

$$I_1 = \frac{1}{2} I_0 \Rightarrow I_1 = 0.075 \frac{W}{m^2}$$

$$I_2 = I_1 \cdot \cos^2(\theta_2 - \theta_1) = 0.075 \cdot \cos^2(-30) \Rightarrow I_2 = 0.0562 \frac{W}{m^2}$$

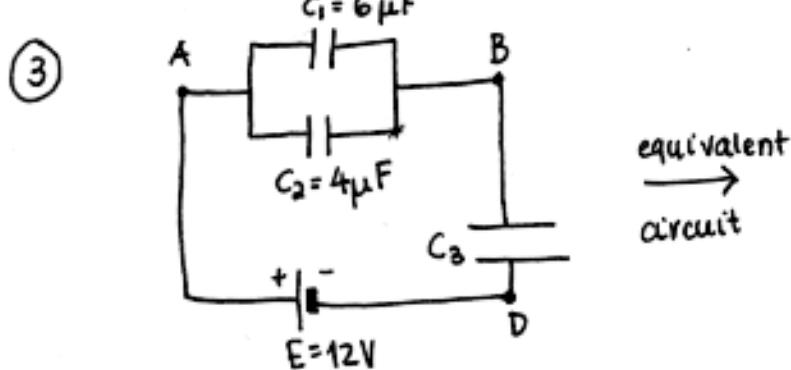
$$I_3 = I_2 \cdot \cos^2(\theta_3 - \theta_2) = 0.0562 \cdot \cos^2(-30) \Rightarrow I_3 = 0.0421 \frac{W}{m^2}$$

$$I_4 = I_3 \cdot \cos^2(\theta_4 - \theta_3) = 0.0421 \cdot \cos^2(60) \Rightarrow I_4 = 0.0105 \frac{W}{m^2}$$

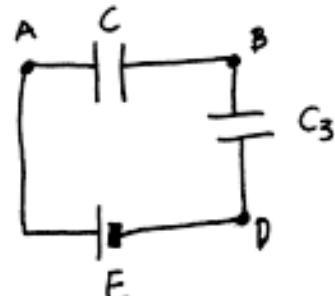
② Initial voltages: $V_{AC} = 12V$, $V_{BC} = 12V$

Final voltages: $V_{AF} = 12V$, $V_{BF} = 12V$

So the initial and final currents are the same
so the brightness of the bulbs does not change.



equivalent
circuit



$C = C_1 + C_2 = 10 \mu F$. C and C3 are in series so they have the same charge!

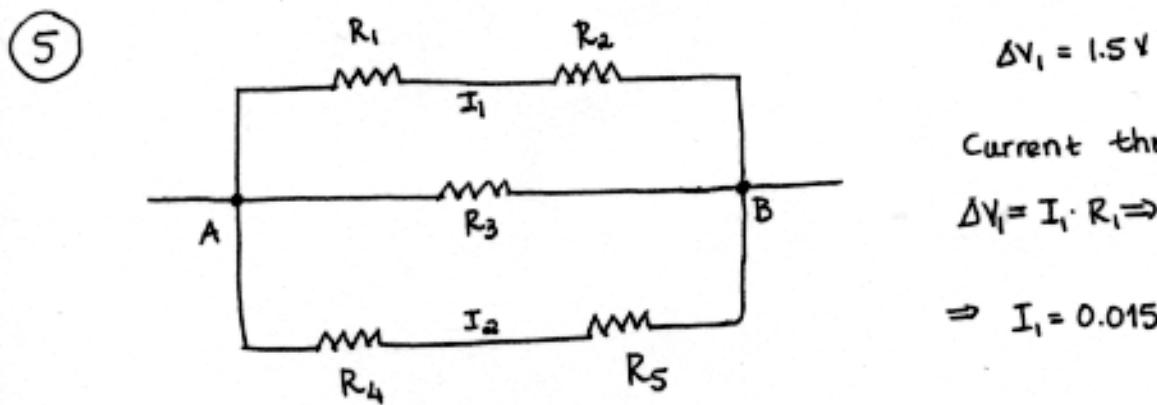
$$C = \frac{Q}{V_{AB}} \Rightarrow C_3 = \frac{Q}{V_{BD}} \Rightarrow C \cdot V_{AB} = C_3 \cdot V_{BD} \Rightarrow V_{BD} = \frac{C}{C_3} \cdot V_{AB}$$

$$V_{AB} + V_{BD} = E \Rightarrow \left(1 + \frac{C}{C_3}\right) V_{AB} = E \Rightarrow \frac{C}{C_3} = \frac{E}{V_{AB}} - 1 \Rightarrow C_3 = C \cdot \left[\frac{E}{V_{AB}} - 1 \right]$$

$$\boxed{C_3 = 5 \mu F}$$

(4) Resistance: $R = \rho \cdot \frac{l}{A} \Rightarrow R = 1.7 \times 10^{-8} \cdot \frac{2 \times 10^{-2}}{\pi \cdot (10^{-2})^2} \Omega \Rightarrow$
 $\Rightarrow R = 1.08 \times 10^{-6} \Omega$

$$\Delta V = I \cdot R \Rightarrow I = \frac{10^{-3}}{108 \times 10^{-6}} A \Rightarrow I = 925 A$$



Voltage between points A and B:

$$\Delta V_{AB} = I_1 \cdot (R_1 + R_2) \Rightarrow \Delta V_{AB} = 0.015 (100 + 200) V \Rightarrow \Delta V_{AB} = 4.5 V$$

$$\Delta V_{AB} = I_2 \cdot (R_4 + R_5) \Rightarrow I_2 = \frac{4.5}{50 + 250} A \Rightarrow I_2 = 0.015 A$$

(6) $R = -30 \text{ cm}$ (convex mirror)

First object: $p_1 = 20 \text{ cm}$, $\frac{1}{p_1} + \frac{1}{q_1} = \frac{2}{R} \Rightarrow \frac{1}{q_1} = \frac{2}{-30} - \frac{1}{20} \Rightarrow q_1 = -8.57 \text{ cm}$

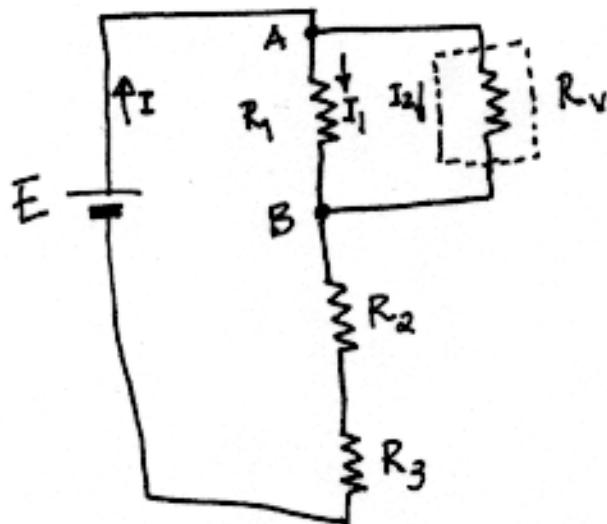
Magnification: $\frac{h'_1}{h_1} = -\frac{q_1}{p_1} \Rightarrow \frac{h'_1}{h_1} = -\frac{-8.57}{20} \Rightarrow \frac{h'_1}{h_1} = 0.4285$

Second object: $h_2 = 3 \cdot h_1$, $h'_2 = h'_1$

$$\frac{h'_2}{h_2} = -\frac{q_2}{p_2} \Rightarrow \frac{h'_2}{3 \cdot h_1} = -\frac{q_2}{p_2} \Rightarrow -\frac{p_2}{q_2} = 7 \Rightarrow q_2 = -\frac{p_2}{7}$$

$$\frac{1}{p_2} + \frac{1}{q_2} = \frac{2}{R} \Rightarrow \frac{1}{p_2} - \frac{7}{p_2} = \frac{2}{R} \Rightarrow -\frac{6}{p_2} = \frac{2}{R} \Rightarrow p_2 = -3R \Rightarrow p_2 = 90 \text{ cm}$$

(7)



$$\Delta V_{AB} = 4.2 \text{ V}$$

$$\left. \begin{aligned} \Delta V_{AB} &= I_1 \cdot R_1 \\ &= I_2 \cdot R_v \end{aligned} \right\} \Rightarrow I_1 = I_2 \cdot \frac{R_v}{R_1}$$

$$R_v \cdot I_2 = \Delta V_{AB} \Rightarrow I_2 = \frac{4.2}{8000} \Rightarrow$$

$$I_2 = 5.25 \times 10^{-4} \text{ A}$$

$$\text{So: } I_1 = 1.05 \times 10^{-3} \text{ A}$$

$$\text{and } I = I_1 + I_2 = 1.575 \times 10^{-3} \text{ A}$$

$$E = \Delta V_{AB} + I \cdot R_2 + I \cdot R_3 \Rightarrow \boxed{E = 26.25 \text{ V}}$$

$$(8) \quad \frac{1}{D} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{q} = \frac{1}{-50} - \frac{1}{20} \Rightarrow q = -14.3 \text{ cm}$$

$$M = \frac{h'}{h} = -\frac{q}{P} \Rightarrow h' = -\frac{-14.3}{20} \cdot 3 \text{ cm} \Rightarrow \boxed{h' = +2.14 \text{ cm}}$$

$$(9) \quad L = \frac{1}{4} \lambda$$

$$c = f \cdot \lambda \Rightarrow \lambda = \frac{3 \times 10^8}{89.1 \times 10^6} \text{ m} \Rightarrow \lambda = 3.367 \text{ m}$$

$$L = 0.84 \text{ m} \Rightarrow \boxed{L = 84 \text{ cm}}$$

⑩ Energy density = $\frac{I}{c} \Rightarrow I_0 = 3 \times 10^{+2} \frac{W}{m^2}$

$$I_1 = I_0 \cdot \frac{1}{2} = 150 \frac{W}{m^2}$$

$$I_2 = I_1 \cdot \cos^2 30 \Rightarrow I_2 = 112.5 \frac{W}{m^2}$$

$$I_3 = I_2 \cdot \cos^2 60 \Rightarrow I_3 = 28.125 \frac{W}{m^2}$$

$$I_4 = I_3 \cdot \cos^2(45) \Rightarrow \boxed{I_4 = 14.1 \frac{W}{m^2}}$$

⑪



$$F_E = mg \Rightarrow qE = mg \Rightarrow E = \frac{9.11 \times 10^{-31} \cdot 9.8}{1.6 \times 10^{-19}} \frac{V}{m}$$

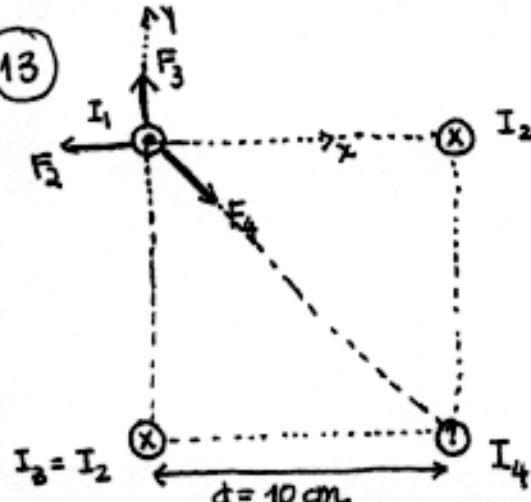
$$\Rightarrow \boxed{E = 5.6 \times 10^{-11} \frac{V}{m}}$$

⑫

$$\mathcal{E} = \frac{\Delta \Phi}{\Delta t} = \frac{\Phi_{final} - \Phi_{initial}}{\Delta t} \Rightarrow \mathcal{E} = \frac{B \cdot 0 - B \cdot A \cdot \cos 0^\circ}{\Delta t} =$$

$$\Rightarrow \mathcal{E} = \frac{B \cdot \pi R^2}{\Delta t} \Rightarrow \mathcal{E} = \frac{0.5 \cdot \pi \cdot (0.2)^2}{0.025} V \Rightarrow \boxed{\mathcal{E} = 2.5 V}$$

13



The force between 1 and 4 must be attractive to cancel out F_2 and F_3 . Also:

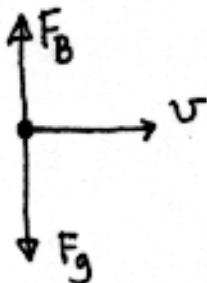
$$F_{4x} = F_2$$

$$F_{4y} = F_3$$

$$\text{So: } F_4 = \sqrt{F_{4x}^2 + F_{4y}^2} \Rightarrow \frac{\mu_0 I_1 I_4}{\sqrt{2} \cdot d \cdot 2\pi} = \sqrt{\left(\frac{\mu_0 I_1 I_2}{2\pi d}\right)^2 + \left(\frac{\mu_0 I_1 I_2}{2\pi d}\right)^2} \Rightarrow$$

$$\Rightarrow \frac{\mu_0 I_1 I_4}{2\pi d \cdot \sqrt{2}} = \sqrt{2} \cdot \frac{\mu_0 I_1 I_2}{2\pi d} \Rightarrow I_4 = 2I_2 \Rightarrow \boxed{I_4 = 8A \text{ out of the page}}$$

14

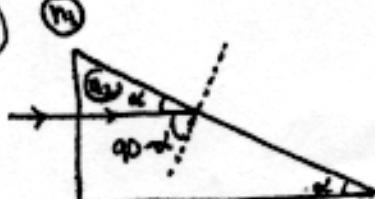


F_B balances F_g , so the field should point into the page.

$$F_g = F_B \Rightarrow mg = Bvq \Rightarrow$$

$$\Rightarrow m = \frac{Bvq}{g} = \frac{20 \cdot 5 \cdot 10^8 \cdot 10^{-12}}{9.8} \Rightarrow \boxed{m = 10^{-3} \text{ kg}}$$

15

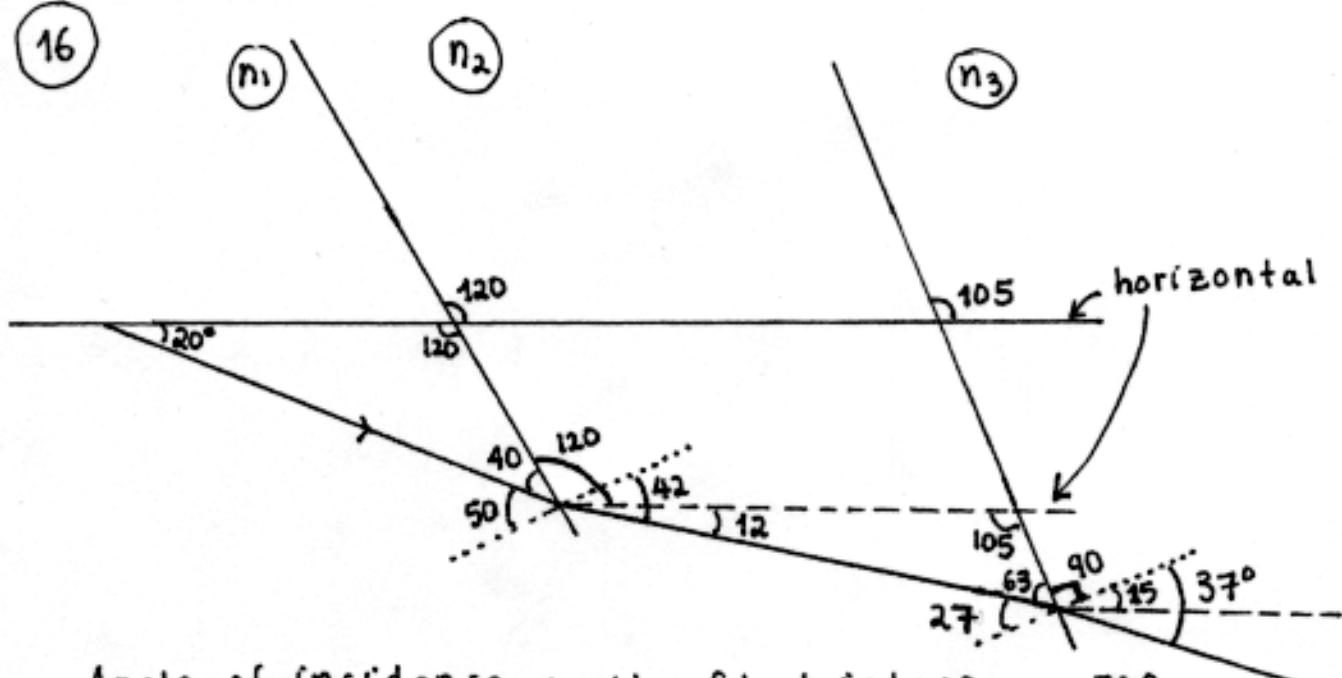


Angle of incidence on the right side of the prism: $90 - \alpha$. That must be equal to θ_c .

$$\theta_c = 90 - \alpha \Rightarrow \sin^{-1}\left(\frac{n_1}{n_2}\right) = 90 - \alpha \Rightarrow$$

$$\Rightarrow \alpha = 90 - \sin^{-1}\left(\frac{1.08}{1.2}\right) \Rightarrow \boxed{\alpha = 26^\circ}$$

16



Angle of incidence on the first interface: 50° .

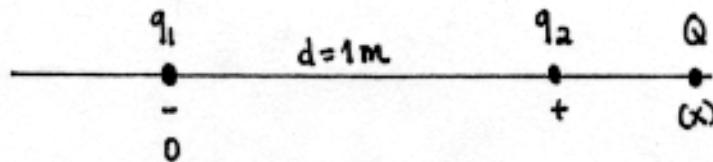
$$n_1 \cdot \sin 50 = n_2 \cdot \sin \theta_2 \Rightarrow \theta_2 = \sin^{-1} \left(\frac{1.4}{1.6} \cdot \sin 50 \right) \Rightarrow \theta_2 = 42^\circ$$

Angle of incidence on the second interface: 27°

$$n_2 \cdot \sin 27 = n_3 \cdot \sin \theta_3 \Rightarrow \theta_3 = \sin^{-1} \left(\frac{1.6}{1.2} \cdot \sin 27 \right) \Rightarrow \theta_3 = 37^\circ$$

So: 22° below the horizontal.

17



Net force on Q :

$$F_{\text{net}} = F_1 - F_2 = 0 \Rightarrow k \frac{|q_1|Q}{x^2} - k \frac{|q_2|Q}{(x-d)^2} = 0 \Rightarrow$$

$$\Rightarrow 8(x-d)^2 = 2x^2 \Rightarrow 2(x-d) = x \Rightarrow x = 2d \Rightarrow$$

$x = 2 \text{ m}$

(18)

$$I_{\max} = \frac{E}{R}$$

$$I(t) = \frac{E}{R} \left(1 - e^{-\frac{tR}{L}}\right) \Rightarrow 0.5 \frac{E}{R} = \frac{E}{R} \left(1 - e^{-\frac{tR}{L}}\right) \Rightarrow$$

$$\Rightarrow e^{-\frac{tR}{L}} = 0.5 \Rightarrow -t \frac{R}{L} = \ln(0.5) \Rightarrow t = -\frac{L}{R} \cdot \ln(0.5) \Rightarrow$$

$$t = 0.416 \text{ s}$$

(19)

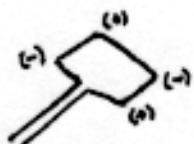
(2)

(i) motor:



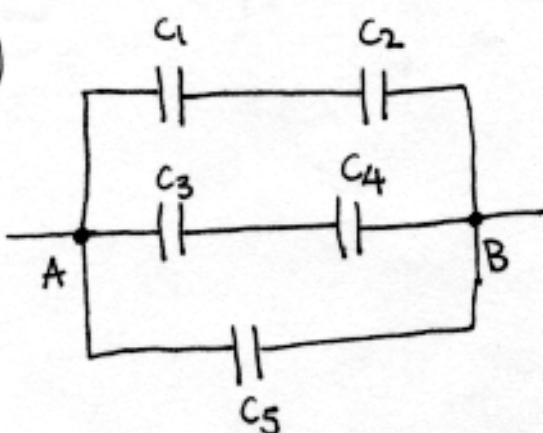
F_1 makes the loop move clockwise. | current to the left.

(ii) generator:



The polarity of the induced emf is | current to the right.

(20)



$$\text{For } C_3: W_3 = \frac{1}{2} \frac{Q_3^2}{C_3} \Rightarrow Q_3 = \sqrt{2W_3 \cdot C_3} =$$

$$\Rightarrow Q_3 = 2.83 \times 10^{-6} \text{ C}$$

$$Q_4 = Q_3 = 2.83 \times 10^{-6}$$

$$\Delta V_{AB} = \Delta V_3 + \Delta V_4 = \frac{Q_3}{C_3} + \frac{Q_4}{C_4} =$$

$$\Rightarrow \Delta V_{AB} = 3.18 \text{ V}$$

$$W_5 = \frac{1}{2} C_5 \cdot \Delta V_{AB}^2 \Rightarrow W_5 = 5 \mu\text{J}$$