Midterm 2

Electric field $\vec{E}$

Electric force $\vec{F}_E$

Electric potential V

Electric potential energy U_E

$\vec{F}_E = q\vec{E}$

$\vec{E}_x = -\frac{\Delta V}{\Delta x}\hat{x}$

$\vec{E}_q = \frac{kq}{r^2}\hat{r}$

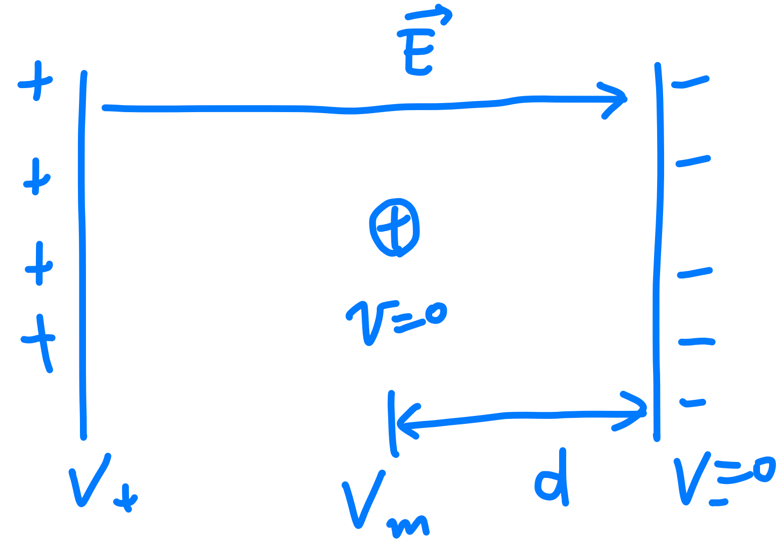
$\vec{F}_E \cdot \Delta\vec{r} = -\Delta U_E$

$V_q = \frac{kq}{r}$

$U_E = qV$

2. (5 points) A proton is released from rest at the midpoint between two parallel plate capacitors. If the proton hits the negative plate with $1.0 \times 10^{-18}\ J$ of energy, what is the voltage difference between the plates?

q_{sp}



$$E_i = KE_i + U_{E_i}$$
$$= qV_m$$

$$E_f = KE_f + U_{E_f}$$
$$= \frac{1}{2}mv^2 = 1\times10^{-18}\,J$$

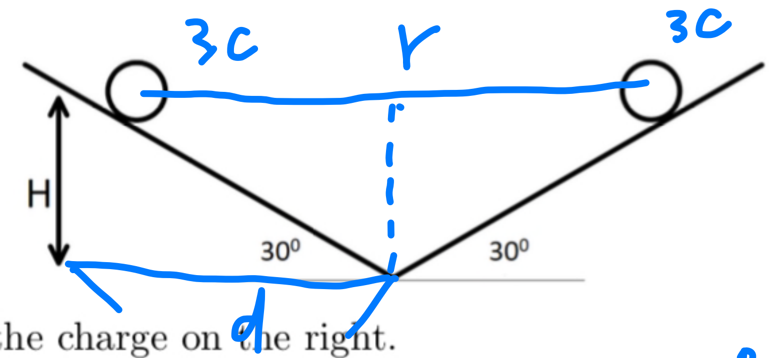
$$E_i = E_f$$
$$qV_m = \frac{1}{2}mv^2 = 1\times10^{-18}\,J$$

$$V_m = \frac{1\times10^{-18}}{1.6\times10^{-19}} = 6.25\ V$$

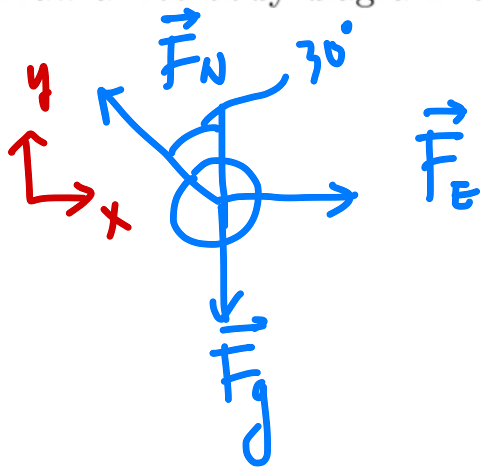
$$V = \vec{E}\cdot\vec{X}_{low\to high} \qquad V_m = E\cdot d = 6.25$$

$$V_+ = E\cdot 2d = \underline{12.5\,V}$$

9. Two positively charged spheres are at rest in equilibrium on the pictured diagram. They each have a mass of 1.0 kg, and a charge of 3.0 Coulombs.



a. (2 pts) Draw a free body diagram for the charge on the right.



$$\tan 30° = \frac{H}{d}$$

$$d = \frac{H}{\tan 30°}$$

$$r = 2d = \frac{2H}{\tan 30°}$$

b. (8 pts) What is their height, H?

$$F_N \sin 30° = F_E \rightarrow mg \tan 30° = F_E = \frac{kq^2}{r^2}$$

$$F_N \cos 30° = F_g = mg$$

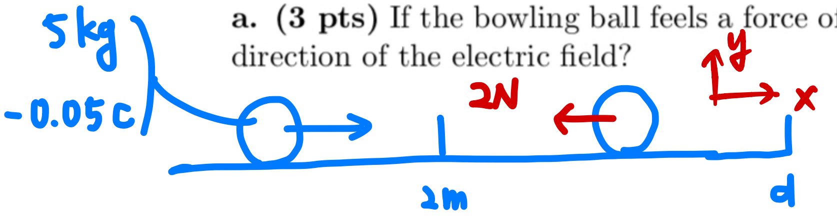
$$F_N = \frac{mg}{\cos 30°}$$

$$mg \tan 30° = \frac{kq^2}{\left(\frac{2H}{\tan 30°}\right)^2}$$

$$H^2 = \frac{kq^2 \tan 30°}{4mg} \Rightarrow H = 35\,km$$

8. An electrically charged bowling ball of mass = 5.0 kg and charge = – 0.05 C slides to the right across a flat frictionless surface. It slides through a uniform horizontal electric field which starts at x = 2.0 m and ends at x = d.

a. (3 pts) If the bowling ball feels a force of 2 N to the left, what is the magnitude and direction of the electric field?



$$\vec{F}_E = 2N\langle -1, 0\rangle$$

$$\vec{F}_E = q\vec{E} = (-0.05\,C)\vec{E}$$

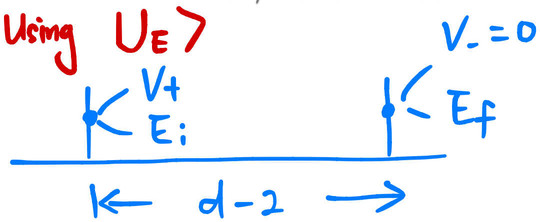
$$\Rightarrow (-0.05\,C)\vec{E} = 2N\langle -1, 0\rangle$$

$$\vec{E} = \frac{2N}{-0.05\,C}\langle -1, 0\rangle = \underbrace{40\,\frac{N}{C}}_{\text{magnitude}}\langle 1, 0\rangle$$

direction $+x$

b. (5 pts) If the bowling ball has a speed of 3.0 m/s at x = 0.0 m, and a speed of 2.2 m/s after it exits the field, what is d?

⟨Using U_E⟩



$$E_i = \frac{1}{2}mv_i^2 + qV_+$$

$$E_f = \frac{1}{2}mv_f^2$$

$$E_i = E_f \Rightarrow \frac{1}{2}mv_i^2 + qV_+ = \frac{1}{2}mv_f^2$$

$$\frac{1}{2}m(v_i^2 - v_f^2) = -qV_+$$

$$V_+ = E\Delta x = 40(d-2)$$

$$\Rightarrow \frac{1}{2}m(v_i^2 - v_f^2) = -q\,40(d-2)$$

$$\frac{1}{2}(5)(3^2 - 2.2^2) = \underbrace{(0.05)(40)}_{2}(d-2)$$

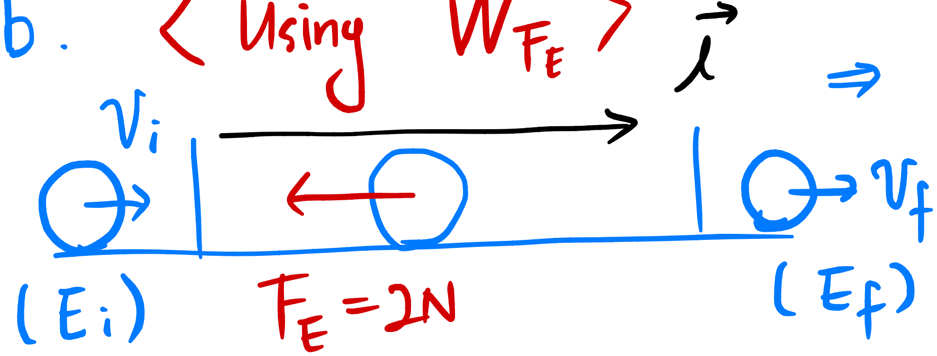
$$d = 2 + \frac{5}{4}(3^2 - 2.2^2)$$

$$\underline{d = 7.2\,m}$$

c. (2 pts) Through what electric potential difference, delta V, did the bowling ball travel?

Next Pg.

b. < Using W_{F_E} >



$\Rightarrow \quad W_{F_E} = \vec{F}_E \cdot \vec{l}$

$= F_E \, l \cos 180^\circ$

$= -F_E \, l = -F_E (d-2)$

$\Rightarrow \quad W_{F_E} = -2(d-2)$

$\Rightarrow \quad E_i = \frac{1}{2} m v_i^2$

$E_f = \frac{1}{2} m v_f^2$

$E_i + W_{F_E} = E_f$

$\frac{1}{2} m v_i^2 - 2(d-2) = \frac{1}{2} m v_f^2$

$\frac{1}{2} m (v_i^2 - v_f^2) = 2(d-2)$

$d = 2 + \frac{m}{4}(v_i^2 - v_f^2) = \underline{7.2\,m}$

c. $\Delta V = E \cdot \Delta X$

$= 40 \frac{N}{C} (d-2)$

$= 40 \cdot (5.2)\ v$

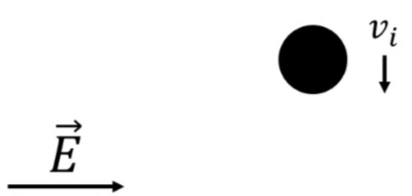
$= \underline{208\ V}$

9. (12 points) A ball with charge $\mathbf{q} = \mathbf{-2.3\ C}$ and mass $\mathbf{m} = \mathbf{0.85\ kg}$ is falling due to gravity. A uniform vertical electric field of strength $\mathbf{E} = \mathbf{5.3\ N/C}$ exists between the ground and **D** meters above the ground. The ball enters the electric field from the top with a downward velocity $\vec{\mathbf{v}}_i = \mathbf{5.0\ m/s}$ and hits the ground with a downward velocity $\vec{\mathbf{v}}_f = \mathbf{4.0\ m/s}$.

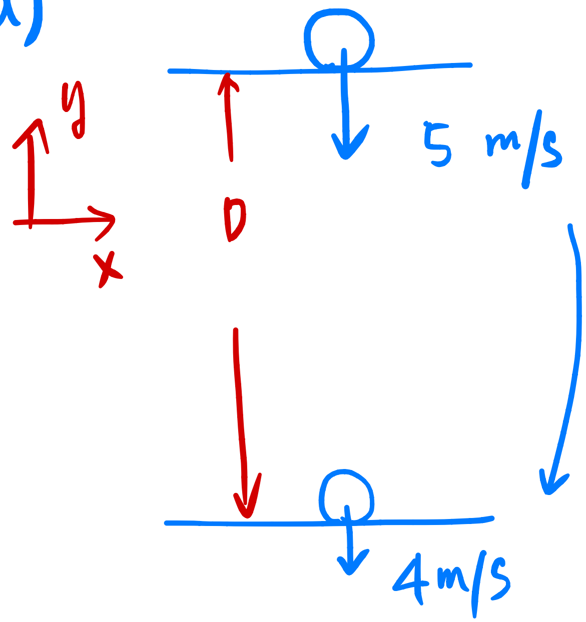
a) (2 point) What direction does the electric field point?

b) (8 pts) What is the distance **D**?

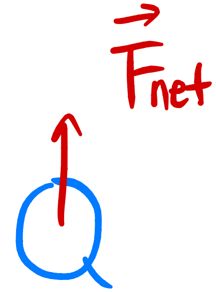
b) (2 pts) The same situation occurs, except the uniform electric field of strength **E** now points horizontally to the right. Sketch the path of the ball as it falls through the electric field.



a)



decelerate $\Rightarrow$



$\downarrow \vec{E}$.

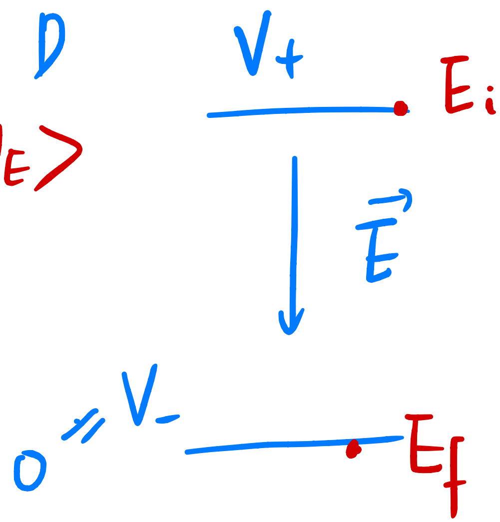
some positive constant

$$\vec{F}_E = \underline{\underline{F}}\langle 0,1\rangle = q\vec{E}$$

$$\vec{E} = \frac{F}{q}\langle 0,1\rangle = \frac{F}{2.3}\langle 0,\underline{\underline{-1}}\rangle$$

b) Find D

$\langle$ Using $U_E \rangle$



$$E_i = \frac{1}{2}mv_i^2 + mgD + qV_+$$

$$E_f = \frac{1}{2}mv_f^2$$

$$\Rightarrow \frac{1}{2}mv_i^2 + mgD + qV_+ = \frac{1}{2}mv_f^2$$

$$V_+ = E\Delta h = 5.3D \text{ V}$$

$$\frac{1}{2}mv_i^2 + mgD + q\times 5.3D = \frac{1}{2}mv_f^2$$

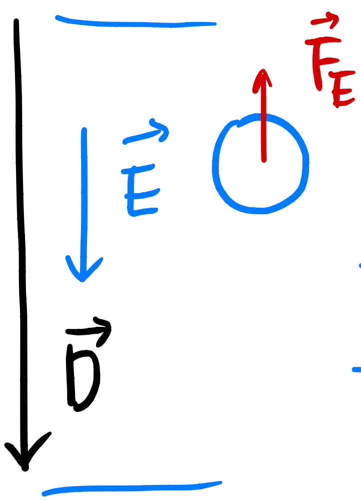
$$\frac{1}{2}m(5^2-4^2) = (-5.3q - mg)D$$

$-2.3\,C$

$$D = \frac{\frac{1}{2}(0.85\,kg)(5^2-4^2)}{(5.3\times 2.3 - 0.85\times 9.81)} = 0.99\,m$$

Same

<Using W_{F_E}>



$$W_{F_E} = F_E\cdot D\cdot\cos 180^\circ = -F_E D$$

$$F_E = |qE| = |-2.3\times 5.3|\,N = 12\,N$$

$$E_i = \frac{1}{2}mv_i^2 + mgD$$

$$E_f = \frac{1}{2}mv_f^2$$

$$\Rightarrow E_i + W_{F_E} = E_f$$

$$\Rightarrow \frac{1}{2}mv_i^2 + mgD - F_E D = \frac{1}{2}mv_f^2$$

$$\frac{1}{2}m(v_i^2 - v_f^2) = (F_E - mg)D$$

c)