Phys 132
Fall 2018

Electromagnetism and Optics: Class Exam II

10 October 2018

Name: ______________________________ **Total:** /70

Instructions

- There are 9 questions on 6 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$$e = 1.61 \times 10^{-19}\,\mathrm{C} \qquad q_{\text{electron}} = -e \qquad q_{\text{proton}} = +e$$

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

$$k = 9.0 \times 10^{9}\,\mathrm{Nm^2/C^2} \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$$

Question 1

Electrons travel in a straight line as illustrated. The current in this beam is 3.2×10^{-5} A and points right. Determine the number of electrons that pass any point in 60 s and describe the direction in which they move.

$I = \frac{\Delta Q}{\Delta t}$ and $\Delta Q = N e$
↳ number of electrons

$3.2\times10^{-5}\mathrm{A}\ \Delta t = \Delta Q \Rightarrow \Delta Q = 3.2\times10^{-5}\mathrm{A}\times 60\mathrm{s} = 19.2\times10^{-4}\mathrm{C}$

So $Ne = 19.2\times10^{-4}\mathrm{C}$

$\Rightarrow N\ 1.6\times10^{-19}\mathrm{C} = 19.2\times10^{-4}\mathrm{C}$

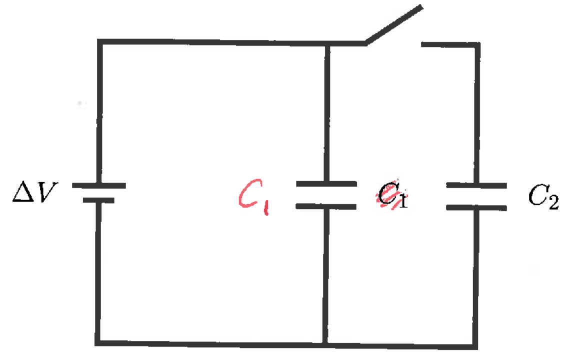
$N = \frac{19.2\times10^{-4}\mathrm{C}}{1.6\times10^{-19}\mathrm{C}} = 1.2\times10^{16}$

/~~XX~~ 6

Current opposite to motion $\Rightarrow$ moves ←

Question 2

Consider the illustrated circuit, which contains two identical capacitors. Initially the switch is open and capacitor 1 (the capacitor on the left) is allowed to charge completely. The switch is then closed. Which of the following (choose one) is true a long time **after the switch is closed**?



i) The charge on capacitor 1 is the same as it was just before the switch was closed.
ii) The charge on capacitor 1 is twice what it was just before the switch was closed.
iii) The charge on capacitor 1 is half of what it was just before the switch was closed.
iv) The charge on capacitor 1 is four times of what it was just before the switch was closed.
v) The charge on capacitor 1 is a quarter of what it was just before the switch was closed.

Briefly explain your answer.

ΔV stays same across capacitor 1 +2 $Q = C\Delta V$ +1 means Q stays same.

/~~XX~~ 6 6

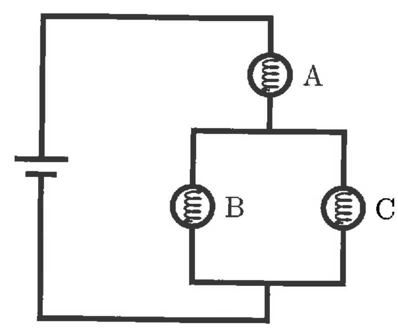
If all have resistance 1Ω and ΔV = 3.0V

Before $R_{eq} = 1 + \left(\frac{1}{1}+\frac{1}{1}\right)^{-1} = \frac{3}{2} \Rightarrow I_{battery} = \Delta V/R = 2A. \Rightarrow I_A = 2A$, $I_B = 1A$

After $R_{eq} = 1 + 1 = 2 \Rightarrow I = \frac{3.0V}{2\Omega} = 1.5A \Rightarrow I_A = 1.5A$, $I_B = 1.5A$

Question 3

The bulbs in the illustrated circuit are all identical. Bulb C is removed leaving a gap in that part of the circuit. The following questions concern the changes in bulbs A and B caused by the removal of bulb C.



a) Which of the following (choose one) occurs in bulb A after C is removed?
   i) The brightness of A stays the same.
   ii) Bulb A becomes brighter.
   iii) Bulb A becomes dimmer.

resistance of lower part increases ⇒ Overall resistance increases ⇒ current in battery decreases ⇒ I_A decreases

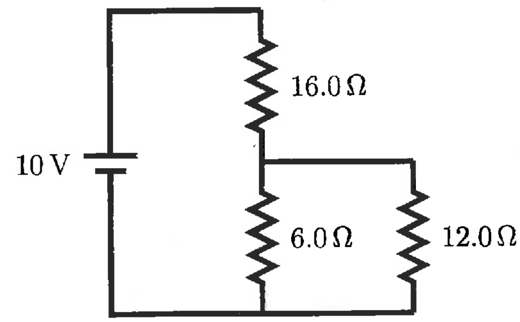
b) Which of the following (choose one) occurs in bulb B after C is removed?
   i) The brightness of B stays the same.
   ii) Bulb B becomes brighter.
   iii) Bulb B becomes dimmer.

resistance of lower part increases. So voltage share across lower part increases ⇒ voltage across B increases. ⇒ B brighter

/~~XX~~ 8

Question 4

Consider the illustrated circuit. Determine the **current** through each resistor, the **voltage** across each resistor and the **power** dissipated by each resistor.



Need current through battery I via

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

+4 ~~+6~~ ~~+A~~

Now for parallel $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

$= \frac{1}{6} + \frac{1}{12} = \frac{3}{12} \Rightarrow R_{eq} = 4\Omega$

So for entire circuit $R_{eq} = 20\Omega$

+1 Thus $10V = I\,20\Omega \Rightarrow I = 0.50A$ for battery and $0.50A$ for 16Ω.

Then for 16Ω $\Delta V = IR \Rightarrow \Delta V = 0.50A \times 16\Omega = 8.0V$ +1

$\Rightarrow$ for 6Ω and $12 \Rightarrow \Delta V = 10V - 8.0V = 2.0V$ +~~2~~ same +2

+1

For each $I = \frac{\Delta V}{R}$ so for 6Ω $I = \frac{2.0V}{6.0\Omega} = 0.33A$

for 12Ω $I = \frac{2.0V}{12\Omega} = 0.17A$ +2

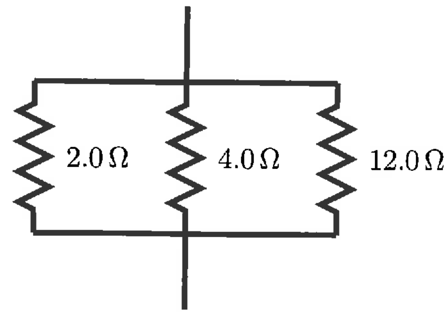
	ΔV	I	+1 $P = I\Delta V$
16Ω	8.0V	0.50A	4.0W
12Ω	2.0V	0.~~3~~17A	0.34W
6Ω	2.0V	0.33A	0.66W

+3 ~~+7~~

/~~XX~~ 16

Question 5

Three resistors are connected as illustrated. Determine the equivalent resistance of the combination.



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{2.0\Omega} + \frac{1}{4.0\Omega} + \frac{1}{12.0\Omega}$$

$$= \frac{6 + 3 + 1}{12.0\Omega} = \frac{10}{12\Omega}$$

$$\Rightarrow \quad R_{eq} = 12\Omega/10 = 1.2\Omega$$

/~~XX~~ 6

Question 6

A bulb is connected to a 120 V power supply and produces power 30 W. Determine the amount of time that it takes for a total charge of 20 C to pass any point in the circuit.

$$I = \frac{\Delta Q}{\Delta t} \Rightarrow \quad \Delta t = \frac{\Delta Q}{I} = \frac{20C}{I}$$

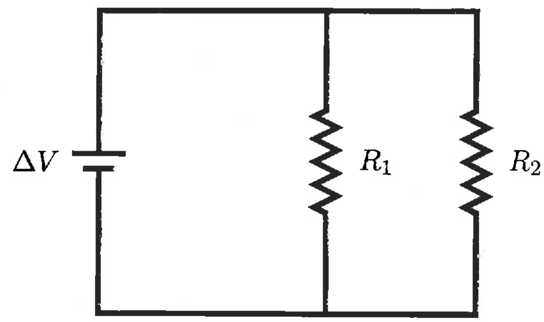
But $\quad P = I\Delta V \Rightarrow \quad 30V = I\,120V \Rightarrow \quad I = 0.25A$

$$\Delta t = \frac{20C}{0.25A} = 80s$$

/~~XX~~ 6

Question 7

Consider the two resistors connected as illustrated, where $R_1 = 10\,\Omega$ and $R_2 = 20\,\Omega$. Which of the following (choose one) is true?



i) The power dissipated by ~~each~~ either resistor is the same as that for the battery.

ii) The power dissipated by ~~each~~ either resistor is smaller than that for the battery; the power dissipated by resistor 1 is the same as that dissipated by resistor 2.

iii) The power dissipated by ~~each~~ either resistor is smaller than that for the battery; the power dissipated by resistor 1 is larger than that dissipated by resistor 2.

iv) The power dissipated by ~~each~~ either resistor is smaller than that for the battery; the power dissipated by resistor 1 is smaller than that dissipated by resistor 2.

Briefly explain your answer.

Same ΔV. Now

$$P = I \Delta V$$

$$= \frac{\Delta V}{R} \Delta V = \frac{(\Delta V)^2}{R}.$$

8

/~~XX~~

For 1 R_1 is smaller $\Rightarrow$ P larger. for 1 than 2.

Total power for both = power battery

$\Rightarrow$ power either < P battery.

/8

Question 8

A heater operates by passing current through a filament with low resistance (assume that this does not change with temperature). The heater is initially connected to a 120 V power supply and delivers power P_i. The heater is then connected to a 240 V power supply; denote the power delivered by P_f.

~~4~~ 3 a) Describe which of the following change when the heater is switched from the 120 V power supply to the 240 V power supply: **current, voltage**. Briefly explain your answer.

Voltage: doubles   120V → 240V

Current: $I = \frac{\Delta V}{R}$ also doubles since ΔV doubles.

4 5 b) Which of the following (choose one) describes how the power with the 240 V power supply is related to that with the 120 V power supply?

i) $P_f = P_i$

ii) $P_f = 2P_i$

iii) $P_f = 4P_i$

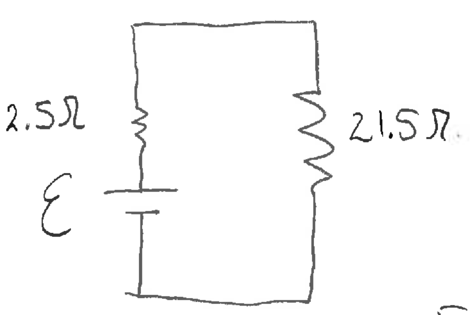
iv) $P_f = 8P_i$

$$\underbrace{P = \overset{\text{doubles}}{I}\ \overset{\text{doubles}}{\Delta V}}_{4 \text{ times}}$$

/~~XX~~ ~~8~~ 8

Question 9

A particular real battery can be modeled as a perfect battery with EMF 3.0 V connected in series with an internal resistance of 2.5 Ω. This is connected (in series) to an external (load) resistor with resistance 21.5 Ω. Determine the current through and the voltage across the external resistor.



$I = \frac{\varepsilon}{R_{eq}}$ $R_{eq} = R_1 + R_2 = 24\Omega$

$= \frac{3.0V}{24\Omega} = 0.125A$

$I = 0.125A$

+~~4~~ 3

For load resistor

$\Delta V = IR = 0.125A \times 21.5\Omega$

$= 2.7V$

+3

/~~XX~~ ~~6~~ 6