(Q1) (a) The charges on the wire are all on its outer surface, since the $\underset{\sim}{E}$ field is zero in the conducting metal, so by Gauss' Law there can be no net charge.

By the same reasoning, the charge (per unit length) on the inside surface of the metal cylinder is $-\lambda$, so that the internal charge adds to zero for $r_2 < r < r_3$.

Finally, to achieve $+2\lambda$ total charge (per unit length) on the cylinder, we need $+3\lambda$ on the outside surface.

(b) In all cases, use cylindrical gaussian surfaces.
The end caps are $\perp$ to $\underset{\sim}{E}$, $\therefore$ make zero contribution to $\underset{\sim}{E} \cdot \underset{\sim}{ds}$
For $r < r_1$, $q = 0$ $\therefore$ $E = 0$ everywhere

(c) For $r_1 < r < r_2$

$$\oint \underset{\sim}{E} \cdot \underset{\sim}{dA} = E\, 2\pi r l = \frac{\lambda l}{\epsilon_0}$$

$$\therefore E = \frac{\lambda}{2\pi r \epsilon_0}$$

(d) For $r_2 < r < r_3$

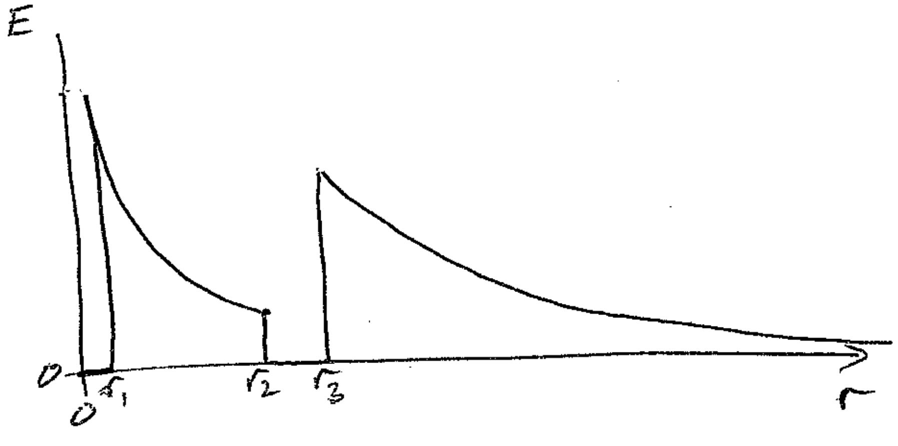
$$q_{int} = 0 \quad \therefore \underset{\sim}{E} = 0$$

(e) For $r > r_3$

$$q_{int} = 3\lambda l$$

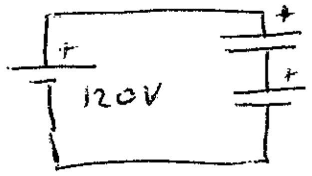
$$\therefore E = \frac{3\lambda}{2\pi r \epsilon_0}$$

(f)



Q2 15

(a)



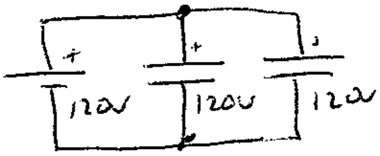
two capacitors

$$E = 2 \times \tfrac{1}{2} C V^2$$

$$= 2 \times \tfrac{1}{2} \times 3000 \times 60^2$$

$$= 1.08 \times 10^7 \text{ J}$$

(b)

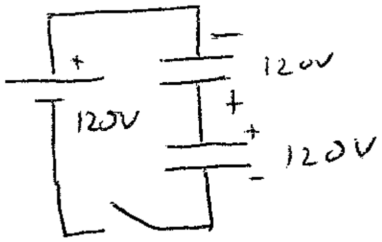


$$E = 2 \times \tfrac{1}{2} C V^2$$

$$= 2 \times \tfrac{1}{2} \times 3000 \times 120^2$$

$$= 4.32 \times 10^7 \text{ J}$$

(c)



← just before connection

The top capacitor will discharge, the bottom one will charge by the same amount. Therefore ΔV of each capacitor will be equal & opposite, resulting in a final voltage of 180 V on the lower one and 60V on the upper.

(2)

$$E = \tfrac{1}{2} C V_1^2 + \tfrac{1}{2} C V_2^2$$

$$= \tfrac{1}{2} \times 3000 \times (60^2 + 180^2)$$

(1) $= 5.40 \times 10^7 \text{ J}$

Q3 (a) For the left-hand loop, $\mathcal{E} = -\frac{d\Phi_B}{dt} = +Blv$.

and $i_1 = \frac{\mathcal{E}}{R_1} = \frac{Blv}{R_1} = \frac{0.85 \times 0.50 \times 4.0}{2.00}$

$= \underline{0.85\text{ A}}$

For the right-hand loop

$i_2 = \frac{Blv}{R_2} = \frac{0.85 \times 0.50 \times 4.0}{5.00}$

$= \underline{0.34\text{ A}}$

(b) Total power $= i_1^2 R_1 + i_2^2 R_2$

$= \frac{B^2 l^2 v^2}{R_1} + \frac{B^2 l^2 v^2}{R_2}$

$= B^2 l^2 v^2 \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$

$= (0.85 \times 0.50 \times 4.0)^2 \left(\frac{1}{2.00} + \frac{1}{5.00} \right)$

$= \underline{2.02\text{ W}}$

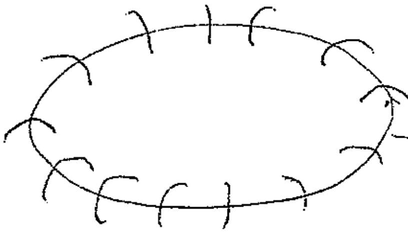
(c) Power = force × velocity

$\therefore$ force $= \frac{\text{power}}{\text{velocity}} = \frac{2.02}{4.0} = \underline{0.51\text{ N}}$

and the direction is the same as velocity, i.e. to the right.

Q4

(a)



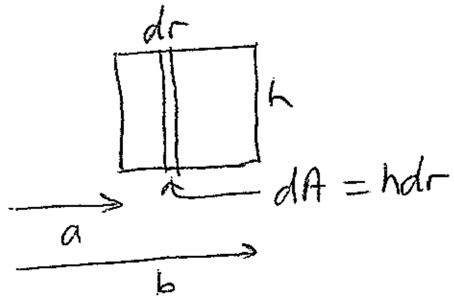
amperian loop:

$$\oint \underset{\sim}{B} \cdot d\underset{\sim}{s} = \mu_0 N I \quad \leftarrow \text{Ampere's Law}$$

$$LHS = \oint \underset{\sim}{B} \cdot d\underset{\sim}{s} = B 2\pi r = \mu_0 N I$$

$$\therefore B = \frac{\mu_0 N I}{2\pi r}$$

(b)



$$\Phi_B = \int B\,dA$$

$$= \int_a^b B h\,dr \quad (2)$$

$$= \int_a^b \frac{\mu_0 N I}{2\pi r} h\,dr = \frac{\mu_0 N I h}{2\pi} \ln\left(\frac{b}{a}\right)$$

(c)

$$L = \frac{N \Phi_B}{I} = \frac{\mu_0 N^2 h}{2\pi} \ln\left(\frac{b}{a}\right)$$