Prb. #	ANSWERS

1

$F = \frac{k_e\, q_1 q_2}{r^2}$: $k_e \cong 10^{10}\ N/C^2.m^2$, $r \cong 1\,m$, q1 = q2 = 1% of charge in person

Say have 100 kg person made of water.
Water is ~ 10 g/mole ; 1 mole ≅ 10^{24} molecules ; water molecules have ~10 e^-.

So in 100 kg have $\frac{10^5\ g}{10\ g/mole}$ = 10^4 moles. Which is 10^{28} atoms, and that gives 10^{29} charges.

1% of this is 10^{27} charges, so $q_1 = q_2 = 10^{27}\ e^-$.

$$F = \frac{10^{10}\ 10^{27} 10^{27}\ 10^{-19}\ 10^{-19}}{1^2} = 10^{26}\ N$$

Mass of Earth ~ 10^{25} kg

$F = mg = 10^{26}\ N$

Thus the forces are of the same order of magnitude.

2

(a) Let the third bead have charge Q and be located distance x from the left end of the rod. This bead will experience a net force given by

$$\vec{\mathbf{F}} = \frac{k_e(3q)Q}{x^2}\hat{\mathbf{i}} + \frac{k_e(q)Q}{(d-x)^2}(-\hat{\mathbf{i}}), \text{ where } d = 1.50\text{ m}$$

The net force will be zero if $\frac{3}{x^2} = \frac{1}{(d-x)^2}$, or $d - x = \frac{x}{\sqrt{3}}$.

This gives an equilibrium position of the third bead of

$$x = 0.634d = 0.634(1.50\text{ m}) = \boxed{0.951\text{ m}}$$

(b) $\boxed{\text{Yes, if the third bead has positive charge.}}$ The equilibrium would be stable because if charge Q were displaced either to the left or right on the rod, the new net force would be opposite to the direction Q has been displaced, causing it to be pushed back to its equilibrium position.

note on (a): This example uses $q_1 = 3q$, but the value of q_1 differs for each person.

3

Each charge exerts a force of magnitude $\frac{k_e qQ}{(d/2)^2 + x^2}$ on the negative charge $-Q$: the top charge exerts its force directed upward and to the left, and bottom charge exerts its force directed downward and to the left, each at angle $\theta = \tan^{-1}\left(\frac{d}{2x}\right)$, respectively, above and below the x axis. The two positive charges together exert a net force:

$$\vec{\mathbf{F}} = -2\frac{k_e qQ}{(d/2)^2 + x^2}\cos\theta\hat{\mathbf{i}}$$

$$= -2\left[\frac{k_e qQ}{(d^2/4 + x^2)}\right]\left[\frac{x}{(d^2/4 + x^2)^{1/2}}\right]\hat{\mathbf{i}}$$

$$= \left[\frac{-2xk_e qQ}{(d^2/4 + x^2)^{3/2}}\right]\hat{\mathbf{i}} = m\vec{\mathbf{a}}$$

or for $x \ll \frac{d}{2}$, $\vec{\mathbf{a}} \approx -\left(\frac{2k_e qQ}{md^3/8}\right)\vec{\mathbf{x}} \rightarrow \vec{\mathbf{a}} \approx -\left(\frac{16k_e qQ}{md^3}\right)\vec{\mathbf{x}}$

(a) The acceleration of the charge is equal to a negative constant times its displacement from equilibrium, as in $\vec{\mathbf{a}} = -\omega^2\vec{\mathbf{x}}$, so we have Simple Harmonic Motion with $\omega^2 = \frac{16k_e qQ}{md^3}$.

(b) $\omega^2 = \left(\frac{2\pi}{T}\right)^2 = \frac{16k_e qQ}{md^3} \rightarrow T = \frac{2\pi}{\omega} = \boxed{\frac{\pi}{2}\sqrt{\frac{md^3}{k_e qQ}}}$, where m is the mass of the object with charge $-Q$.

(c) $v_{max} = \omega A = \boxed{4a\sqrt{\frac{k_e qQ}{md^3}}}$

4

Call $Q = 3.00$ nC and $q = |-2.00 \text{ nC}| = 2.00$ nC, and $r = 4.00$ cm $= 0.040\,0$ m. Then,

$$E_1 = E_2 = \frac{k_e Q}{r^2} \quad \text{and} \quad E_3 = \frac{k_e q}{r^2}$$

Then,

$$E_y = 0$$

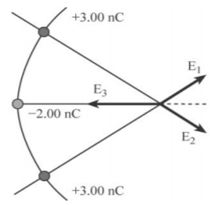
$$E_x = E_{total} = 2\frac{k_e Q}{r^2}\cos 30.0° - \frac{k_e q}{r^2}$$

$$E_x = \frac{k_e}{r^2}(2Q\cos 30.0° - q)$$

$$E_x = \left[\frac{8.99\times10^9 \text{ N}\cdot\text{m}^2/\text{C}^2}{(0.040\,0 \text{ m})^2}\right] \times\left[2\left(3.00\times10^{-9}\text{ C}\right)\cos 30.0° - 2.00\times10^{-9}\text{ C}\right]$$

$$= 1.80\times10^4 \text{ N/C}$$

(a) $\boxed{1.80\times10^4 \text{ N/C to the right}}$



ANS. FIG. P22.19

(b) The electric force on a point charge placed at point P is

$$F = qE = \left(-5.00\times10^{-9}\text{ C}\right)E = \boxed{-8.98\times10^{-5}\text{ N (to the left)}}$$

note for (b) that the given value of q may vary

5

Field lines emerge from positive charge and enter negative charge.

(a) The number of field lines emerging from positive q_2 and entering negative charge q_1 is proportional to their charges:

$$\frac{q_1}{q_2} = \frac{-6}{18} = \boxed{-\frac{1}{3}}$$

(b) From above, $\boxed{q_1 \text{ is negative, } q_2 \text{ is positive}}$.

6

(a) $N = \left(\frac{10.0\text{ grams}}{107.87\text{ grams/mol}}\right)\left(6.02\times10^{23}\ \frac{\text{atoms}}{\text{mol}}\right)\left(47\ \frac{\text{electrons}}{\text{atom}}\right)$

$= \boxed{2.62\times10^{24}}$

In (a), the given mass may vary

(b) $\#\text{ electrons added} = \frac{Q}{e} = \frac{1.00\times10^{-3}\text{ C added}}{1.60\times10^{-19}\text{ C/electron}}$

$= 6.25\times10^{15}$ electrons added

Thus,

$$\left(6.25\times10^{15}\text{ added}\right)\left(\frac{1}{2.62\times10^{24}\text{ present}}\right) = \left(\frac{2.38\text{ added}}{10^9\text{ present}}\right)$$

$\rightarrow$ 2.38 electrons for every 10^9 already present

In (b), the given value of Q may vary