Electromagnetism and Optics: Class Exam II

9 March 2026

Name: SOLUTION **Total:** /80

Instructions

- There are 8 questions on 6 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

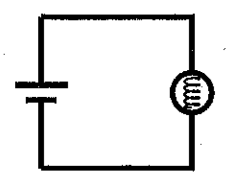
$$e = 1.60 \times 10^{-19}\,\mathrm{C} \qquad q_{\text{electron}} = -e \qquad q_{\text{proton}} = +e$$

$$m_{\text{electron}} = 9.11 \times 10^{-31}\,\mathrm{kg} \qquad m_{\text{proton}} = 1.67 \times 10^{-27}\,\mathrm{kg}$$

$$k = 8.99 \times 10^{9}\,\mathrm{Nm^2/C^2} \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$$

Question 1 → Like Quiz 5

A bulb, which can be regarded as a resistor, is connected to a battery. When the bulb is connected to a 3.00 V battery it produces power of 4.00 W. The same bulb is connected to a 1.50 V battery. Determine the power produced by the bulb when it is connected to the 1.50 V battery.



The bulb resistance is constant. Then

$$P = I\Delta V \qquad I = \Delta V/R$$

$$\Rightarrow \quad P = \Delta V^2/R$$

Now initially $P_i = (\Delta V_i)^2/R$

finally $P_f = (\Delta V_f)^2/R$

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$$\Rightarrow P_f = P_i \frac{(\Delta V_f)^2}{(\Delta V_i)^2} = 4.00\,\mathrm{W} \frac{(1.50\,\mathrm{V})^2}{(3.00\,\mathrm{V})^2} = 1.00\,\mathrm{W}$$

$I = I_1 + I_2 \Rightarrow I_D > I_A$

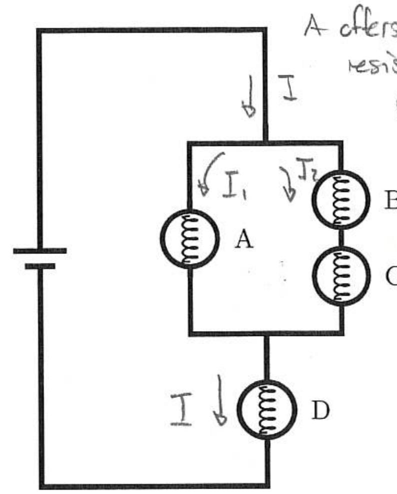
$I_D > I_B = I_C$

A offers less resistance than B/C

$\Rightarrow I_A > I_B$

Question 2

A circuit containing several identical bulbs is connected as illustrated.



HW5 Discussion 5

Q119

Q121

a) Which of the following (choose one) describes the ranking of the bulbs in order of descending brightness?

i) $A = B = C > D$

ii) $A > B = C > D$

iii) $A = B > C > D$

iv) $D > A > B = C$

v) $D > B = C > A$

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b) Suppose that bulb A is replaced by a wire. What happens to the brightness (increase, decrease, stay the same) of each bulb compared to what it was before replacement? Explain your answer.

5

No current will flow through B, C $\Rightarrow$ B, C decrease

The overall resistance is reduced to A only $\Rightarrow$ A increases

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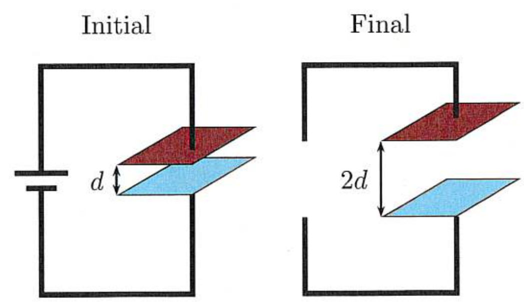
Question 3 Class 13 Question3

A parallel plate capacitor with movable plates is connected to a battery whose voltage is 9 V. After charging, the battery is completely disconnected. After this, the separation between the plates is doubled. What is the voltage across the capacitor ΔV after the separation has been increased?



i) $\Delta V = 9\,\mathrm{V}$

ii) $\Delta V = 18\,\mathrm{V}$

iii) $\Delta V = 4.5\,\mathrm{V}$

iv) $\Delta V = 2.25\,\mathrm{V}$

Q is constant

$Q = C\Delta V$

$\Rightarrow \Delta V = Q/C$

$C = \frac{\epsilon_0 A}{d}$

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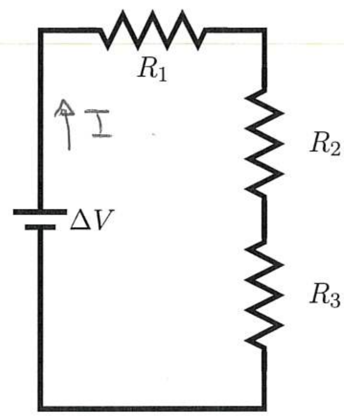
Doubling d halves C $\Rightarrow$ ΔV doubles

Question 4 HW 5 Q 123.

Three resistors are connected to a battery as illustrated in the following circuit.



a) Determine an expression for the potential difference across R_2. The answer must be expressed in terms of R_1, R_2, R_3 and ΔV.

$\Delta V_2 = I R_2$ +1

This means we need I. Now

$\Delta V = I R_{eq}$ +1

In series

$R_{eq} = R_1 + R_2 + R_3$ +1 $\Rightarrow \Delta V = I(R_1 + R_2 + R_3)$

$\Rightarrow I = \Delta V / (R_1 + R_2 + R_3)$

Thus $\Delta V_2 = \Delta V \dfrac{R_2}{R_1 + R_2 + R_3}$ +5

b) Determine an expression for the power delivered by R_2. The answer must be expressed in terms of R_1, R_2, R_3 and ΔV.

$P_2 = I \Delta V_2$ +1 $= \Delta V^2 \dfrac{R_2}{(R_1 + R_2 + R_3)^2}$

~~+3~~ ~~+4~~ +3

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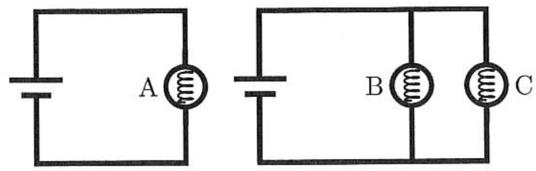
Question 5 HW 4

Identical bulbs are connected to identical ideal batteries as illustrated. The wires have zero resistance. Which of the following (choose one) is true?



i) The current through bulb C is less than the current through bulb A.

ii) The current through bulb C is more than the current through bulb A.

iii) The current through bulb C is the same as the current through bulb A.

Explain your answer.

The potential difference across C is the same as across A

$\Rightarrow$ current same

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Question 6 Discussion Q9?

A capacitor is charged with potential difference across it 150 V. The capacitor discharges rapidly over a period of 3.00 ms and while doing so provides ~~constant~~ average power of 6.00 W.

a) Determine the energy stored in the capacitor just before it discharges.

$$P = \frac{\Delta E}{\Delta t} \Rightarrow \Delta E = P\Delta t = 6.00\,W \times 3\times10^{-3}\,s$$
$$= 18\times10^{-3}\,J$$
$$= 1.80\times10^{-2}\,J.$$

b) Determine the capacitance of the capacitor.

$$U_c = \frac{1}{2}C(\Delta V)^2 \Rightarrow 1.80\times10^{-2}\,J \times 2 = C\,(150V)^2 = 1.60\times10^{-6}\,F$$

c) Determine the charge stored in the capacitor just before it discharges.

$$Q = C\Delta V = 1.60\times10^{-6}\,F \times 150V$$
$$= 2.4\times10^{-4}\,C$$

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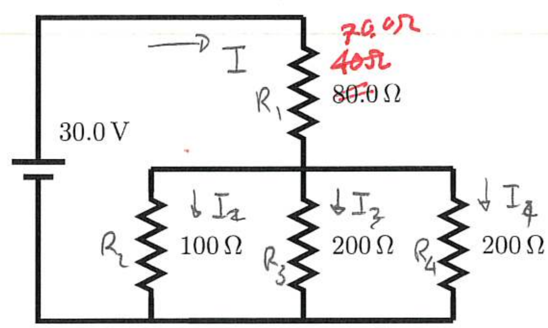
HW Q131

Question 7

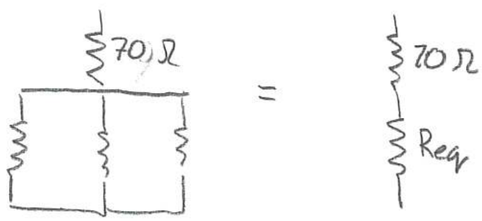
Determine:

- the currents through,
- the voltages across and,
- the power dissipated

by *each* resistor in the illustrated circuit.



Reduce the circuit to get I

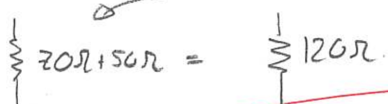


(+1)

$$\frac{1}{R_{eq}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{100\Omega} + \frac{1}{200\Omega} + \frac{1}{200\Omega}$$

$$= \frac{2+1+1}{200\Omega} = \frac{1}{50\Omega} \Rightarrow R_{eq} = 50\Omega$$



(+3)

Thus $\Delta V = I R_{eq} \Rightarrow 30V = I\, 120\Omega \Rightarrow I = 0.250A$ (+1)

Now $\Delta V_1 = I R_1 = 0.25A \times 70\Omega = 17.5V$ (+1)

Then the voltage across the remaining is the same for each. So

$\Delta V = \Delta V_1 + \Delta V_2 \Rightarrow \Delta V_2 = 30V - 17.5V = 12.5V$

Now

$I_2 = \Delta V_2 / R_2 = \frac{12.5V}{100\Omega} = 0.125A$

$I_3 = \Delta V_3 / R_3 = \frac{12.5V}{200\Omega} = 0.0625A$

(+7)

	I	ΔV	P = IΔV
R_1	0.250A	17.5 V	4.38 W
R_2	0.125A	12.5V	1.56 W
R_3	0.0625A	12.5V	0.781W
R_4	0.0625A	12.5V	0.781W

(+3)

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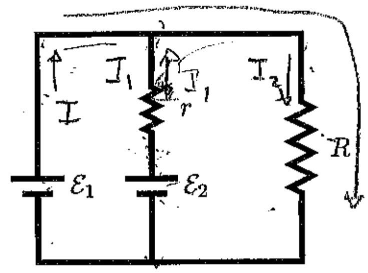
Question 8 Q137 HW

Two batteries, one ideal and the other with an internal resistance, are connected to a resistor as illustrated. Suppose that the ideal battery provides EMF $\mathcal{E}_1 = 3.00\,\text{V}$. The battery with internal resistance provides EMF $\mathcal{E}_2 = 27.5\,\text{V}$ and internal resistance $r = 2.50\,\Omega$. The resistor has resistance $R = 30.0\,\Omega$.



a) Determine the magnitude and direction of the current that flows through R.

Use the outer loop $\mathcal{E}_1 - I_2 R = 0 \Rightarrow \mathcal{E}_1 = I_2 R$

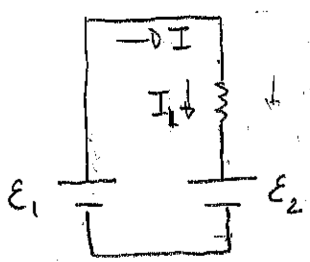
$\Rightarrow I_2 = \mathcal{E}_1/R$

$\Rightarrow I_2 = \dfrac{3.00\,\text{V}}{30.0\,\Omega}$

$I_2 = 0.100\,\text{A}$ ↓

b) Determine the magnitude and direction of the current that flows through r.

Consider



$\mathcal{E}_1 - I_1 r - \mathcal{E}_2 = 0$

$\Rightarrow \mathcal{E}_1 - \mathcal{E}_2 = I_1 r$

$\Rightarrow 3.00\text{V} - 2.75\text{V} = I_1\ 2.50\Omega$

$\Rightarrow 0.25\text{V} = I_1\ 2.50\Omega$

$\Rightarrow I_1 = 0.10\text{A}\ \text{A}$ ↓

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