PHYSICS PAPER I

MORE THAN ONE CORRECT TYPE

Q. 1

Sol. **[a, b]**

If $q_1 = q_2 = Q$

$F_i \propto q_1 q_2$ $\therefore F_i \alpha Q^2$

After touching new charges on each

ball is $\frac{Q_1 + Q_2}{2} = \frac{2Q}{2} = Q$

$F_{new} \propto Q^2$

$\therefore F_i = F_{new}$

if $q_1 \neq q_2$

$F_{new} = \left(\frac{q_1 + q_2}{2}\right)^2$

$= \frac{q_1^2}{4} + \frac{q_2^2}{4} + \frac{2q_1q_2}{4}$

$F_{new} > F_i$

Q.2 **[a,b,c,d]**

Sol.

$a = \frac{F}{m} = \frac{qE}{m} = \frac{q(\alpha - \beta x)}{m}$

$a = 0$ at $x = \frac{\alpha}{\beta}$

Force on the particle is zero at $x = \frac{\alpha}{\beta}$

So, mean position of particle is at $x = \frac{\alpha}{\beta}$

$$\frac{vdv}{dx} = \frac{q}{m}(\alpha - \beta x)$$

Solve for v = $\sqrt{\frac{2qx}{m}\left(\alpha - \frac{\beta}{2}x\right)}$

v = 0 at x = 0 and x = $\frac{2\alpha}{\beta}$

So the particle will oscillate between x = 0 to x = $\frac{2\alpha}{\beta}$ with mean position at $x = \frac{\alpha}{\beta}$.Therefore amplitude of particle is $\frac{\alpha}{\beta}$.

Maximum acceleration of particle is at extreme position (at x = 0 or x = $\frac{2\alpha}{\beta}$) and $\alpha_{max} = \frac{q\alpha}{m}$.

Q.3 [a,c,d]

Sol. The potential at surface, 5 cm from surface and 10 cm from surface outwards is

$V_s = \frac{KQ}{R}$ ......(1)

$\frac{KQ}{R+5}$ = 100 ...... (2)

$\frac{KQ}{R+10}$ = 75 ......(3)

From equation (2) and (3) $\Rightarrow$ R = 10 cm

$\therefore$ from equation (2)

Q = $\frac{100\times 15\times 10^{-2}}{9\times 10^{9}}$ = $\frac{5}{3}$ × 10^{-9} C

$\Rightarrow$ B is false

$V_{surface}$ = $\frac{KQ}{R}$ = $\frac{100\times(R+5)}{R}$ = $\frac{100\times 15}{10}$ = 150 V $\Rightarrow$ A is true

V_{centre} = $\frac{3}{2}\frac{KQ}{R}$ = 225 volts

$\Rightarrow$ D is true

$E_{surface} = \frac{KQ}{R^2} = \frac{150}{10 \times 10^{-2}} = 1500 V/m$

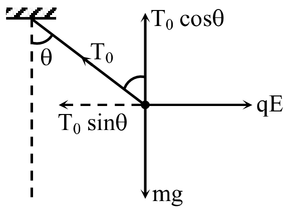
$\Rightarrow$ C is true

Q.4 bcd

SOLN. Potential at each point on y-z plane is zero. The electric field will be zero on y-z plane at a distance $\sqrt{2}a$ from origin.

Q.5

Sol. **[a,d]**



$E = \sigma/2\epsilon_0$

$T_0 \cos\theta = mg$

$T_0 \sin\theta = qE$

$\tan\theta = \frac{q}{mg} (\sigma/2\epsilon_0)$

As $T_0 = \sqrt{(mg)^2 + (qE)^2}$

i.e. $T_0 > mg$

i.e. the effective value of g is increased, hence time period of oscillation decreases.

Q.6 **[a,c]**

Sol. At the instant shown, both particle are at their mean position and moving in opposite direction. Phase difference = 180°

As 'ω' is same for both particle

$\left\{\omega = \sqrt{\frac{GM}{R^3}}\right\}$ the phase difference will be maintained throughout and they can never meet.

$v_{max} = A\omega \rightarrow$ For particle undergoing S.H.M.

$\therefore\ \frac{v_1}{v_2} = \frac{R}{R/2} = \frac{2}{1}$

Q.7 **[a,b,c]**

Sol.

$v^2 = 144 - 9x^2$

$2v\frac{dv}{dx} = -18x$

$\therefore\ v\frac{dv}{dx} = -9x \Rightarrow \omega = 3 \Rightarrow T = \frac{2\pi}{3}$ units

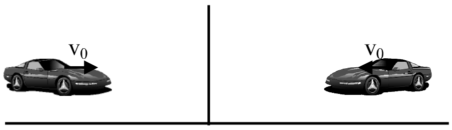
Also, $v^2 = 144 - 9A^2 = 0$

$A = 4$ units

Now, $|a| = \omega^2 x = 9 \times 3 = 27$ units

Q.8 **[a,d]**

Sol.



Let velocity of vehicle be v_0

$\therefore\ n_1 = \frac{v + v_0}{v - v_0}.\nu - \nu$

$\Rightarrow n_1 = \frac{2v_0\nu}{v - v_0}$ ...(i)

$n_2 = \nu - \frac{v - v_0}{v + v_0}\ \nu$

$\Rightarrow n_2 = \frac{2\nu v_0}{v + v_0}$ ...(ii)

[Where ν = Frequency of horn

v = Velocity of sound in air]

From (i) and (ii)

$\nu = \frac{n_1 n_2}{n_1 - n_2}$

and $v_0 = \frac{n_1 - n_2}{n_1 + n_2}.v$

Q.9 **[b, c]**

Sol. As $f_1 : f_2 : f_3 = 3 : 5 : 7$, string is fixed at one end. Its fundamental frequency is $f_0 = \frac{f_1}{3} = \frac{105}{3}$ = 35 Hz.

Q.10. abcd

Conceptual

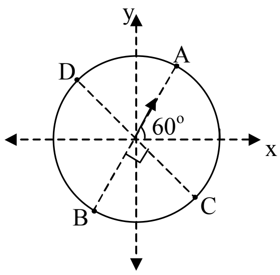
MATRIX MATCH TYPE

1. A – S B – PQR C – QR D – S

Conceptual

2. A – P B – RS C – PQ D - RS

The resultant dipole moment has magnitude $\sqrt{\left(\sqrt{3}\,P\right)^2 + P^2} = 2P$ at an angle $\theta = \tan^{-1}\left(\frac{\sqrt{3}\,P}{P}\right) = 60^\circ$ with the positive x-direction.



Diameter AB is along net dipole moment and diameter CD is normal to net dipole moment.

Potential at $A\left(\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$ is maximum.

Potential is zero at $C\left(\frac{\sqrt{3}R}{2}, -\frac{R}{2}\right)$ and $D\left(-\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$.

Magnitude of electric field is $\frac{1}{4\pi\varepsilon_o}\frac{4p}{R^3}$

At $A\left(\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$ and $B\left(-\frac{R}{2}, -\frac{\sqrt{3}R}{2}\right)$

Magnitude of electric field is $\frac{1}{4\pi\varepsilon_o}\frac{2p}{R^3}$ at $C\left(\frac{\sqrt{3}R}{2}, -\frac{R}{2}\right)$ and $D\left(-\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$.

INTEGER TYPE

1. 0

2.

$$\tan\theta = \frac{F}{mg} \qquad \tan\theta^{1} = \frac{F}{kmg\left(1-\frac{\sigma}{\rho}\right)}$$

As $\theta^{1} = \theta$ we have

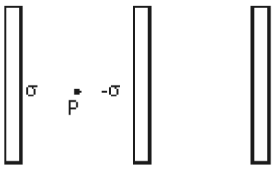
$$\frac{F}{mg} = \frac{F}{kmg\left(1-\frac{\sigma}{\rho}\right)}$$

$\Rightarrow k = 2$

3. 8

4. 2

5.



From Gauss theorem surface charge density on C face is $-\sigma$.

$$\therefore\ E_P = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = 5.0\ N/C$$

6. 9

Potential due to a dipole $V = \frac{Kp}{r^2} = \frac{K(\vec{p}.\vec{r})}{r^3}$

Then $\vec{r} = \vec{r}_N - \vec{r}_M = \left(4\hat{i} - \hat{j}\right) - \left(2\hat{i} - 3\hat{j} + \hat{k}\right)$

$\vec{r} = 2\hat{i} + 2\hat{j} - \hat{k}$

$\therefore\ |\vec{r}| = \sqrt{2^2 + 2^2 + (-1)^2} = 3$

$$\therefore\ V = \frac{9\times10^9 \times \left(9\hat{i} + 3\hat{j} - 3\hat{k}\right).\left(2\hat{i} + 2\hat{j} - \hat{k}\right)}{3^3} = \frac{9}{27}\times10^9 \times [18 + 6 + 3] = 9\times10^9$$

7.

Sol. **[5]**

AP = 4.47 m

BP = 4.12 m

d = 0.35 m

destructive

$d = \frac{\lambda}{2}$

$\lambda = 2d$

$f = \frac{v}{2d}$ = 500 Hz.

$= 5 \times 10^2$ Hz

$\therefore$ n = 5

8.

Sol. **[2]**

$f_1 = \frac{300+30}{300}.f$

$f_2 = \frac{300-30}{300}.f$

$\nu = f_1 - f_2 = 2$ Hz