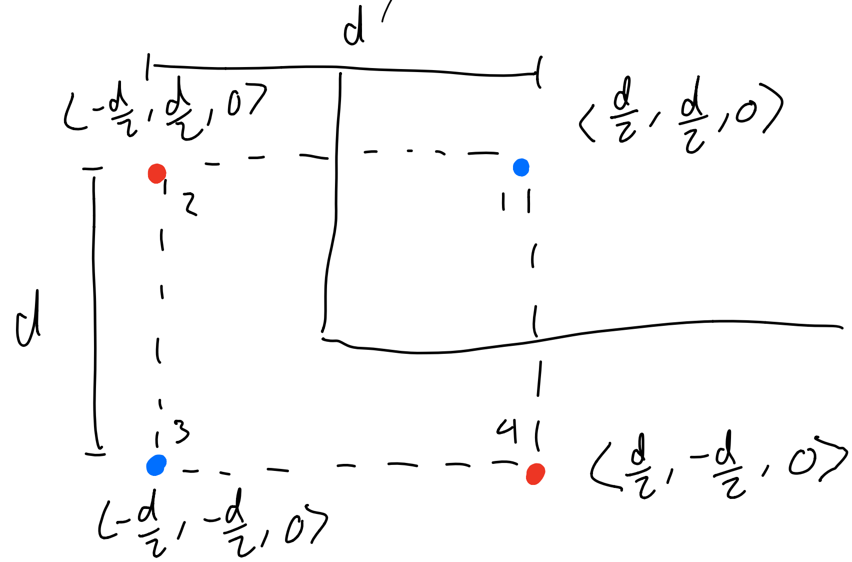
1.) Many possible answers

one possibility



$\vec{E}_1 = $ $\vec{r} = \langle -\frac{d}{2}, -\frac{d}{2}, 0\rangle$ $\quad \vec{E}_1 = \frac{-1}{4\pi\epsilon_0} \frac{e}{d^2/2} \frac{\sqrt{2}}{2} \langle -1, -1\rangle$

$|\vec{r}| = \sqrt{\frac{1}{2}d^2} = \frac{\sqrt{2}}{2}d$

$\hat{r} = \frac{2}{\sqrt{2}d} \langle -\frac{d}{2}, -\frac{d}{2}, 0\rangle$, $\vec{E}_1 = \frac{\sqrt{2}}{4\pi\epsilon_0} \frac{e}{d^2} \langle -1, -1\rangle$

$\hat{r} = \frac{\sqrt{2}}{2} \langle -1, -1\rangle$

$$\vec{E}_1 = \frac{\sqrt{2}}{4\pi\epsilon_0} \frac{e}{d^2} \langle 1, 1\rangle$$

$$\vec{E}_2 = \frac{\sqrt{2}}{4\pi\epsilon_0} \frac{e}{d^2} \langle 1, -1\rangle$$

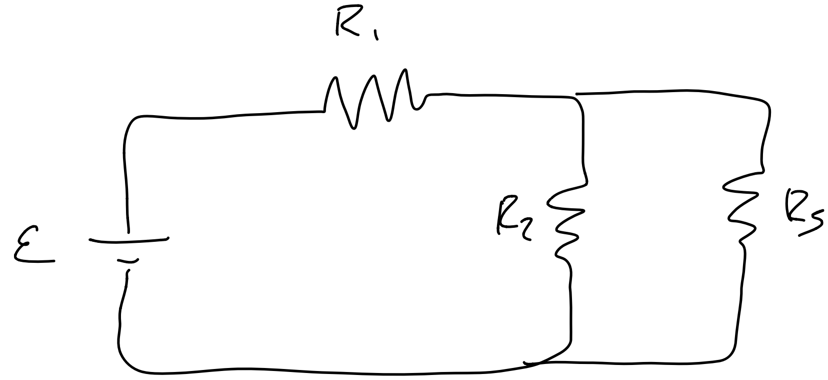
$$\vec{E}_3 = \frac{\sqrt{2}}{4\pi\epsilon_0}\frac{e}{d^2}\langle -1,-1\rangle$$

$$\vec{E}_4 = \frac{\sqrt{2}}{4\pi\epsilon_0}\frac{e}{d^2}\langle -1,1\rangle$$

$$\vec{E} = 0 \quad \checkmark$$

2.

(a)



Find ΔV_1 w/o meter

$$R_{eq} = R_1 + \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$$

$$I = \frac{\mathcal{E}}{R_{eq}}, \quad \Delta V_1 = I R_1$$

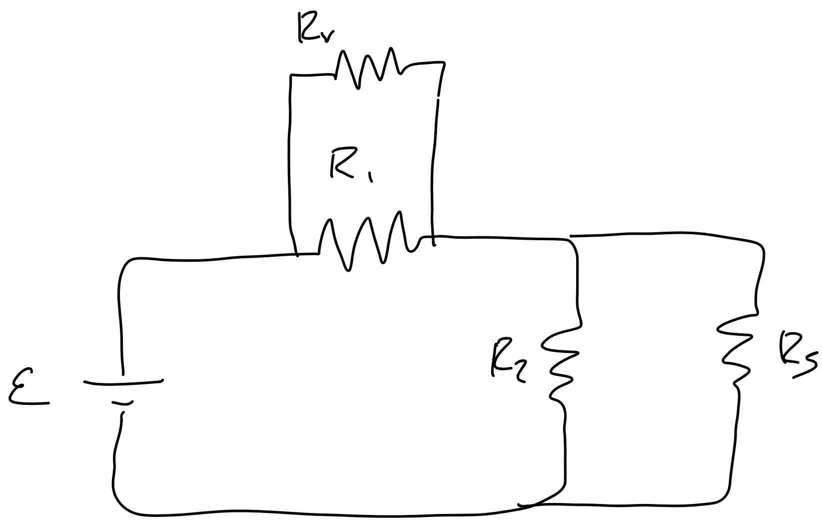
$$\Delta V_1 = \frac{\mathcal{E}}{R_{eq}} R_1$$

$$R_{eq} = 120 + \left(\frac{1}{100} + \frac{1}{150}\right)^{-1}$$

$$R_{eq} = 180$$

$$\Delta V_1 = \frac{9}{180}(120) = 6V$$

$$\boxed{\Delta V_1 = 6V \quad \leftarrow \text{true}}$$



$$R_{1-v} = \left(\frac{1}{R_1} + \frac{1}{R_v}\right)^{-1}$$

$$R_{eq} = R_{1-v} + \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$$

$$= 107.143 + 60$$

$$R_{eq} = 167.143\ \Omega$$

$$I = \frac{\mathcal{E}}{R_{eq}} = 0.054\ldots\ A$$

$$\Delta V_1 = I(R_{1-v}) \approx 5.77\ V$$

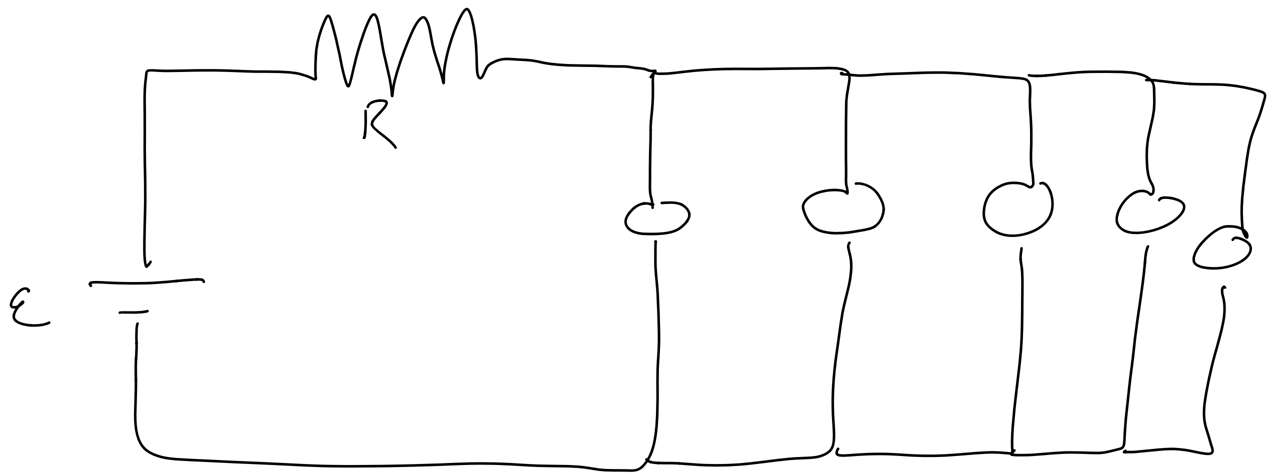
$$\text{Error} = \frac{\Delta V_{meas} - \Delta V_{true}}{\Delta V_{true}} \cdot 100 = \frac{-0.231}{6} \cdot 100$$

$$\boxed{\text{Error} \approx -3.85\ \%}$$

2

(b) Many possible designs

Here is one



$$R_{eq} = R + \left(\frac{1}{R_b} + \frac{1}{R_b} + \frac{1}{R_b} + \frac{1}{R_b} + \frac{1}{R_b}\right)^{-1}$$

$$= R + \left(\frac{5}{R_b}\right)^{-1}$$

$$R_{eq} = R + \frac{R_b}{5}$$

$$I_{tot} = \frac{\varepsilon}{R_{eq}} = \frac{\varepsilon}{R + \frac{1}{5} R_b}$$

$$I_{bulb} = \frac{1}{5} I_{tot}$$

$$P_{bulb} = I_{bulb}^2 R_{bulb} = \left(\frac{1}{5} I_{tot}\right)^2 R_{bulb}$$

$$P_{bulb} = \frac{1}{25}\left(\frac{\mathcal{E}}{R + \frac{1}{5}R_{bulb}}\right)^2 R_{bulb}$$

$$P_{bulb} \geq 0.5$$

$$\frac{1}{25}\left(\frac{\mathcal{E}}{R + \frac{1}{5}R_{bulb}}\right)^2 R_{bulb} \geq 0.5$$

$$\left(\frac{\mathcal{E}}{R+\frac{1}{5}R_{bulb}}\right)^2 \geq \frac{25}{R_{bulb}}(0.5)$$

$$\frac{\mathcal{E}}{R+\frac{1}{5}R_{bulb}} \geq \sqrt{\frac{1}{2}\frac{25}{R_{bulb}}}$$

$$\frac{\mathcal{E}}{\sqrt{\frac{1}{2}\frac{25}{R_{bulb}}}} \geq R + \frac{1}{5}R_{bulb}$$

$$R \leq \frac{\mathcal{E}}{\sqrt{\frac{1}{2}\frac{25}{R_b}}} - \frac{1}{5}R_b$$

$$R \leq 105.33\ \Omega$$

$$I_{bulb} = \frac{1}{5}\frac{\mathcal{E}}{R+\frac{1}{5}R_b} \leq 3$$

$$\frac{\mathcal{E}}{R + \frac{1}{5}R_b} \leq 15$$

$$\mathcal{E} \leq 15\left(R + \frac{1}{5}b\right)$$

$$\frac{1}{15}\mathcal{E} \leq R + \frac{1}{5}R_b$$

$$R \geq \frac{\mathcal{E}}{15} - \frac{R_b}{5}$$

$$R \geq 6$$

$$\boxed{6\,\Omega \leq R \leq 105.33\,\Omega}$$

3) $P = I \Delta V$

$$I = \frac{\Delta V}{R}$$

$$P = \frac{\Delta V^2}{R}$$

$$\Delta V = \mathcal{E} = BLv$$

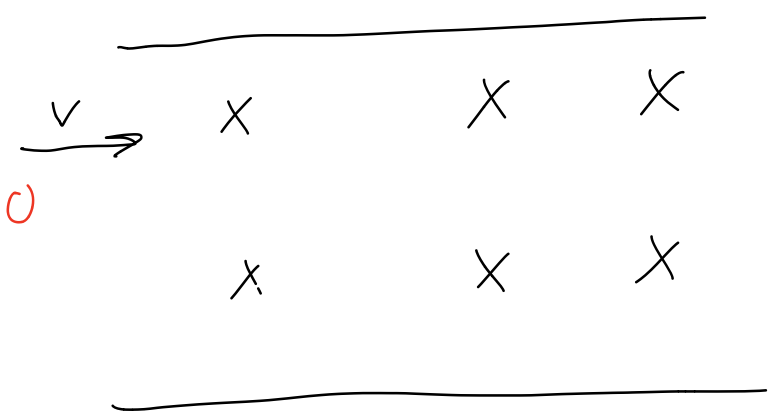
$$P = \frac{1}{R}(BLv)^2$$

$$\sqrt{RP} = BLv$$

$$v = \frac{\sqrt{RP}}{BL} = \frac{\sqrt{10(0.5)}}{2(0.1)}$$

$$\boxed{v \approx 11.2 \ m/s}$$

4)



$$\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$$

$$\vec{F} = 0$$

$$\vec{E} + \vec{v} \times \vec{B} = 0$$

$$\vec{v} = V_0 \hat{x}$$

$$\vec{B} = -B_0 \hat{z}$$

$$\vec{E} = -\vec{v} \times \vec{B}$$

$$= -\left(V_0 \hat{x} \times -B_0 \hat{z}\right)$$

$$\vec{E} = -B_0 V_0 \hat{y}$$

$$\vec{E} = -(0.3)(700)\,\hat{y} = -210\,\hat{y}$$

$$\Delta V = -\vec{E} \cdot \vec{\Delta y} = -\left(-210\hat{y} \cdot d(\hat{y})\right) = 210\,d$$

$$= 4.2\,V$$

$$\boxed{\Delta V = 4.2\,V}$$

5)

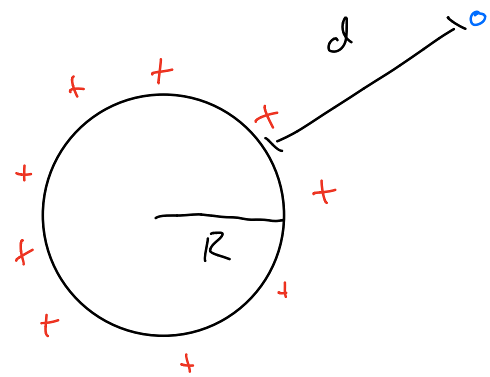
a) sphere is charge neutral

Gauss' Law

$$\Phi_E = \frac{q_{inside}}{\epsilon_0}$$

$q_{inside} = 0$, $\boxed{\Phi_E = 0}$

b)



$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$$

$$\Delta K = -\Delta U$$

$$\Delta U = q\Delta V$$

$$\Delta V = -\int_{R+d}^{R} \vec{E}\cdot d\vec{r}$$

$$= -\int_{R+d}^{R} \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\,dr$$

$$= -\frac{Q}{4\pi\epsilon_0}\left[-\frac{1}{R} + \frac{1}{R+d}\right]$$

$$\Delta V = \frac{Q}{4\pi\epsilon_0}\left[\frac{1}{R} - \frac{1}{R+d}\right]$$

$$\Delta U = \frac{-eQ}{4\pi\epsilon_0}\left[\frac{1}{R} - \frac{1}{R+d}\right]$$

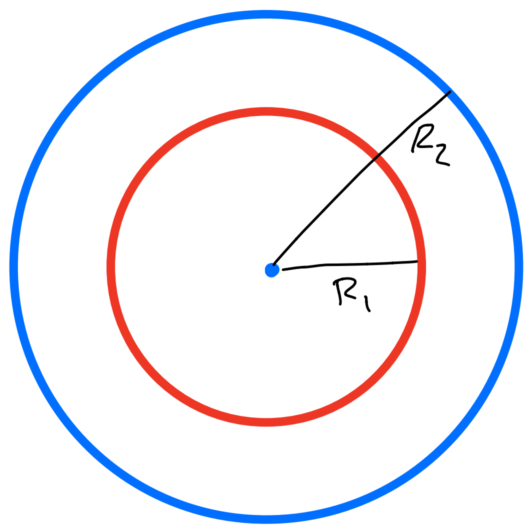
$$\Delta K = -\Delta U \approx 2.44 \times 10^{-34} \text{ J}$$

$$\Delta K = \frac{1}{2} m v^2$$

$$v^2 = \frac{2\Delta K}{m}$$

$$v = \sqrt{\frac{2\Delta K}{m}}$$

$$\boxed{v = 2.3 \times 10^{7} \ \frac{m}{s}}$$



a) $$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{Q_{pt} + Q_{inner}}{r^2}\hat{r} \quad , \quad R_1 < r < R_2$$

$$\Delta V = -\int \vec{E}\cdot d\vec{r} = -\frac{(Q_{pt} + Q_{inner})}{4\pi\epsilon_0}\int_{R_1}^{R_2}\frac{1}{r^2}\,dr$$

$$\Delta V = \frac{(Q_{pt} + Q_{inner})}{4\pi\epsilon_0}\left(\frac{1}{R_2} - \frac{1}{R_1}\right)$$

$$\boxed{\Delta V = 3\times 10^{4}\ V}$$

b)

$$\vec{E} = \frac{Q_{pt} + Q_{inner} + Q_{outer}}{4\pi\epsilon_0} \frac{1}{r^2}\hat{r}, \quad r > R_2$$

$r = 0.5\,m$

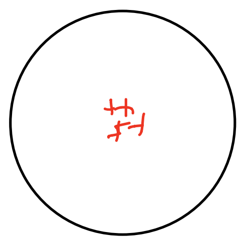
$\vec{F} = q\vec{E}, \; q = e$

$$\boxed{|\vec{F}| = -2.3 \times 10^{-14}\ N}$$

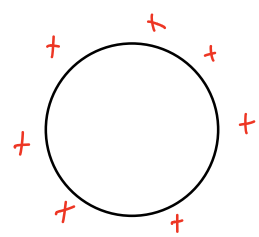
7. 1,3

a) Magnetic field does no work

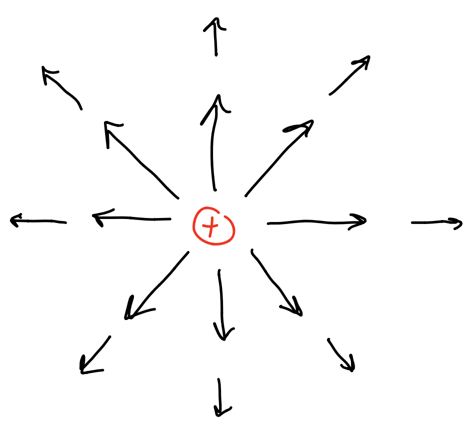
b) i



ii



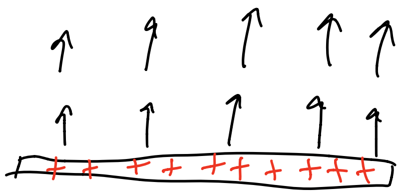
c)

① 

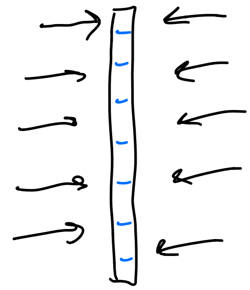
② Not possible

$\oint \vec{E} \cdot d\vec{l} \neq 0$

3



4



8.

$$\Phi_B = (A)(B)\cos\theta$$

$$|\varepsilon| = \frac{d\Phi}{dt} = AB\frac{d\theta}{dt}\sin\theta$$

$$\max(|\varepsilon|) = AB\omega$$

$$= whB\omega$$

$$= (0.1)(0.15)(0.2)(4\omega)$$

$$\boxed{\varepsilon_{max} = 1.2\,V}$$