Physicsaholics

DPP – 5 (Electrostatics)

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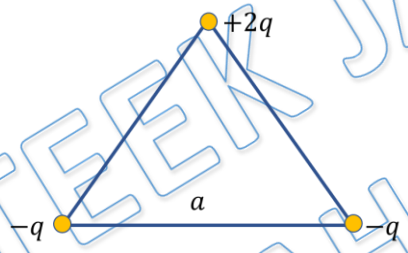
Q 1. A system has two charges $q_A = 2.5 \times 10^{-7} C$ and $q_B = -2.5 \times 10^{-7} C$ located at points A(0,0,-0.15m) and B(0,0,+0.15) respectively. What is the electric dipole moment of the system?

(a) 7.5×10^{-8} C-m (b) 2.5×10^{-8} C-m
(c) 0.15×10^{-8} C-m (d) 7.5×10^{-5} C-m

Q 2. Three charges of +2q, -q, -q are placed at the corners A, B and C of an equilateral triangle of side a as shown in the adjoining figure. Determine the dipole moment of this combination:

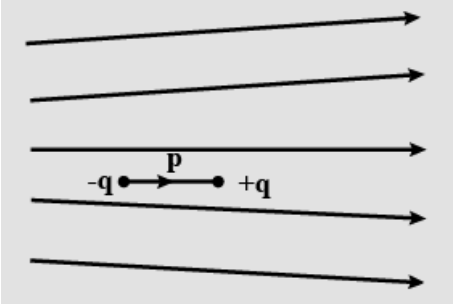


(a) $2\sqrt{3}qa$ (b) $\sqrt{3}qa$ (c) $2qa$ (d) $\sqrt{2}qa$

Q 3. An electric dipole is placed along the x-axis centered at the origin O. A point P at a distance 20cm from the origin such that OP makes an angle $\frac{\pi}{3}$ with the x-axis. if electric field at P makes an angle ϕ with the x-axis, the value of ϕ would be:

(a) $\frac{\pi}{3} + \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$ (b) $\frac{\pi}{3}$ (c) $\frac{2\pi}{3}$ (d) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

Q 4. Electric field lines in which an electric dipole P is placed as shown. Which of the following statements is correct?



(a) The dipole will not experience any force.
(b) The dipole will experience a force towards right
(c) The dipole will experience a force towards left
(d)The dipole will experience a force upwards

Q 5. A and B are two points on the axis and the perpendicular bisector, respectively, of an electric dipole. A and B are far away from the dipole and at equal distances from it. The fields at A and B are $\overrightarrow{E_A}$ and $\overrightarrow{E_B}$. Then:

(a) $\overrightarrow{E_A} = \overrightarrow{E_B}$ (b) $\overrightarrow{E_A} = 2\overrightarrow{E_B}$

(c) $\overrightarrow{E_A} = -2\overrightarrow{E_B}$ (d) None of these

Q 6. Two charges +10 μC and -10 μC are held 2 cm apart. Calculate the electric field at a point on the equatorial line at a distance of 50 cm from the centre of the dipole:

(a) $1.44 \times 10^4\ N/C$ (b) $3.44 \times 10^4\ N/C$

(c) $1.88 \times 10^4\ N/C$ (d) $2.44 \times 10^5\ N/C$

Q 7. The electric force on a point charge situated on the axis of a short dipole is F. If the charge is shifted along the axis to double the distance, the electron force acting will be:

(a) 4F (b) F/2

(c) F/4 (d) F/8

Q 8. What is the electric field intensity at a point at a distance 20 cm on a line making an angle of 45° with the axis of the dipole of moment 10 C-m?

(a) 1.77×10^{13} V/m (b) 0.177×10^{13} V/m

(c) 17.7×10^{13} V/m (d) 177×10^{13} V/m

Q 9. An electric dipole with dipole moment 4×10^{-9} C m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^4 N C^{-1}. Calculate the magnitude of the torque acting on the dipole:

(a) 10^{-4} Nm (b) 10^4 Nm

(c) 2×10^{-4} Nm (d) 2×10^4

Q 10. An electric dipole of length 2 cm, when placed with its axis making an angle of 60^0 with a uniform electric field, experiences a torque of $8\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of $\pm 4nC$

(a) -8 joule (b) 8 joule

(c) -16 joule (d) 16 joule

Q 11. An electric dipole moment $\vec{P} = (2\hat{\imath} + 3\hat{\jmath})\mu Cm$ is placed in a uniform electric field $\vec{E} = (3\hat{\imath} + 2\hat{k}) \times 10^5\ NC^{-1}$:

(a) The torque that $\vec{E}$ exerts on $\vec{P}$ is $(0.6\hat{\imath} - 0.4\hat{\jmath} - 0.9\hat{k})Nm$

(b) The potential energy of the dipole is -0.6J

(c) Both (a) and (b)

(d) The potential energy of the dipole is 0.9J

Q 12. Two dipoles each of moment 5×10^{-12}C-m form a cross with their axis (- to +) along the coordinate axes. The potential at a point 20cm away in a direction making an angle of 30^0 with x-axis is (if the potential at an infinite distance is taken to be zero):

(a) 1.12 V (b) 2.12 V (c) 2.4 V (d) 1.536 V

Q 13. What is the electric potential at a point distant 100 cm from the centre of an electric dipole of moment 2×10^{-4} C-m on a line making an angle of 60° with the axis of dipole?
(a) 7×10^5 V (b) 8×10^5 V
(c) 9×10^5 V (d) 10×10^5 V

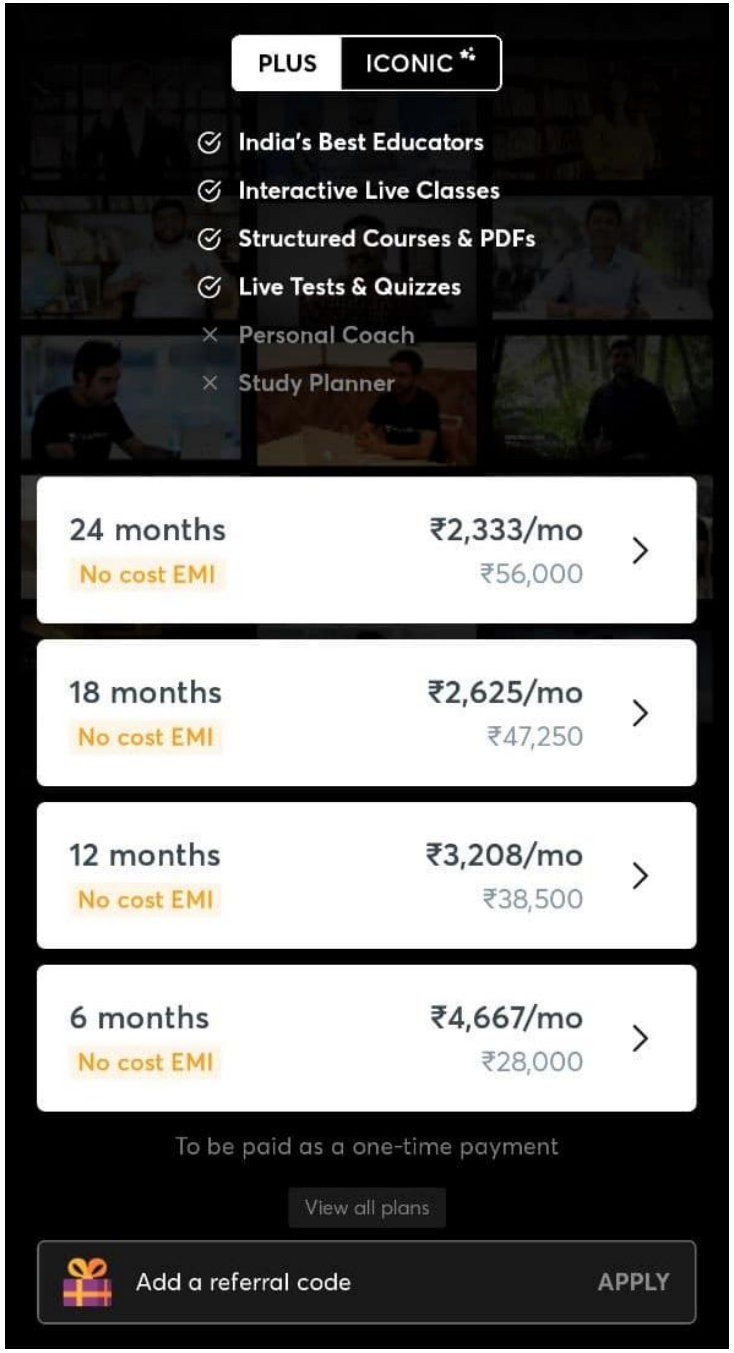
Q 14. A short electric dipole has dipole moment of 4×10^{-9} C-m. Determine the electric potential due to the dipole at a point distant 0.3 m from the centre of the dipole situated on
(1) the axial line (V_1),
(2) on equatorial line (V_2)
(a) $V_1 = 400\ V, V_2 = 0\ V$ (b) $V_1 = 400\ V, V_2 = 200\ V$
(c) $V_1 = 400\ V, V_2 = 20\ V$ (d) $V_1 = 400\ V, V_2 = -200\ V$

Q 15. Two short dipoles, each of dipole moment P are placed at a large separation r. The force between them:
(a) is proportional to product of dipole momenta
(b) is inversely proportional to r^4
(c) the force is attractive, if direction of dipole momenta is same, repulsive if opposite
(d) all options are correct

Q 16. An electric dipole consists of two opposite charges of magnitude $1\mu C$ separated by a distance of 2cm. The dipole is placed in an electric field $10^{-5}\ Vm^{-1}$. The maximum torque that the field exerts on the dipole is:
(a) $10^{-3}\ Nm$ (b) $2 \times 10^{-13}\ Nm$
(c) $3 \times 10^{-3}\ Nm$ (d) $4 \times 10^{-3}\ Nm$

Answer Key

Q.1 a	**Q.2 b**	**Q.3 a**	**Q.4 c**	**Q.5 c**
Q.6 a	**Q.7 d**	**Q.8 a**	**Q.9 a**	**Q.10 a**
Q.11 c	**Q.12 d**	**Q.13 c**	**Q.14 a**	**Q.15 d**
Q.16 b				



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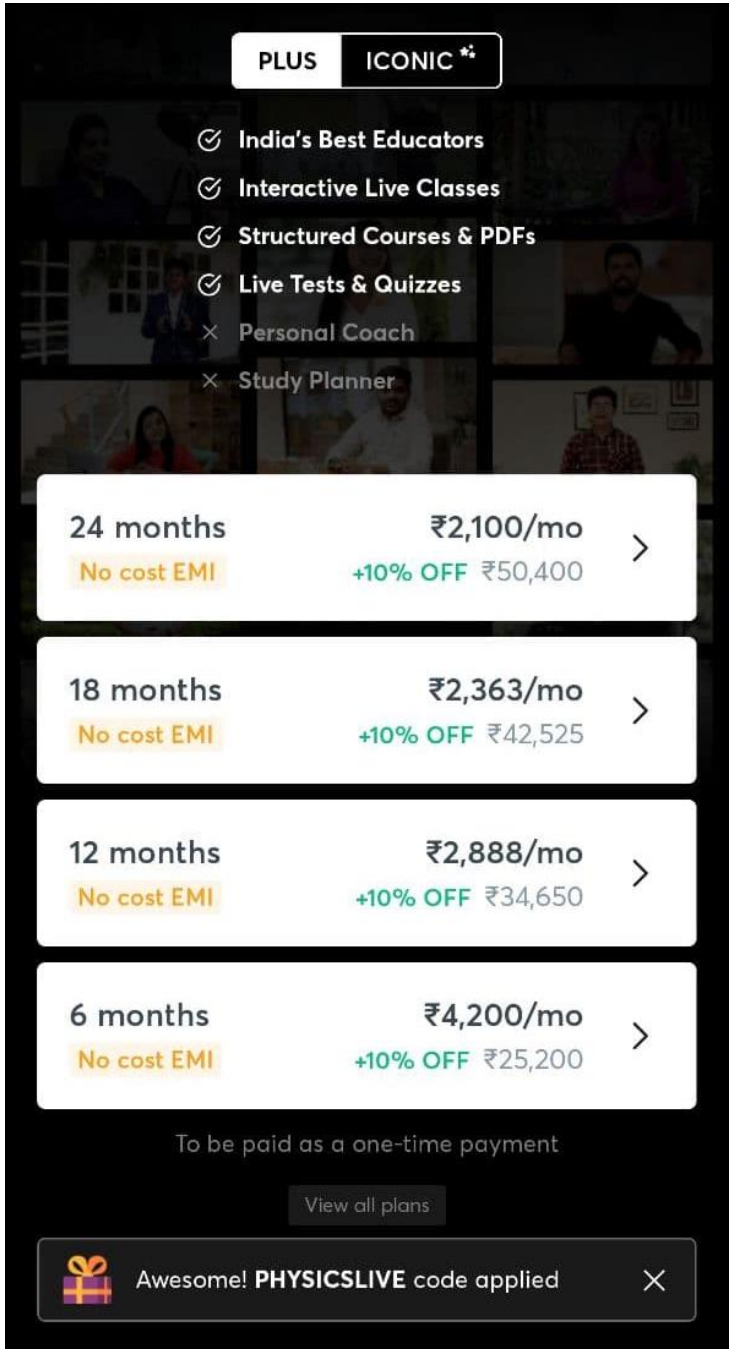


Written Solution

DPP-5 Electric Dipole

By Physicsaholics Team

Solution: 1

$q_A = 2.5 \times 10^{-7}\ C$

$q_B = -2.5 \times 10^{-7}\ C$

$(0, 0, -0.15\ m)$ $(0, 0, 0.15\ m)$

$d = 2(0.15) = 0.3\ m.$

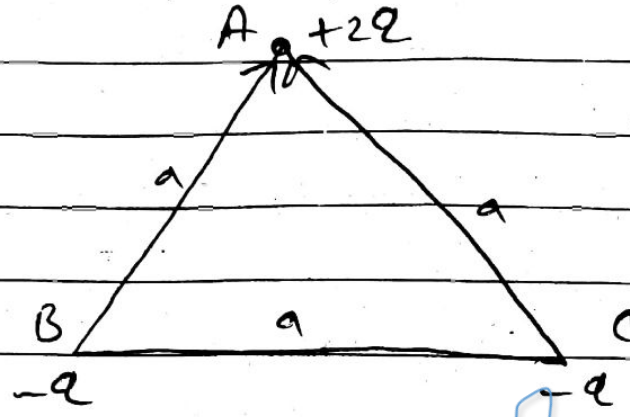
$P = qd$

$P = 2.5 \times 10^{-7} \times 0.3$

$\boxed{P = 7.5 \times 10^{-8}\ C\text{-}m}$

Ans. a

Solution: 2



$|\vec{P}_{BA}| = q(a)$

$|\vec{P}_{CA}| = q(a)$

$\vec{P}_{BA}$ & $\vec{P}_{CA}$ are at an angle of 60° with each other

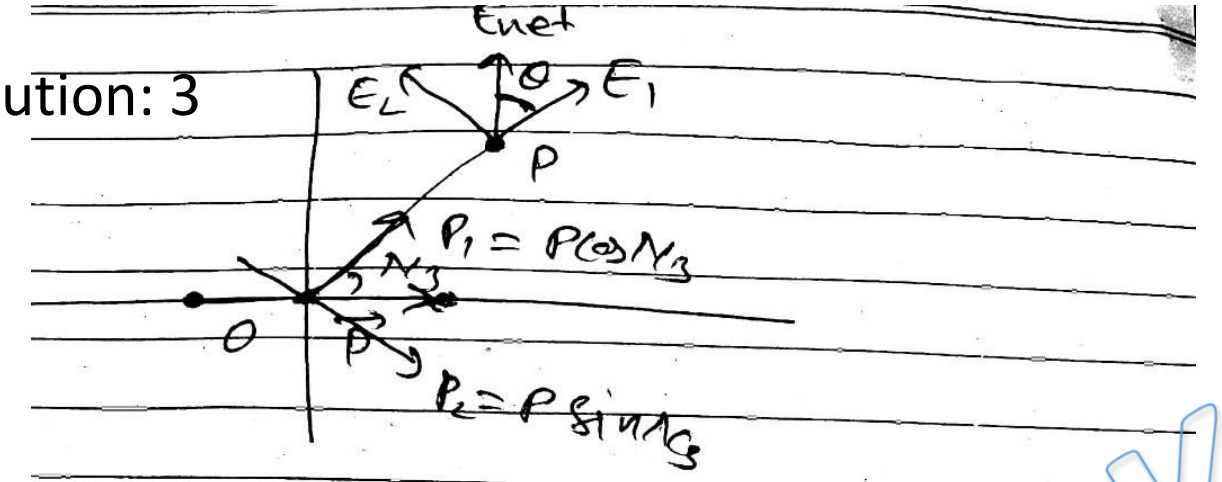
$\therefore |\vec{P}_{BA}| = |\vec{P}_{CA}| = P$

$\therefore P_{net} = \sqrt{3}\, P$

$$\boxed{P_{net} = \sqrt{3}\, qa}$$

Ans. b

Solution: 3



$$\theta = \tan^{-1}\frac{E_2}{E_1}$$

$$E_2 = \frac{k(P\sin\lambda_3)}{(20\times10^2)^3}$$

$$E_1 = \frac{2k(P\cos\lambda_3)}{(20\times10^2)^3}$$

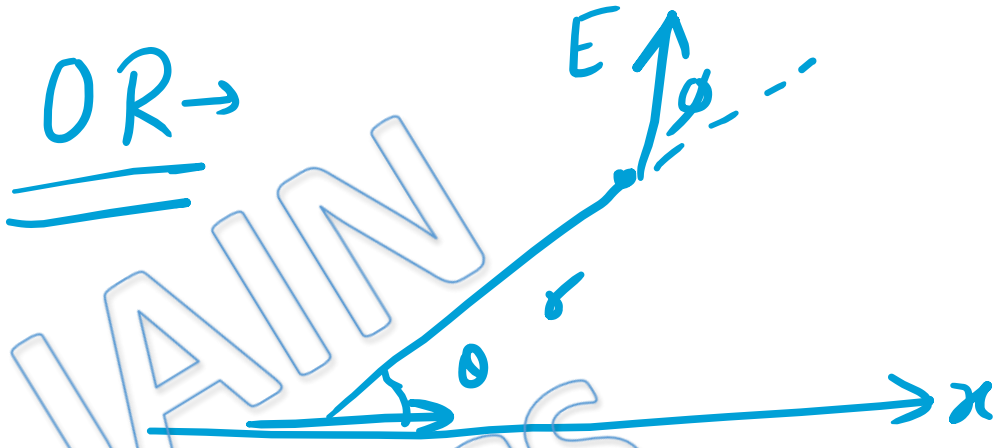
$$\theta = \tan^{-1}\left(\frac{\sin\lambda_3}{2\cos\lambda_3}\right) = \tan^{-1}\left(\frac{\tan\lambda_3}{2}\right)$$

$$\theta = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

$\therefore$ Total angle $= \phi = \frac{\lambda}{3} + \theta$

$$\boxed{\phi = \frac{\lambda}{3} + \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)}$$

OR →



$$\tan\phi = \frac{1}{2}\tan\theta$$

$$= \frac{1}{2}\tan 60^\circ$$

$$= \sqrt{3}/2$$

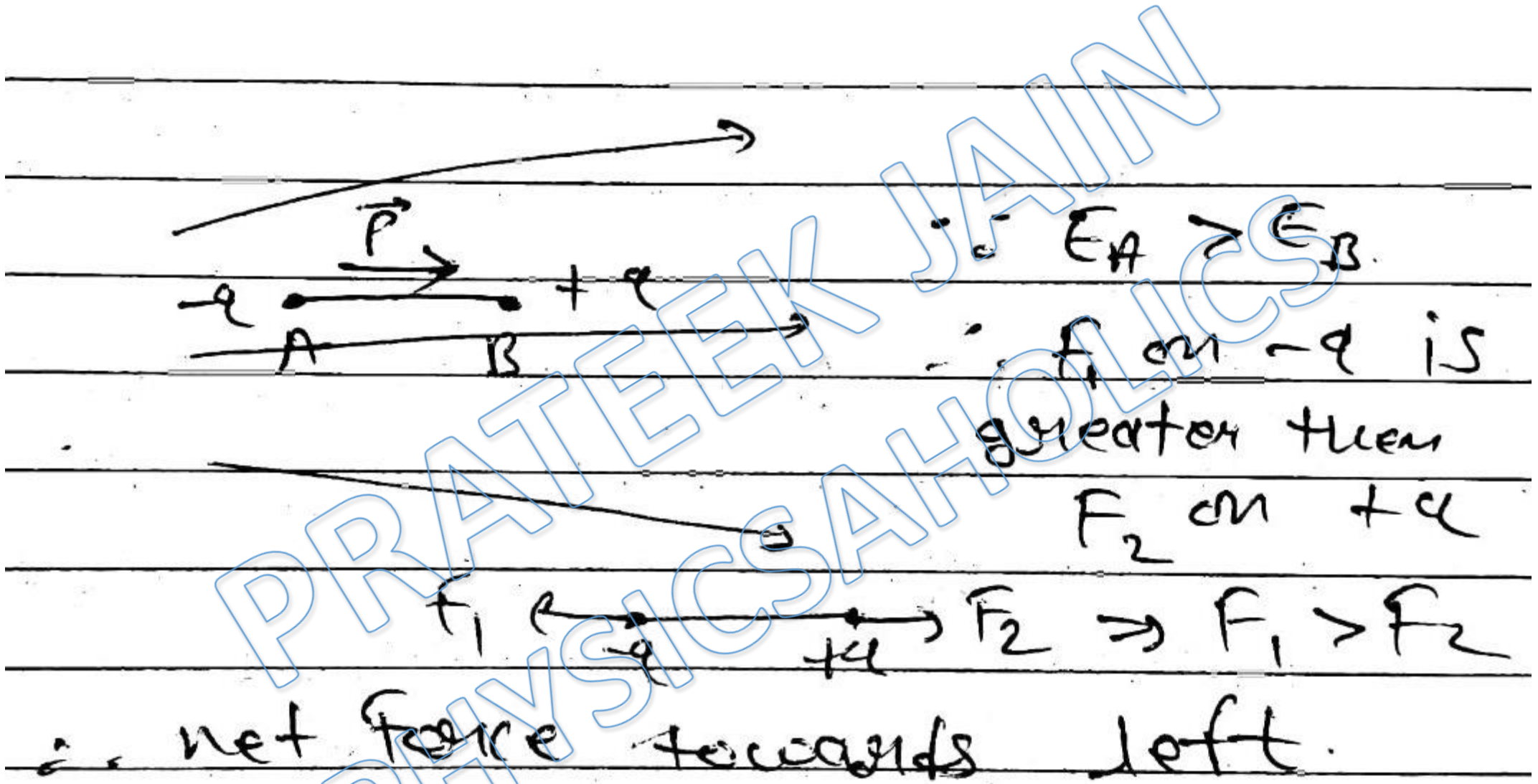
$$\phi = \tan^{-1}(\sqrt{3}/2)$$

angle of $\vec{E}$ with x axis

$$= 60^\circ + \tan^{-1}(\sqrt{3}/2)$$

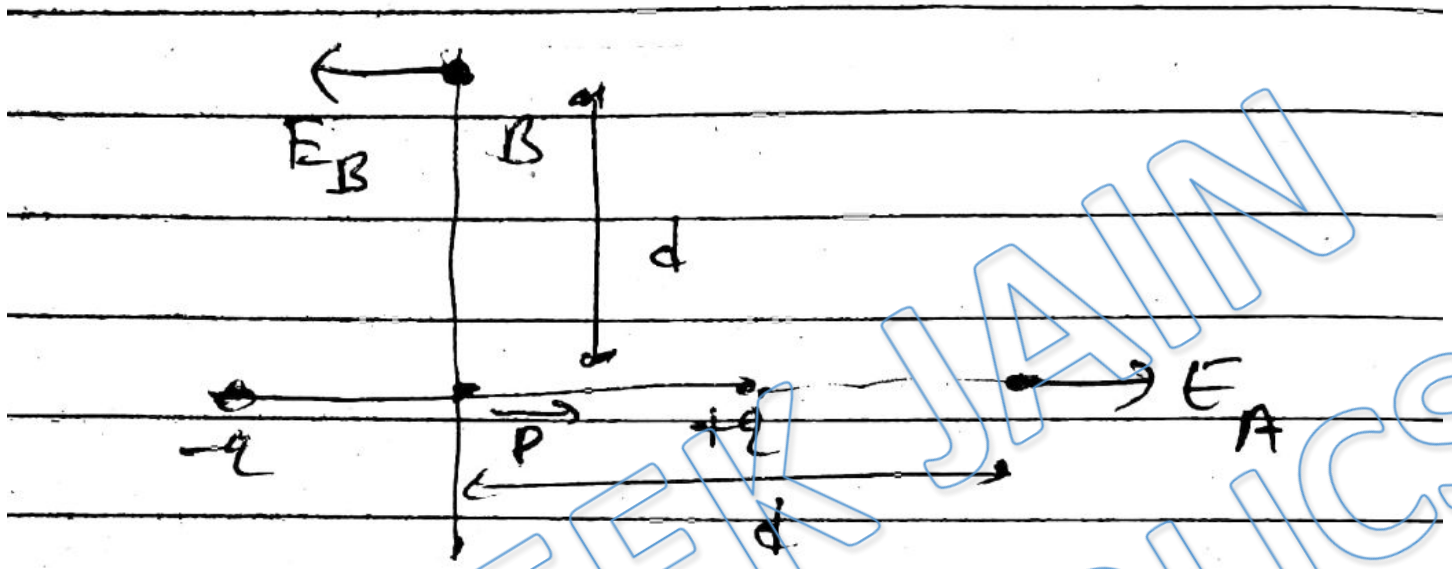
Ans. a

Solution: 4



Ans. c

Solution: 5



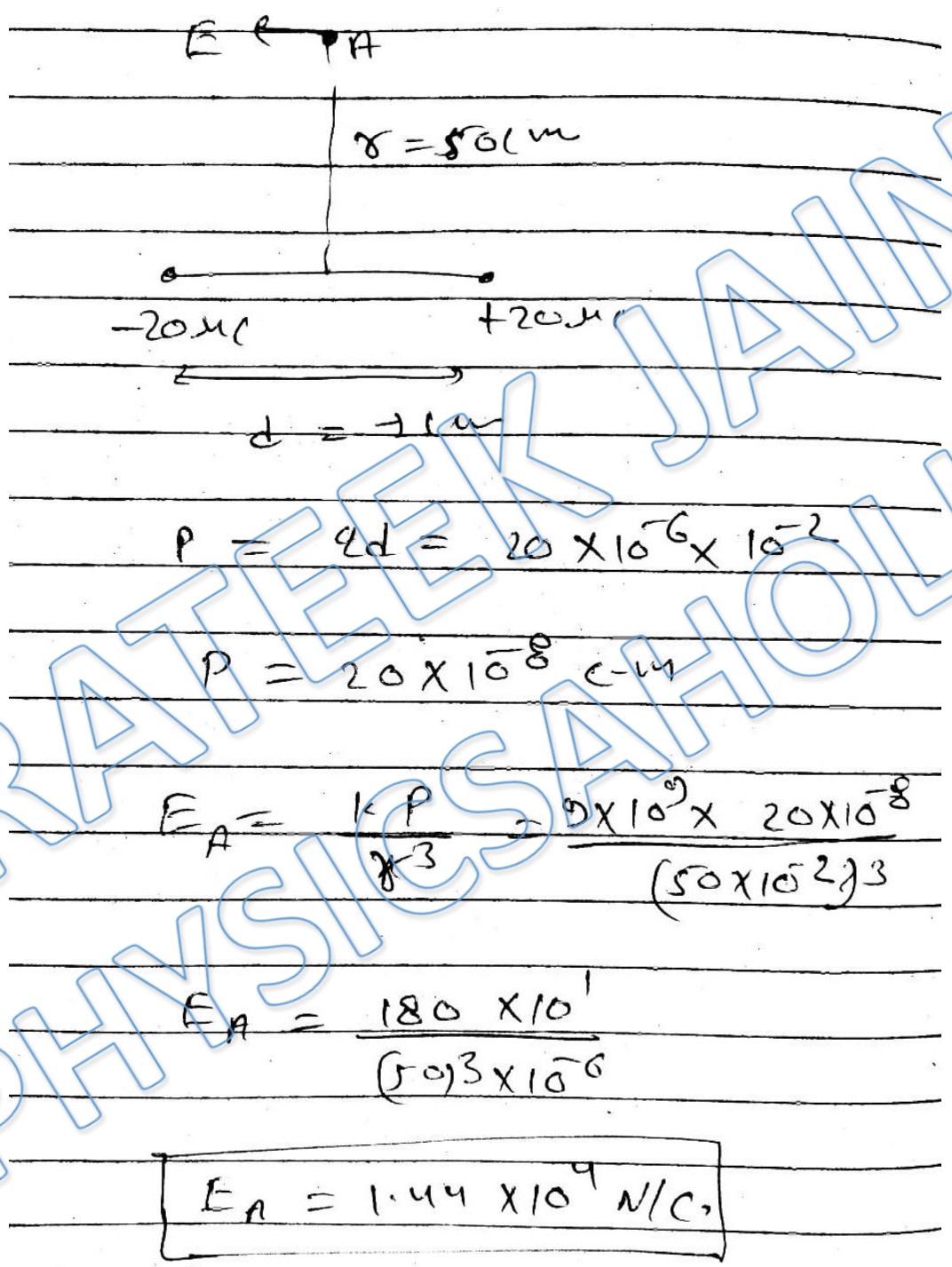
$$\vec{E}_A = \frac{2k\vec{p}}{d^3} \quad ; \quad \vec{E}_B = -\frac{k\vec{p}}{d^3}$$

$$\vec{E}_A = -2\left(\frac{-k\vec{p}}{d^3}\right)$$

$$\boxed{\vec{E}_A = -2\vec{E}_B}$$

Ans. c

Solution: 6



$$P = qd = 20 \times 10^{-6} \times 10^{-2}$$

$$P = 20 \times 10^{-8} \text{ C-m}$$

$$E_A = \frac{kP}{r^3} = \frac{9 \times 10^9 \times 20 \times 10^{-8}}{(50 \times 10^{-2})^3}$$

$$E_A = \frac{180 \times 10^1}{(0.5)^3 \times 10^{-6}}$$

$$\boxed{E_A = 1.44 \times 10^9 \text{ N/C}}$$

Ans. a

Solution: 7

field on axis of dipole $= \frac{2KP}{r^3}$

force on point charge due to dipole

$F = qE \Rightarrow F = \frac{2KPq}{r^3}$

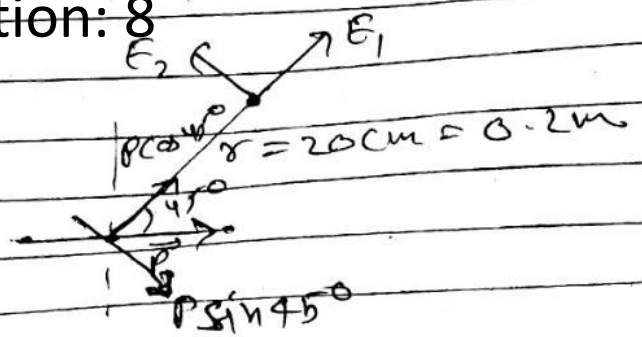
$F \propto \frac{1}{r^3}$

↓ $\frac{1}{8}$ times.

↳ 2 times

Ans. d

Solution: 8



$P = qd = 10\ C\text{-}m$

$$E_1 = \frac{2kP\cos45^\circ}{r^3}$$

$$= \frac{2\times9\times10^9\times(10)(1/\sqrt{2})}{(0.2)^3}$$

$$= \frac{2\times9\times10^9\times10\times(1/\sqrt{2})}{8\times10^{-3}}$$

$$E_1 = 1.59\times10^{13}\ N/C$$

$$E_2 = \frac{k(P\sin45^\circ)}{(0.2)^3}$$

$$= \frac{9\times10^9\times(1/\sqrt{2})\times10}{8\times10^{-3}}$$

$$E_2 = 0.79\times10^{13}\ V/m$$

$$E = \sqrt{E_1^2+E_2^2} = \sqrt{(1.59\times10^{13})^2+(0.79\times10^{13})^2}$$

$$E = 10^{13}\times\sqrt{(1.59)^2+(0.79)^2}$$; $E = 1.77\times10^{13}\ V/m$

OR

Electric field at a general point due to dipole:

$$E = \frac{kP}{r^3}\left[\sqrt{3\cos^2\theta+1}\right]$$

$$= \frac{9\times10^9\times10}{(20\times10^{-2})^3}\times\left[\sqrt{3\times(\cos45^\circ)^2+1}\right]$$

$$= \frac{9\times10^9\times10}{8\times10^{-3}}\left[\sqrt{3\times\frac{1}{2}+1}\right]$$

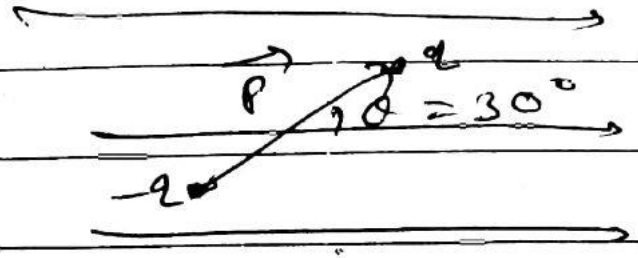
$$= \frac{9}{8}\times10^{13}\times\left[\frac{\sqrt{5}}{2}\right]$$

$$= \frac{9}{8}\times\sqrt{2.5}\times10^{13} \approx \frac{9}{8}\times1.6\times10^{13}$$

$$E \approx 1.8\times10^{13}\ N/C$$ Ans

Ans. a

Solution: 9



$E = 5 \times 10^9$ N/C

$P = 4 \times 10^{-9}$ C m.

$\tau = \vec{P} \times \vec{E} = PE \sin\theta$

$\tau = 4 \times 10^{-9} \times 5 \times 10^4 \times \sin 30°$

$= 20 \times 10^{-5} \times \frac{1}{2}$

$\boxed{\tau = 10^{-4} \text{ N m}}$

Ans. a

Solution: 10

$$\tau = PE \sin\theta$$

$$U = -PE \cos\theta$$

$$\frac{\tau}{U} = -\frac{\sin\theta}{\cos\theta} = -\tan\theta$$

$$U = -\frac{\tau}{\tan\theta} = -\frac{(8\sqrt{3})}{\tan 60^\circ}$$

$$U = -\frac{8\sqrt{3}}{\sqrt{3}}$$

$$\boxed{U = -8 \text{ Joule}}$$

Ans. a

Solution: 11

$$\vec{P} = (2\hat{i} + 3\hat{j}) \times 10^{-6} \text{ cm}$$

$$\vec{E} = (3\hat{j} + 2\hat{k}) \times 10^{5} \text{ N/C}$$

$$\vec{\tau} = \vec{P} \times \vec{E}$$

$$= (2\hat{i} + 3\hat{j}) \times (3\hat{j} + 2\hat{k}) \times 10^{-6} \times 10^{5}$$

$$= (-4\hat{j} - 9\hat{k} + 6\hat{i}) \times 10^{-1}$$

$$\boxed{\vec{\tau} = 0.6\hat{i} - 0.4\hat{j} - 0.9\hat{k}}$$

$$U = -\vec{P} \cdot \vec{E} = -(2\hat{i} + 3\hat{j}) \cdot (3\hat{j} + 2\hat{k}) \times 10^{-6} \times 10^{5}$$

$$U = -(6) \times 10^{-1}$$

$$\boxed{U = -0.6 \text{ Joule.}}$$

Ans. c

Solution: 12

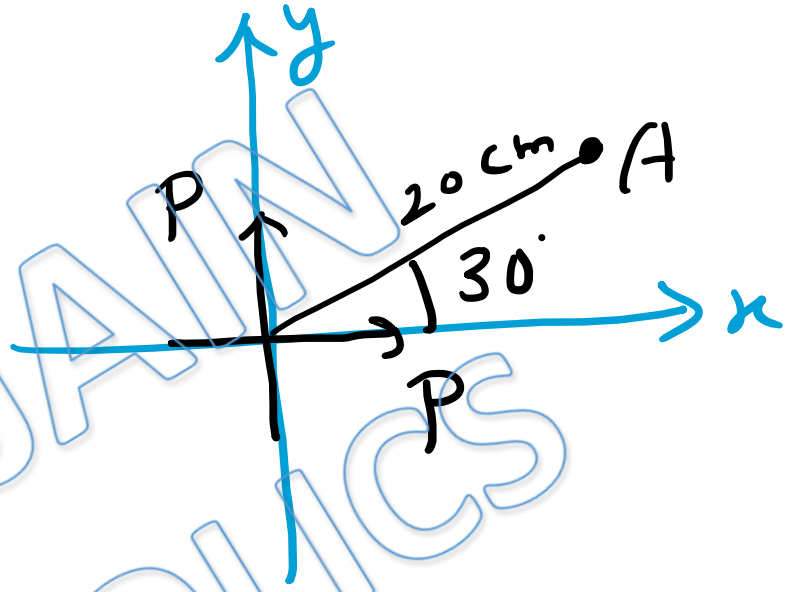
Potential at point A

$$V_A = \frac{KP\cos 30^\circ}{r^2} + \frac{KP}{r^2}\cos 60^\circ$$

$$= \frac{KP}{r^2}\left(\frac{\sqrt{3}}{2} + \frac{1}{2}\right)$$

$$= \frac{9\times10^9 \times 5\times10^{-12}}{(\cdot2)^2}\left(\frac{\sqrt{3}+1}{2}\right)$$

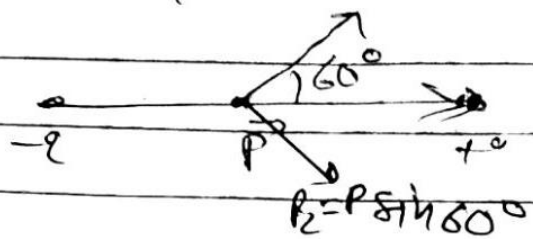
$$= \frac{45(\sqrt{3}+1)}{8}\times10^{-1} = 1.536\ V$$



Ans. d

Solution: 13

$P_1 = P\cos 60°$ $r = 100\,cm = 1\,m$,



$P_1 = P\cos 60°$, $P_2 = P\sin 60°$

~~Electric~~ Potential due to P_2 is zero (∵ equitorial position)

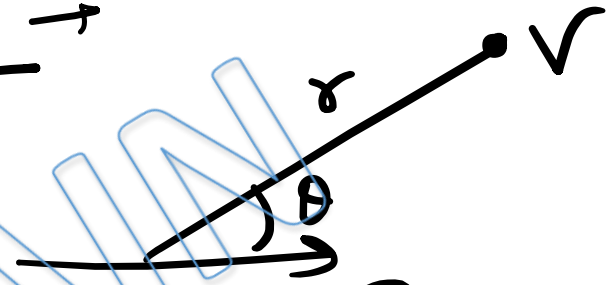
Potential = V = due to P_1

$$V = \frac{kP_1}{r^2} = \frac{kP\cos 60°}{r^2}$$

$$V = \frac{9\times10^9 \times (2\times10^{-4})\left(\frac{1}{2}\right)}{(1)^2}$$

$$\boxed{V = 9\times10^5 \text{ volt}}$$

OR →



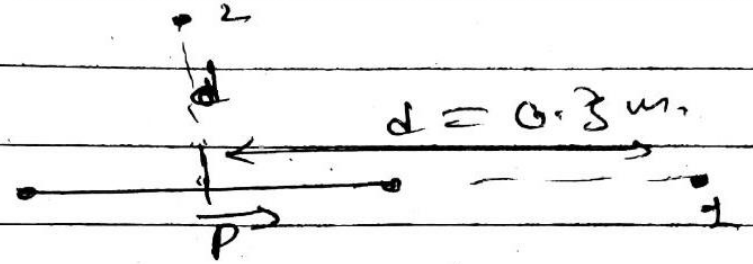
$$V = \frac{1}{4\pi\varepsilon_0}\frac{P\cos\theta}{r^2}$$

$$= \frac{9\times10^9 \times 2\times10^{-4} \times \cos 60°}{1^2}$$

$$= 9\times10^5 \text{ V}$$

Ans. c

Solution: 14



$$V_1 = \frac{kP}{\gamma_2}$$

$$V_1 = \frac{9\times10^9 \times 4\times10^{-9}}{(0.3)^2}$$

$$V = \frac{36}{9\times10^{-2}}$$

$$\boxed{V = 400 \text{ volt}}$$

V_2 = Point '2' is on equitorial

$$\boxed{V_2 = 0}$$

Ans. a

Solution: 15

$$F = \frac{G k P^2}{r^4}$$

$$F \propto \frac{1}{r^4}, \quad F \propto P^2$$

F is inversely proportional to r^4, directly proportional to $P_1 P_2$ or P^2.

Ans. d

Solution: 16

$$p = q \times d$$

$$= 10^{-6} \times 2 \times 10^{-2}$$

$$p = 2 \times 10^{-8} \text{ C-m}$$

$$E = 10^{-5} \text{ V/m}$$

$$\tau_{max} = pE(\sin\theta)_{max} = pE$$

$$= 2 \times 10^{-8} \times 10^{+5}$$

$$\boxed{\tau_{max} = 2 \times 10^{-13} \text{ N-m}}$$

Ans. b

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