29/06/2022
Evening

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Answers & Solutions

Time : 3 hrs. *for* M.M. : 300

JEE (Main)-2022 (Online) Phase-1

(Physics, Chemistry and Mathematics)

IMPORTANT INSTRUCTIONS:

(1) The test is of **3 hours** duration.

(2) The Test Booklet consists of 90 questions. The maximum marks are 300.

(3) There are **three** parts in the question paper consisting of **Physics**, **Chemistry** and **Mathematics** having 30 questions in each part of equal weightage. Each part (subject) has two sections.

(i) **Section-A:** This section contains 20 multiple choice questions which have only one correct answer. Each question carries **4 marks** for correct answer and **–1 mark** for wrong answer.

(ii) **Section-B:** This section contains 10 questions. In Section-B, attempt any **five questions out of 10.** The answer to each of the questions is a numerical value. Each question carries **4 marks** for correct answer and **–1 mark** for wrong answer. For Section-B, the answer should be rounded off to the nearest integer.

PHYSICS

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

Choose the correct answer :

1. A small toy starts moving from the position of rest under a constant acceleration. If it travels a distance of 10 m in *t* s, the distance travelled by the toy in the next *t* s will be :

   (A) 10 m (B) 20 m

   (C) 30 m (D) 40 m

Answer (C)

Sol. $\frac{1}{2}at^2 = 10$ m

$\frac{1}{2}a(2t)^2 = 40$ m

$\Rightarrow$ Distance travelled in next *t* s

= 40 – 10 = 30 m

2. At what temperature a gold ring of diameter 6.230 cm be heated so that it can be fitted on a wooden bangle of diameter 6.241 cm? Both the diameters have been measured at room temperature (27°C).

   (Given: coefficient of linear thermal expansion of gold $\alpha_L = 1.4 \times 10^{-5}$ K^{-1})

   (A) 125.7°C (B) 91.7°C

   (C) 425.7°C (D) 152.7°C

Answer (D)

Sol. $\Delta D = D\alpha\Delta T$

$$\Delta T = \frac{0.011}{6.230 \times 1.4 \times 10^{-5}}$$

= 126.11°C

$\Rightarrow$ $T_f = T + \Delta T$

= (27 + 126.11)°C

= 153.11°C

$\Rightarrow$ Option (D) is correct

3. Two point charges *Q* each are placed at a distance *d* apart. A third point charge *q* is placed at a distance *x* from mid-point on the perpendicular bisector. The value of *x* at which charge *q* will experience the maximum Coulombs force is :

   (A) $x = d$ (B) $x = \frac{d}{2}$

   (C) $x = \frac{d}{\sqrt{2}}$ (D) $x = \frac{d}{2\sqrt{2}}$

Answer (D)

Sol. Force experienced by the charge *q*

$$F = \frac{kQqx}{\left[\left(\frac{d}{2}\right)^2 + x^2\right]^{\frac{3}{2}}}$$

For maximum Coulomb's force for *x*

$$\frac{dF}{dx} = 0$$

On solving $x = \frac{d}{2\sqrt{2}}$

4. The speed of light in media '*A*' and '*B*' are 2.0×10^{10} cm/s and 1.5×10^{10} cm/s respectively. A ray of light enters from the medium *B* to *A* at an incident angle 'θ'. If the ray suffers total internal reflection, then

   (A) $\theta = \sin^{-1}\left(\frac{3}{4}\right)$ (B) $\theta > \sin^{-1}\left(\frac{2}{3}\right)$

   (C) $\theta < \sin^{-1}\left(\frac{3}{4}\right)$ (D) $\theta > \sin^{-1}\left(\frac{3}{4}\right)$

Answer (D)

Sol. $\mu_A = \frac{3 \times 10^8}{2 \times 10^8} = 1.5$

$\mu_B = \frac{3 \times 10^8}{1.5 \times 10^8} = 2$

For *TIR*

$\theta > i_c$

$\theta > \sin^{-1}\left(\frac{1.5}{2}\right)$

$\theta > \sin^{-1}\left(\frac{3}{4}\right)$

5. In the following nuclear reaction,

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^-} D_2 \xrightarrow{\alpha} D_3 \xrightarrow{\gamma} D_4$$

Mass number of D is 182 and atomic number is 74. Mass number and atomic number of D_4 respectively will be ______

(A) 174 and 71

(B) 174 and 69

(C) 172 and 69

(D) 172 and 71

Answer (A)

Sol. Equivalent reaction can be written as

$D \longrightarrow D_4 + 2\alpha + \beta^- + \gamma$

$\Rightarrow$ Mass number of D_4 = Mass number of $D - 2 \times 4$

$= 182 - 8 = 174$

$\Rightarrow$ Atomic number of D_4

= Atomic number of $D - 2 \times 2 + 1$

$= 74 - 4 + 1 = 71$

6. The electric field at a point associated with a light wave is given by

$E = 200[\sin(6 \times 10^{15})t + \sin(9 \times 10^{15})t]\ \text{Vm}^{-1}$

Given : $h = 4.14 \times 10^{-15}$ eVs

If this light falls on a metal surface having a work function of 2.50 eV, the maximum kinetic energy of the photoelectrons will be

(A) 1.90 eV

(B) 3.27 eV

(C) 3.60 eV

(D) 3.42 eV

Answer (D)

Sol. Frequency of EM waves = $\frac{6}{2\pi} \times 10^{15}$ and $\frac{9}{2\pi} \times 10^{15}$

Energy of one photon of these waves

$= \left(4.14 \times 10^{-15} \times \frac{6}{2\pi} \times 10^{15}\right)$ eV

and $\left(4.14 \times 10^{-15} \times \frac{9}{2\pi} \times 10^{15}\right)$ eV

= 3.95 eV and 5.93 eV

$\Rightarrow$ Energy of maximum energetic electrons

= 5.93 – 2.50 = 3.43 eV

7. A capacitor is discharging through a resistor R. Consider in time t_1, the energy stored in the capacitor reduces to half of its initial value and in time t_2, the charge stored reduces to one eighth of its initial value. The ratio $\frac{t_1}{t_2}$ will be

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

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

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

(D) $\frac{1}{6}$

Answer (D)

Sol. For a discharging capacitor when energy reduces to half the charge would become $\frac{1}{\sqrt{2}}$ times the initial value.

$\Rightarrow \left(\frac{1}{2}\right)^{1/2} = e^{-t_1/\tau}$

Similarly, $\left(\frac{1}{2}\right)^{3} = e^{-t_2/\tau}$

$\Rightarrow \frac{t_1}{t_2} = \frac{1}{6}$

8. Starting with the same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways. The work done by the gas is W_1 if the process is purely isothermal, W_2, if the process is purely adiabatic and W_3 if the process is purely isobaric. Then, choose the correct option.

(A) $W_1 < W_2 < W_3$

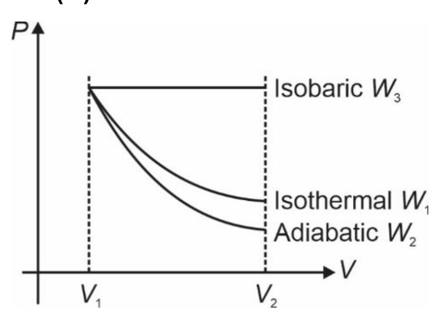
(B) $W_2 < W_3 < W_1$

(C) $W_3 < W_1 < W_2$

(D) $W_2 < W_1 < W_3$

Answer (D)

Sol.



Comparing the area under the PV graph

$A_3 > A_1 > A_2$

$\Rightarrow W_3 > W_1 > W_2$

9. Two long current carrying conductors are placed parallel to each other at a distance of 8 cm between them. The magnitude of magnetic field produced at mid-point between the two conductors due to current flowing in them is 30 μT. The equal current flowing in the two conductors is:

(A) 30 A in the same direction

(B) 30 A in the opposite direction

(C) 60 A in the opposite direction

(D) 300 A in the opposite direction

Answer (B)

Sol. As $B_{\text{net}} \neq 0$ that is the wires are carrying current in opposite direction.

$$\frac{\mu_0 I \times 2}{2\pi(4\times10^{-2})} = 30\times10^{-6}\ \text{T}$$

$$\Rightarrow\ I = \frac{30\times10^{-6}}{10^{-6}}\text{A} = 30\ \text{A in opposite direction.}$$

10. The time period of a satellite revolving around earth in a given orbit is 7 hours. If the radius of orbit is increased to three times its previous value, then approximate new time period of the satellite will be

(A) 40 hours (B) 36 hours

(C) 30 hours (D) 25 hours

Answer (B)

Sol. $T_2^2 = \left(\frac{R_2}{R_1}\right)^3 T_1^2$

$$\Rightarrow\ T_2 = (3)^{3/2}\times7 \approx 5.2\times7$$

$$T_2 \cong 36\ \text{hrs}$$

11. The TV transmission tower at a particular station has a height of 125 m. For doubling the coverage of its range, the height of the tower should be increased by

(A) 125 m (B) 250 m

(C) 375 m (D) 500 m

Answer (C)

Sol. Range $R = \sqrt{2h\text{Re}}$

Let the height be h' to double the range so

$2R = \sqrt{2h'\text{Re}}$

On solving $h' = 4h$

$h' = 500$ m

So $\Delta h = 375$ m

12. The motion of a simple pendulum executing S.H.M. is represented by the following equation.

$y = A\sin(\pi t + \phi)$, where time is measured in second.

The length of pendulum is

(A) 97.23 cm (B) 25.3 cm

(C) 99.4 cm (D) 406.1 cm

Answer (C)

Sol. $\omega = \pi = \sqrt{\frac{g}{\ell}}$

So $\ell = \frac{g}{\pi^2}$

$\simeq$ 99.4 cm (Nearest value)

13. A vessel contains 16 g of hydrogen and 128 g of oxygen at standard temperature and pressure. The volume of the vessel in cm^3 is:

(A) 72×10^5 (B) 32×10^5

(C) 27×10^4 (D) 54×10^4

Answer (C)

Sol. Total number of moles are

$$n = n_{H_2} + n_{O_2}$$

$$= \frac{16}{2} + \frac{128}{32}$$

= 12 moles

Using $PV = nRT$

$$V = \frac{nRT}{P}$$

$$= \frac{12\times8.31\times273.15}{10^5}\ \text{m}^3$$

$= 0.27\ \text{m}^3 = 27 \times 10^4\ \text{cm}^3$

14. Given below are two statements:

Statement I: The electric force changes the speed of the charged particle and hence changes its kinetic energy; whereas the magnetic force does not change the kinetic energy of the charged particle.

Statement II: The electric force accelerates the positively charged particle perpendicular to the direction of electric field. The magnetic force accelerates the moving charged particle along the direction of magnetic field.

In the light of the above statements, choose the most appropriate answer from the options given below:

(A) Both statement I and statement II are correct

(B) Both statement I and statement II are incorrect

(C) Statement I is correct but statement II is incorrect

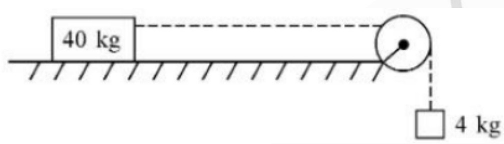
(D) Statement I is incorrect but statement II is correct

Answer (C)

Sol. Electric field accelerates the particle in the direction of field $\left(\vec{F} = q\vec{E} = m\vec{a}\right)$ and magnetic field accelerates the particle perpendicular to the field $\left(\vec{F} = q\vec{v} \times \vec{B} = m\vec{a}\right)$

15. A block of mass 40 kg slides over a surface, when a mass of 4 kg is suspended through an inextensible massless string passing over frictionless pulley as shown below.

The coefficient of kinetic friction between the surface and block is 0.02. The acceleration of block is (Given g = 10 ms^{-2}.)



(A) 1 ms^{-2}

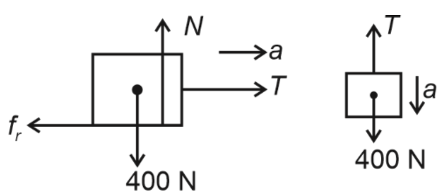
(B) 1/5 ms^{-2}

(C) 4/5 ms^{-2}

(D) 8/11 ms^{-2}

Answer (D)

Sol.



$f_{r_{max}} = \mu N$

$= 0.02 \times 400$

$= 8$ N

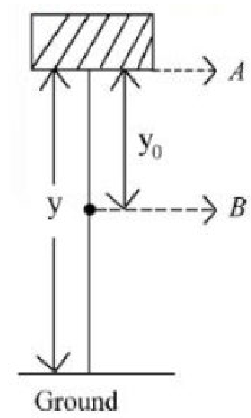
Let the acceleration is a as shown then.

$40 - T = 4a$

$T - 8 = 40a$

$\Rightarrow \quad a = \frac{32}{44} = \frac{8}{11}$ m/s^2

16. In the given figure, the block of mass m is dropped from the point 'A'. The expression for kinetic energy of block when it reaches point 'B' is



(A) $\frac{1}{2}mgy_0^2$

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

(C) $mg(y - y_0)$

(D) mgy_0

Answer (D)

Sol. Loss is potential energy = gain in kinetic energy

$-(mg(y - y_0) - mgy) = KE - 0$

$\Rightarrow KE = mgy_0$

17. A block of mass M placed inside a box descends vertically with acceleration 'a'. The block exerts a force equal to one-fourth of its weight on the floor of the box.

The value of 'a' will be

(A) $\frac{g}{4}$

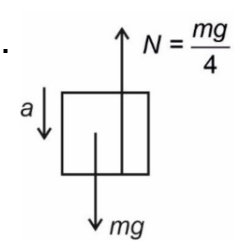
(B) $\frac{g}{2}$

(C) $\frac{3g}{4}$

(D) g

Answer (C)

Sol.



Using Newton's second law

$$mg - \frac{mg}{4} = ma$$

$$\Rightarrow a = \frac{3g}{4}$$

18. If the electric potential at any point (x, y, z)m in space is given by $V = 3x^2$ volt.

The electric field at the point (1, 0, 3)m will be

(A) 3 Vm^{-1}, directed along positive x-axis

(B) 3 Vm^{-1}, directed along negative x-axis

(C) 6 Vm^{-1}, directed along positive x-axis

(D) 6 Vm^{-1}, directed along negative x-axis

Answer (D)

Sol. $\vec{E} = -\frac{dV}{dx}\hat{i}$

$\vec{E} = -6x\hat{i}$

So, $\vec{E}$ at (1, 0, 3) is

$\vec{E} = -6\hat{i}$ V/m

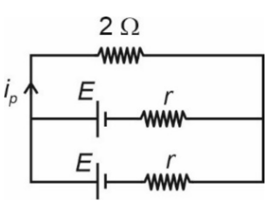
19. The combination of two identical cells, whether connected in series or parallel combination provides the same current through an external resistance of 2 Ω. The value of internal resistance of each cell is

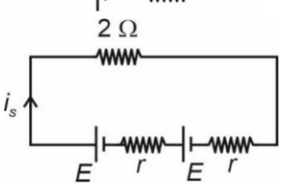
(A) 2 Ω (B) 4 Ω

(C) 6 Ω (D) 8 Ω

Answer (A)

Sol.





From diagram

$i_p = \frac{E}{2+\frac{r}{2}}$ and $i_s = \frac{2E}{2+2r}$

given $i_p = i_s$

$\frac{1}{2+\frac{r}{2}} = \frac{1}{1+r}$

$1 + r = 2 + \frac{r}{2}$

$r = 2\ \Omega$

20. A person can throw a ball upto a maximum range of 100 m. How high above the ground he can throw the same ball?

(A) 25 m (B) 50 m

(C) 100 m (D) 200 m

Answer (B)

Sol. $R_{max} = \frac{u^2}{g} = 100$ m

So, $H_{max} = \frac{u^2}{2g} = 50$ m

SECTION - B

Numerical Value Type Questions: This section contains 10 questions. In Section B, attempt any five questions out of 10. The answer to each question is a **NUMERICAL VALUE.** For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the second decimal place; e.g. 06.25, 07.00, –00.33, –00.30, 30.27, –27.30) using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.

1. The vernier constant of Vernier callipers is 0.1 mm and it has zero error of (–0.05) cm. While measuring diameter of a sphere, the main scale reading is 1.7 cm and coinciding vernier division is 5. The corrected diameter will be ________ × 10^{-2} cm.

Answer (180)

Sol. Since zero error is negative, we will add 0.05 cm.

$\Rightarrow$ Corrected reading = 1.7 cm + 5 × 0.1 mm + 0.05 cm

= 180 × 10^{-2} cm

2. A small spherical ball of radius 0.1 mm and density 10^4 kg m^{-3} falls freely under gravity through a distance h before entering a tank of water. If, after entering the water the velocity of ball does not change and it continue to fall with same constant velocity inside water, then the value of h will be ______ m.

(Given g = 10 ms^{-2}, viscosity of water = 1.0 × 10^{-5} N-sm^{-2}).

Answer (20)

Sol. $\sqrt{2gh}$ = terminal speed

$$\Rightarrow \sqrt{2gh} = \frac{2}{9}\frac{r^2 g(\rho - \rho')}{\eta}$$

$$= \frac{2}{9} \times \frac{10^{-8} \times 10 \times 9000}{10^{-5}}$$

$$\Rightarrow h = \frac{400}{2g}$$

$\Rightarrow h = 20$ m

3. In an experiment to determine the velocity of sound in air at room temperature using a resonance tube, the first resonance is observed when the air column has a length of 20.0 cm for a tuning fork of frequency 400 Hz is used. The velocity of the sound at room temperature is 336 ms^{-1}. The third resonance is observed when the air column has a length of _______ cm

Answer (104)

Sol. $400 = \dfrac{v}{4(L_1 + e)}$ ...(i)

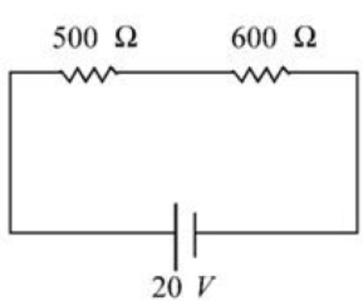
$400 = \dfrac{5v}{4(L_2 + e)}$ ...(ii)

$$\Rightarrow L_1 + e = \frac{\lambda}{4} = 21\,\text{cm}$$

$$L_2 + e = \frac{5\lambda}{4} = 105\text{ cm}$$

$\Rightarrow$ e = 1 cm & L_2 = 104 cm

4. Two resistors are connected in series across a battery as shown in figure. If a voltmeter of resistance 2000 Ω is used to measure the potential difference across 500 Ω resistor, the reading of the voltmeter will be _____ V



Answer (8)

Sol. New $R_{eff} = \dfrac{2000 \times 500}{2500} + 600\ \Omega = 1000\ \Omega$

$\Rightarrow$ Reading of voltmeter = $\dfrac{400}{1000} \times 20 = 8$ volts

5. A potential barrier of 0.4 V exists across a p-n junction. An electron enters the junction from the n-side with a speed of 6.0 × 10^5 ms^{-1}. The speed with which electrons enters the p side will be $\dfrac{x}{3} \times 10^5$ ms^{-1} the value of x is __________.

(Give mass of electron = 9 × 10^{-31} kg, charge on electron = 1.6 × 10^{-19} C)

Answer (14)

Sol. Conserving energy,

$$\frac{1}{2}mv^2 = \frac{1}{2}m(6 \times 10^5)^2 - 0.4\,\text{eV}$$

$$\Rightarrow v = \sqrt{(6 \times 10^5)^2 - \frac{2 \times 1.6 \times 10^{-19} \times 0.4}{9 \times 10^{-31}}}$$

$$= \sqrt{36 \times 10^{10} - \frac{1.28}{9} \times 10^{12}}$$

$$\Rightarrow v = \frac{14}{3} \times 10^5\ \text{m/s}$$

$\Rightarrow x = 14$

6. The displacement current of 4.425 μA is developed in the space between the plates of parallel plate capacitor when voltage is changing at a rate of 10^6 Vs^{-1}. The area of each plate of the capacitor is 40 cm^2. The distance between each plate of the capacitor x × 10^{-3} m. The value of x is,

(Permittivity of free space, E_0 = 8.85 × 10^{-12} C^2 N^{-1} m^{-2})

Answer (8)

Sol. 4.425 μA = $\dfrac{E_0 A}{d} \times \dfrac{dV}{dt}$

$$\Rightarrow d = \frac{8.85 \times 10^{-12} \times 40 \times 10^{-4}}{4.425 \times 10^{-6}} \times 10^6$$

$\Rightarrow d = 8 \times 10^{-3}$ m

$\Rightarrow x = 8$

7. The moment of inertia of a uniform thin rod about a perpendicular axis passing through one end is I_1. The same rod is bent into a ring and its moment of inertia about a diameter is I_2. If $\frac{I_1}{I_2}$ is $\frac{x\pi^2}{3}$, then the value of x will be ______.

Answer (8)

Sol. $I_1 = \frac{ML^2}{3}$ ....(1)

For ring : $I_2 = \frac{MR^2}{2}$

and $2\pi R = L$

$\Rightarrow I_2 = \frac{M}{2}\left(\frac{L^2}{4\pi^2}\right)$ ....(2)

$\Rightarrow \frac{I_1}{I_2} = \frac{8\pi^2}{3}$

$\Rightarrow x = 8$

8. The half life of a radioactive substance is 5 years. After x years, a given sample of the radioactive substance gets reduced to 6.25% of its initial value. The value of x is ______

Answer (20)

Sol. $N = N_0 e^{-\lambda t}$

$\Rightarrow \frac{6.25}{100} = e^{-\lambda t}$

$\Rightarrow e^{-\lambda t} = \frac{1}{16} = \left(\frac{1}{2}\right)^4$

$\Rightarrow t = 4t_{1/2}$

$\Rightarrow t = 20$ years

9. In a double slit experiment with monochromatic light, fringes are obtained on a screen placed at some distance from the plane of slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 3×10^{-3} cm. If the distance between the slits is 1 mm, then the wavelength of the light will be _______ nm.

Answer (600)

Sol. Fringe width $\beta = \frac{\lambda D}{d}$

$\Rightarrow |d\beta| = \frac{\lambda}{d}|d(D)|$

$\Rightarrow 3 \times 10^{-3}\text{cm} = \frac{\lambda}{1\text{ mm}}(5 \times 10^{-2}\text{ m})$

$\Rightarrow \lambda = \frac{3 \times 10^{-8}}{5 \times 10^{-2}}$ m

$\Rightarrow \lambda = 600$ nm

10. An inductor of 0.5 mH, a capacitor of 200 μF and a resistor of 2 Ω are connected in series with a 220 V ac source. If the current is in phase with the emf, the frequency of ac source will be ______ × 10^2 Hz.

Answer (5)

Sol. Current will be in phase with emf when

$\omega L = \frac{1}{\omega C}$

$\Rightarrow \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5 \times 10^{-4} \times 2 \times 10^{-4}}}$

$\Rightarrow \omega = \frac{10^4}{\sqrt{10}}$ rad/s

$\Rightarrow f = \frac{1}{2\pi} \times \frac{10^4}{\sqrt{10}}$ Hz

$\Rightarrow f \simeq 500$ Hz