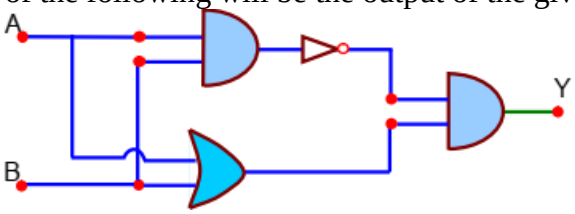
JEE-MAIN-2021 (17th March-Second Shift)

PART – A (PHYSICS)

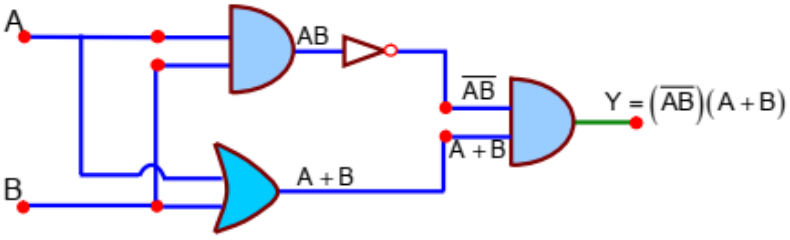
SECTION - A

***Questions*: 1:-** Which one of the following will be the output of the given circuit?



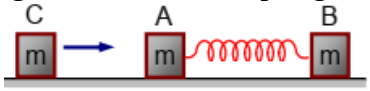
(A) AND Gate (B) NAND Gate
(C) NOR Gate (D) XOR Gate

***Ans*:- (D)**



$Y = (\overline{AB})(A+B) = (\overline{A}+\overline{B})(A+B) = A\overline{B} + \overline{A}B$ (XOR Gate)

***Questions*: 2:-** Two identical blocks A and B each of mass m resting on the smooth horizontal floor are connected by a light spring of natural L and spring constant K.



A third block C of mass m moving with a speed v along the line joining A and B collides with A. The maximum compression in the spring is

(A) $\sqrt{\frac{mv}{K}}$ (B) $\sqrt{\frac{mv}{2K}}$

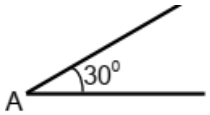
(C) $\sqrt{\frac{m}{2K}}$ (D) $v\sqrt{\frac{m}{2K}}$

***Ans*:- (D)** If collision is elastic, C comes to rest after collision. When compression in spring is maximum, velocities of A and B are same, (say v).

Using conservation of Mechanical Energy, we can write

$$\frac{1}{2}mv^2 = 2x\frac{1}{2}mv^2 + \frac{1}{2}kx^2 \Rightarrow x = v\sqrt{\frac{m}{2k}}$$

***Questions*: 3:-** A sphere of mass 2 kg and radius 0.5 m is rolling with an initial speed of $1ms^{-1}$ goes up an inclined plane which makes an angle of 30^o with the horizontal plane, without slipping. How long will the sphere take to return to the starting point A?



(A) 0.60 s (B) 0.57 s
(C) 0.52 s (D) 0.80 s

***Ans*:- (B)**

$$a = \frac{g\sin\theta}{1+\frac{I}{mr^2}} = \frac{10\sin 30^0}{1+\frac{2}{5}} = \frac{25}{7} m/s^2$$

$$t = \frac{2v}{a} = \frac{2\times 1}{\frac{25}{7}} = 0.57 s.$$

***Questions*: 4:-** The velocity of a particle is $\upsilon = \upsilon_0 + gt + Ft^2$. Its position is x = 0 at t = 0; then its displacement after time (t = 1) is:

(A) $\upsilon_0 + \frac{g}{2} + \frac{F}{3}$ (B) $\upsilon_0 + \frac{g}{2} + F$
(C) $\upsilon_0 + 2g + 3F$ (D) $\upsilon_0 + g + F$

***Ans*:- (A)**

$$S = x - x_0 = \int_0^1 v\,dt = \int_0^1 \left(v_0 + gt + Ft^2\right)dt = v_0 + \frac{g}{2} + \frac{F}{3}$$

***Questions*: 5:-** What happens to the inductive reactance and the current in a purely inductive circuit if the frequency is halved?
(A) Both, inducting reactance and current will be doubled.
(B) Inductive reactance will be halved and current will be doubled.
(C) Inductive reactance will be doubled and current will be halved.
(D) Both, inductive reactance and current will be halved.

***Ans*:- (B)**

$$X_L = \omega L \text{ and } i_0 = \frac{V_0}{\omega L}.$$

If ω is halved, X_L is halved while i_0 is doubled

***Questions*: 6:-** Two identical photo-cathodes receive the light of frequencies f_1 and f_2 respectively. If the velocities of the photo-electrons coming out are υ_1 and υ_2 respectively, then

(A) $\upsilon_1^2 - \upsilon_2^2 = \frac{2h}{m}[f_1 - f_2]$ (B) $\upsilon_1^2 + \upsilon_2^2 = \frac{2h}{m}[f_1 + f_2]$
(C) $\upsilon_1 + \upsilon_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{\frac{1}{2}}$ (D) $\upsilon_1 - \upsilon_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{\frac{1}{2}}$

***Ans*:- (A)**

$$\frac{1}{2}mv_1^2 = hf_1 - \phi \ldots\ldots\ldots(1)$$

$$\frac{1}{2}mv_2^2 = hf_2 - \phi \ldots\ldots\ldots(2)$$

With the help of equation (1) and (2), we can write

$$v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$$

***Questions*: 7:-** A rubber ball is released from a height of 5 m above the floor. It bounces back repeatedly, always rising to $\frac{81}{100}$ of the height through which it falls. Find the average speed of the ball.

(Takeg = $10ms^{-2}$)

(A) $2.0ms^{-1}$ (B) $2.50ms^{-1}$

(C) $3.0ms^{-1}$ (D) $3.50ms^{-1}$

***Ans*:- (B)**

Let $h = 5m$ and $e = 0.9 \Rightarrow e^2 = 0.81$

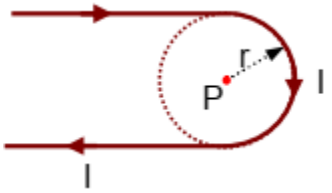
Distance traveled, $d = h + 2e^2h + 2e^4h + \ldots = h + \frac{2he^2}{1-e^2} = h\left(\frac{1+e^2}{1-e^2}\right)$.

Time taken, $t = \sqrt{\frac{2h}{g}} + 2x\sqrt{\frac{2e^2h}{g}} + 2x\sqrt{\frac{2e^4h}{g}} + \ldots = \sqrt{\frac{2h}{g}}(1 + 2e + 2e^2 + \ldots)$

$= \sqrt{\frac{2h}{g}}\left(1 + \frac{2e}{1-e}\right) = \sqrt{\frac{2h}{g}}\left(\frac{1+e}{1-e}\right)$

Average speed $= \frac{d}{t} = \sqrt{\frac{gh}{2}} \cdot \frac{1+e^2}{(1+e)^2} = 5 \times \frac{1.81}{(1.9)^2} = 2.50m/s.$

***Questions*: 8:-** A hairpin like shape as shown in figure is made by bending a long current carrying wire. What is the magnitude of a magnetic field at point P which lies on the centre of the semicircle?



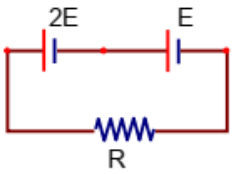
(A) $\frac{\mu_0 I}{4\pi r}(2+\pi)$ (B) $\frac{\mu_0 I}{2\pi r}(2+\pi)$

(C) $\frac{\mu_0 I}{4\pi r}(2-\pi)$ (D) $\frac{\mu_0 I}{2\pi r}(2-\pi)$

***Ans*:- (A)**

$$B = 2 \times \frac{\mu_0 i}{4\pi r} + \frac{\mu_0 i}{4r} = \frac{\mu_0 i}{4\pi r}(2+\pi)$$

***Questions*: 9:-** A carrier signal C (t) = 25 sin (2.512×10^{10} t) is amplitude modulated by a message signal m (t) = 5sin (1.57×10^8 t) and transmitted through an antenna. What will be the bandwidth of the modulated signal?



(A) 8 GHz (B) 2.01 GHz
(C) 50 MHz (D) 1987.5 MHz

***Ans*:- (C)**

Frequency of message signal, $f_m = \frac{1.57\times10^8}{2\times3.14} = 2.5\times10^7\,Hz$

Bandwidth $= 2f_m = 5\times10^7 Hz = 50MHz$

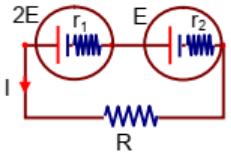
***Questions*: 10:-** Two cells of emf 2E and E with internal resistance r_1 and r_2 respectively are connected in series to an external resistor R (see figure). The value of R, at which the potential difference across the terminals of the first cell becomes zero is

(A) $\frac{r_1}{2}-r_2$ (B) $\frac{r_1}{2}+r_2$
(C) r_1+r_2 (D) r_1-r_2

***Ans*:- (A)**

$$I = \frac{3E}{R+r_1+r_2}$$

$$2E - Ir_1 = 0 \Rightarrow 2E - \frac{3Er_1}{R+r_1+r_2} = 0 \Rightarrow R = \frac{r_1}{2} - r_2$$



***Questions*: 11:-** Match List -I with List –II

List – I	**List - II**
(a) Phase difference between current and voltage in a purely resistive AC circuit	(i) $\frac{\pi}{2}$; current leads voltage
(b) Phase difference between current and voltage in a pure inductive AC circuit	(ii) Zero
(c) Phase difference between current and voltage in a pure capacitive AC circuit	(iii) $\frac{\pi}{2}$; current legs voltage
(d) Phase difference between current and voltage in an LCR series circuit	(iv) $\tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

Choose the most appropriate answer from the options given below:

(A) (a) – (ii), (b) – (iii), (c) – (iv), (d) – (i) (B) (a) – (ii), (b) – (iii), (c) – (i), (d) – (iv)
(C) (a) – (i), (b) – (iii), (c) – (iv), (d) – (ii) (D) (a) – (ii), (b) – (iv), (c) – (iii), (d) – (i)

***Ans*:- (B)**

In purely resistive AC circuit, if $V = V_0 \sin(\omega t)$ then

$$I = \frac{V_0}{X_C}\sin\left(\omega t - \frac{\pi}{2}\right)$$

In LCR series AC circuit, phase difference between current and voltage, $\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

***Questions*: 12:-** If one mole of the polyatomic gas is having two vibrational modes and β is the ratio of molar specific heats for polyatomic gas $\left(\beta = \frac{C_P}{C_V}\right)$ then the value of β is:

(A) 1.02 (B) 1.25
(C) 1.35 (D) 1.2

***Ans*:- (D)** Each vibrational mode contributes two degrees of freedom.

f = 3 + 3 + 4 = 10

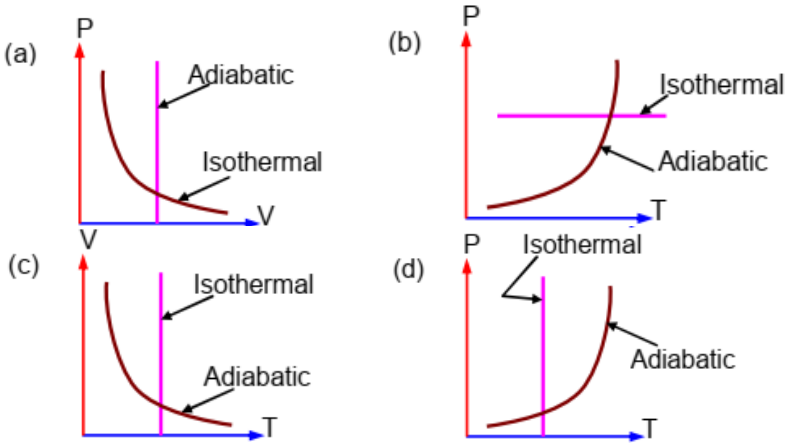
$$\beta = 1 + \frac{2}{f} = 1.2$$

***Questions*: 13:-** The atomic hydrogen emits a line spectrum consisting of various series. Which series of hydrogen atomic spectra is lying in the visible region?

(A) Paschen series (B) Balmer series
(C) Lyman series (D) Brackett series

***Ans*:- (B)** Balmer series lies in the visible region.

***Questions*: 14:-** Which one is the correct option for the two different thermodynamic processes?



(A) (c) and (a) (B) (b) and (c)
(C) (c) and (d) (D) (a) only

***Ans*:- (C)** Pressure decreases with increase in volume, in both isothermal and adiabatic process. In adiabatic process, volume decreases and pressure increases with increase in temperature

***Questions*: 15:-** A sound wave of frequency 245 Hz travels with the speed of 300 ms^{-1} along the positive x – axis. Each point of the wave moves to and for through a total distance of 6 cm. What will be the mathematical expression of this traveling wave?

(A) $Y(x,t) = 0.03\left[\sin 5.1x - \left(1.5\times10^3\right)t\right]$

(B) $Y(x,t) = 0.03\left[\sin 5.1x - \left(0.2\times10^3\right)t\right]$

(C) $Y(x,t) = 0.06\left[\sin 5.1x - \left(1.5\times10^{3}\right)t\right]$

(D) $Y(x,t) = 0.06\left[\sin 0.8x - \left(0.5\times10^{3}\right)t\right]$

***Ans*:- (A)**

$\omega = 2\pi f = 2\times3.14\times245 = 1.5386\times10^{3}\,\text{rad/s} \approx 1.5\times10^{3}\,\text{rad/s}$

$k = \frac{\omega}{v} = \frac{1.53\times10^{3}}{300} = 5.1\ \text{m}^{-1}$

$A = \frac{0.06}{2} = 0.03\text{m}$

***Questions*: 16:-** An object is located at 2 km beneath the surface of the water. If the fractional compression $\frac{\Delta V}{V}$ is 1.36%, the ratio of hydraulic stress to the corresponding hydraulic strain will be ----------.

[Given: density of water is 1000 kgm^{-3} and g = 9.8 ms^{-2}.]

(A) 1.44 × 10^{7} Nm^{-2} (B) 1.96 × 10^{7} Nm^{-2}

(C) 2.26 × 10^{9} Nm^{-2} (D) 1.44 × 10^{9} Nm^{-2}

***Ans*:- (D)**

$B = \frac{-\Delta P}{\frac{\Delta V}{V}} = \frac{\rho gh}{\frac{\Delta V}{V}} = \frac{10^{3}\times9.8\times2\times10^{3}}{1.36\times10^{-2}} = 1.44\times10^{9}\,\text{N/m}^{2}$

***Questions*: 17:-** A geostationary satellite is orbiting around an arbitrary planet 'P' at a height of 11R above the surface of 'P', R being the radius of 'P'. The time period of another satellite in hours at a height of 2R from the surface of 'P' is ---------. 'P' has the time period of 24 hours.

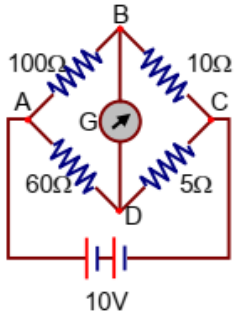
(A) $6\sqrt{2}$ (B) 3

(C) 5 (D) $\frac{6}{\sqrt{2}}$

***Ans*:- (B)**

$\frac{T}{24} = \left(\frac{3}{12}\right)^{3/2} \Rightarrow T = 3\,\text{hours}$

***Questions*: 18:-** The four arms of a Wheatstone bridge have resistances as shown in the figure. A galvanometer of 15 Ω resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10V is maintained across AC.



(A) 4.87μA (B) 2.44 mA

(C) 4.87 mA (D) 2.44 μA

***Ans*:- (C)**

Let, $V_A = 10\,V$, $V_B = x\,V$, $V_C = 0\,V$, and $V_D = y\,V$

Sum of currents away from B is zero, so,

$$\frac{x-10}{100}+\frac{x-y}{15}+\frac{x-0}{10}=0 \Rightarrow 53x-20y=30 \ldots\ldots\ldots (1)$$

Sum of the currents away from D is zero, so,

$$\frac{y-10}{60}+\frac{y-x}{15}+\frac{y-0}{5}=0 \Rightarrow 17y-4x=10 \ldots\ldots\ldots\ldots (2)$$

Solving equations (1) and (2), we can write

$$x = 0.865 \text{ and } y = 0.792,$$

$$i_G = \frac{x-y}{15} = 4.87\,mA$$

***Questions*: 19:-** A block of mass 1 kg attached to a spring is made to oscillate with initial amplitude of 12cm. After 2 minutes the amplitude decreases to 6cm. Determine the value of the damping constant for this motion. (take In 2 = 0.693)

(A) 3.3×10^2 kg s^{-1} (B) 1.16×10^2 kg s^{-1}

(C) 0.69×10^2 kg s^{-1} (D) 5.7×10^{-3} kg s^{-1}

***Ans*:- (D)**

$$A = A_0 e^{\frac{-bt}{m}}$$

$$\Rightarrow \frac{b}{m}t = \ell n\left(\frac{A_0}{A}\right) \Rightarrow b = \frac{m}{t_0}\ell n\left(\frac{A_0}{A}\right) = \frac{1}{2\times 60}\ell n\left(\frac{12}{6}\right) = 5.775\times 10^{-3}\,kg/s$$

***Questions*: 20:-** Two particles A and B of equal masses are suspended from two massless springs of spring constants K_1 and K_2 respectively. If the maximum velocities during oscillations are equal, the ratio of the amplitude of A and B is

(A) $\sqrt{\frac{K_1}{K_2}}$ (B) $\sqrt{\frac{K_2}{K_1}}$

(C) $\frac{K_1}{K_2}$ (D) $\frac{K_2}{K_1}$

***Ans*:- (B)**

$$A_1\sqrt{\frac{K_1}{m}} = A_2\sqrt{\frac{K_2}{m}} \Rightarrow \frac{A_1}{A_2} = \sqrt{\frac{K_2}{K_1}}$$