + 2bt + c \) के अनुसार दी जाती है। यदि कण के त्वरण की \( x \) पर निर्भरता \( x^{-n} \), \( n \) एक पूर्णांक है) द्वारा दी जाती हो तो \( n \) का मान है .......

**Ans.** 3

**Sol.**

\[ x^2 = at^2 + 2bt + c \]

\[ 2xv = 2at + 2b \]

\[ xv = at + b \]

\[ v^2 + ax = a \]

\[ ax = a \left( \frac{at + b}{x} \right)^2 \]

\[ a = \frac{(at^2 + 2bt + c) - (at + b)^2}{x^3} \]

\[ a = \frac{ac - b^2}{x^2} \]

\[ a \propto x^3 \]
22. Both the diodes used in the circuit shown are assumed to be ideal and have negligible resistance when these are forward biased. built in potential in each diode is 0.7 V. For the input voltages shown in the figure, the voltage (in volts) at point A is .......... .

Let \( V_B = 0 \)
Right diode is reversed biased and left diode is forward biased
\( V_A = 0 \)

\( V_E = 12.7 \text{V} - 0.7 \text{V} = 12 \text{V} \)

Ans. 12
Sol.

23. One end of a straight uniform 1 m long bar is pivoted on horizontal table. It is released from rest when it makes an angle 30° from the horizontal (see figure). Its angular speed when it hits the table is given as \( \sqrt{n} \text{ s}^{-1} \), where \( n \) is an integer. The value of \( n \) is ...... .

Ans. 15
24. A body of mass \( m = 10 \) kg is attached to one end of a wire of length 0.3 m. The maximum angular speed (in rad s\(^{-1}\)) with which it can be rotated about its other end in space station is (Breaking stress of wire = \( 4.8 \times 10^7 \) Nm\(^{-2}\) and area of cross section of the wire = \( 10^{-2} \) cm\(^2\)) is:

\[ \text{Ans.} \quad 4 \]

25. In a fluorescent lamp choke (a small transformer) 100 V of reverse voltage is produced when the choke current changes uniformly from 0.25 A to 0 in a duration of 0.025 ms. The self-inductance of the choke (in mH) is estimated to be

\[ \text{Ans.} \quad 10 \]
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