5C-F21 Midterm 2 A

CLAIRE HATHAWAY

TOTAL POINTS

28 / 35

QUESTION 1

10 pts

1.1 1 / 1

✓ **- 0 pts** Correct

- 1 pts incorrect

1.2 1 / 1

✓ **- 0 pts** Correct: from largest to smallest, **VI, IV, III = I, V = II**. The given capacitance values are all _after_ the dielectrics have been slotted in. The given area is not useful to this problem; if we didn't know $$C$$ beforehand, then we would use area and distance to solve for it. However, we're already given $$C$$, so then we use $$C = Q/V$$ to see that higher $$C$$ means higher $$Q$$. Thus, the correct order is putting these capacitors based the value of $$C$$'s.

- 1 pts Incorrect

1.3 0 / 1

- 0 pts Correct

✓ **- 1 pts** incorrect

1 correct answer is A, bulb 3 gets brighter- resistors 1 and 2 are now in parallel; consider the effect this has on the voltage across 3

1.4 1 / 1

✓ **- 0 pts** Correct

- 1 pts incorrect

1.5 1 / 1

✓ **- 0 pts** Correct

- 1 pts incorrect

1.6 1 / 1

✓ **- 0 pts** Correct (b)

- 1 pts incorrect (a)

- 1 pts incorrect (c)

1.7 1 / 1

✓ **- 0 pts** Correct: B. With lower $$R_{eq}$$ due to resistors in parallel, there is more current in the system (from $$V = IR$$). Thus, with $$P = IV$$, circuit 2 would dissipate more power overall.

- 1 pts Incorrect

1.8 1 / 1

✓ **- 0 pts** Correct: A. For capacitors in parallel, we know that the charge on both sets of plates must be the same $$Q_1 = Q_2$$. Using $$Q = CV$$, we see that lower $$C$$ corresponds to higher $$V$$.

- 1 pts Incorrect

1.9 1 / 1

- 0 pts Correct: A. When we put batteries in series, the total voltage is the sum of their individual voltages, $$ V_{tot} = V_1 + V_2$$. Batteries in parallel, however, just produce the same total voltage across the system ($$V_{tot} = V_{bat}$$). Higher $$ V_{tot}$$ means higher current $$I$$ being drawn out from the batteries from $$V_{tot} = IR$$. Higher $$I$$ means higher power $$P = IV$$ being drawn out of the batteries, and thus circuit A is discharged faster.

✓ **- 0 pts** Incorrect

1.10 1 / 1

✓ **- 0 pts** Correct: 100 $$\Omega$$ resistor. The voltage drop across a resistor $$R$$ is $$\Delta V_R = I R$$. We also know both resistors experience the same current $$I$$ because they're in series, so

we can directly say $$\Delta V_R \propto R$$, and therefore $$\Delta V_{100} > \Delta V_{30}$$.

- **1 pts** Incorrect

QUESTION 2

25 pts

2.1 **8 / 8**

✓ **- 0 pts** Correct

- 1 pts Incorrect use of resistance formulae

- 1 pts Incorrect use of Ohm's law

- 1 pts Computational error

- 1 pts Incorrect answer

- 3 pts Did not consider equivalent resistance

- 1 pts Incorrect use of resistance formulae

- 1 pts No justification for use of forumulae

- 1 pts Incorrect use of resistance formulae

- 0.5 pts unit error

2.2 **10 / 10**

✓ **- 0 pts** Correct

- 3 pts Ignored the voltage drop over $$R_4$$ and considered $$R_{123}$$ as if connected directly to the battery

- 2 pts Ignored that the current splits between $$R_{13}$$ and $$R_2$$

- 1 pts Ignored voltage split between $$R_1$$ and $$R_3$$

- 0.5 pts small errors

- 0 pts Correct (mistakes carried over from part a)

- 5 pts Only applied $$P = IV$$ (or a variant of it) to the circuit without calculating the any of the voltage or current splits

- 1 pts Made a significant error calculating the current split between $$R_{13}$$ and $$R_2$$

+ 2 pts Partial credit for calculating current split $$R_{13}$$ and $$R_2$$

2.3 **1 / 7**

- 0 pts Completely Correct!

Correctly concluded that **bulb 3 goes out**, but did **not** use the fact that:

- 0 pts Reasoning: Bulb 1 breaking causes the loop containing bulb 1 and 3 to receive no current, and thus** bulb 3 would go out **as well (decrease in brightness).

- 1 pts **Bulb 1's brightness decreases** because it is burned out (given from the problem).

- 1 pts The resulting circuit is just bulbs 2 and 4 in series

- 1 pts Thus, the new $$R_{eq}$$ is greater than before.

- 1 pts With Bulb 1 and 3 removed from the circuit, the overall resistance of the circuit increases. From $$V = IR$$, the total current that the battery outputs is decreased.

- 1 pts Using $$P = I^2 R$$, **bulb 4 decreases in brightness** because the total current decreases.

- 1 pts There is no longer a "junction" before bulb 2 for the current to split, i.e. $$I_1 = I_2 + I_3$$ _doesn't_ happen with bulbs 1 and 3 out of the picture. Thus, bulb 2 receives "all" of the current, and has more current than it had before. From $$P = I^2 R$$, **bulb 2 _increases_ in brightness**.

Incorrectly concluded that **bulb 3 stays as a part of the circuit**. Bulb 1 burning out effectively creates a disconnection at that spot in the circuit, thus causing _no_ current to go to that loop of the circuit. To not completely cascade off of that mistake, here is the rubric based on if bulb 3 stays connected somehow:

✓ **- 1 pts** **For concluding bulb 3 stays connected**

- 1 pts (Did not mention): **Bulb 1's brightness decreases** (completely dim), as it is burned out

✓ **- 1 pts** **(Did not mention): With bulb 3 still in parallel with 2, the overall resistance of the circuit _decreases_**

✓ **- 1 pts** **(Did not mention): Overall current in the system would _increase_ as a result.**

✓ **- 1 pts** **(Did not mention): **Bulb 3 gets brighter.** From $$I_3 = \Delta V/R_{eq13}$$, which is the current only on bulb 3's loop of the circuit, we see that the current drawn by that section of the circuit is** increased if $$R_{eq13}$$ decreases. More current and $$P = I^2 R$$ means brightness in 3 increases.

✓ - 1 pts (Did not mention) **Bulb 4 gets brighter.** By having the total resistance $$R_{eq}$$ decreased by removing bulb 1, we know that the total current increases from $$I = V/R_{eq} $$. Bulb 4 receives the total current, as the split currents ($$I_1$$ and $$I_2$$ from $$I = I_1 + I_2$$) recombine at the junction just before it. Thus, from $$ P_4 = I^2 R_4$$, we would know that the brightness of 4 increases.

✓ - 1 pts (Did not mention) **Bulb 2 gets dimmer**. Although the total current increases, the total current is still split right before bulb 2. We'd rather use $$P = \Delta V^2 /R$$ in this case rather than explicitly finding the current for $$P = I^2 R$$. To show that the power decreases mathematically, you would **i)** Find the new total current $$I$$, **ii)** Find $$\Delta V_4 = IR_4$$ **iii)** Find $$\Delta V_2 = \Delta V_3 = V_{bat} - \Delta V_4$$ **iv)** Find $$ P_2 = \Delta V_2 ^2 /R_2$$. You could stop at step **ii)**; the moment you know that $$\Delta V_4$$ is greater than before, you know that $$\Delta V_2$$ would have to decrease. As a result, bulb 2 would be dimmer.

plates closer = smaller d

Problem 1

(10 points)

(each multiple-choice question has only one correct answer)

constant V

1. A parallel plate capacitor is charged and then stays connected to the battery. What happens to the charge on the positive plate if you push the plates closer together?

(a) It decreases.

(b) It increases.

(c) It stays the same.

$\uparrow C = \varepsilon_0 \frac{A}{d \downarrow}$ $\qquad \uparrow C = \frac{Q \uparrow}{V}$

2. Six parallel-plate capacitors of identical plate separation have different plate areas, different dielectrics between the plates, and different capacitances. All six capacitors are connected to batteries with the same ~~potential difference~~. Rank the capacitors on the basis of the charge stored on the positive plate (largest to smallest).

same V

$C = \frac{Q}{V}$ $\qquad \uparrow C = \uparrow Q$

I	II	III	IV	V	VI
$A = 8\ \text{cm}^2$, $C = 2\ \text{nF}$	$A = 1\ \text{cm}^2$, $C = 1\ \text{nF}$	$A = 4\ \text{cm}^2$, $C = 2\ \text{nF}$	$A = 2\ \text{cm}^2$, $C = 4\ \text{nF}$	$A = 4\ \text{cm}^2$, $C = 1\ \text{nF}$	$A = 2\ \text{cm}^2$, $C = 8\ \text{nF}$

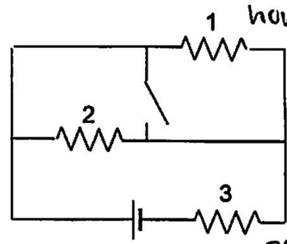
largest

VI > IV > I = III > II = V

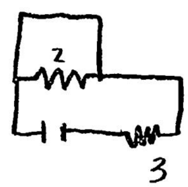
3. What happens to the brightness of bulb 3 when you close the switch?

$\uparrow P = \frac{V^2}{R \downarrow}$ $\qquad \uparrow P = I^2 R \uparrow$

now series



parallel



Req > Req

series

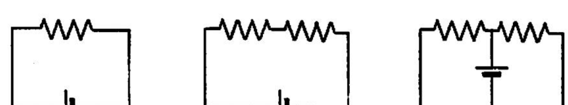
(a) Bulb 3 gets brighter.

(b) Bulb 3 gets dimmer. — now 2 use more V so 3 less which dec I

(c) The brightness of bulb 3 does not change.

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

4. Consider the three circuits shown below with identical resistors and batteries. Which circuit drains the battery the fastest?



a $\qquad$ b $\qquad$ c

parallel drain faster

b/c both full V

① 25 Ω, V constant, $\frac{V}{25}$ A ↑I

↑I means ↑P

② 50 Ω, V constant, $\frac{V}{50}$ A ↓I

5. You connect a 25 Ω and a 50 Ω resistor in parallel to a battery. Which resistor dissipates more power?

(a) The 25 Ω resistor.

(b) The 50 Ω resistor.

(c) Both dissipate the same power.

V constant

↓ higher I

– Q constant

6. A parallel plate capacitor is charged with a battery and then disconnected. If you fill the space between the plates with a dielectric (K=20) the energy stored in the capacitor ...

(a) increases.

(b) decreases.

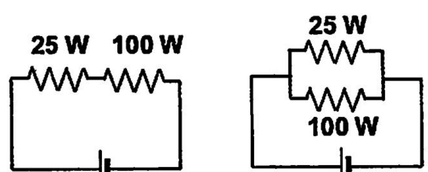
(c) stays the same

$\downarrow E_0 = \frac{Q}{\uparrow K\varepsilon_0 A}$

7. Which of the two circuits shown dissipates more total power?

– parallel better b/c each see full voltage?

↑ $P = I^2 R$ ↑



Circuit 1 Circuit 2

(a) Circuit 1 dissipates more power.

(b) Circuit 2 dissipates more power.

(c) Both circuits dissipate exactly the same power.

\ bigger R so $\downarrow I = \frac{V}{R\uparrow}$ dec I which dec P

C?

8. A 10 μF and a 20 μF capacitor are connected in series to a 12 V battery. Which capacitor has the larger voltage between the plates?

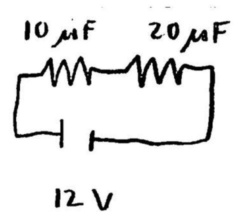
(a) The 10 μF capacitor.

(b) The 20 μF capacitor.

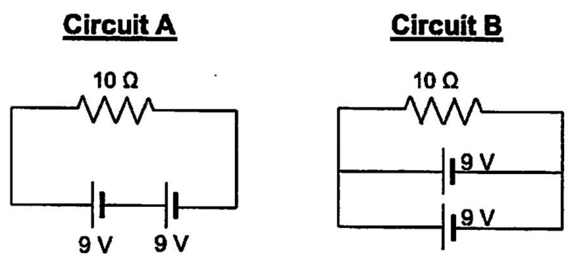
~~(c)~~ Both capacitors have exactly the same voltage between the plates.

$\uparrow C = \frac{Q}{V\downarrow}$

same I



9. Consider the two circuits shown with two identical and fully charged batteries. Which circuit discharges the batteries faster?



(a) Circuit A discharges the batteries faster.

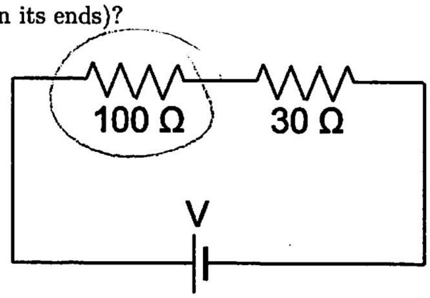
(b) Circuit B discharges the batteries faster. — can use both silmultaneously, time to run out 9

(c) Both circuits discharge the batteries exactly the same.

series only 1 time to run out 18?

10. Consider the circuit shown with two different resistors. Which resistor has the larger voltage drop (i.e. potential difference between its ends)?

write own answer



100 Ω has larger voltage drop

constant I

$V = R \cdot I$

$V = 100 \cdot I$ ← bigger

$V = 30 \cdot I$

(a) It increases.

(b) It decreases.

(c) It stays the same.

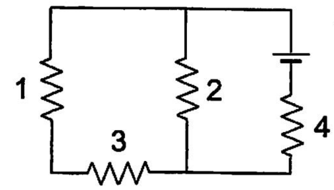
(extra space)

(extra space)

Problem 2

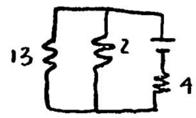
(25 points)

The circuit shown below consists of a 9 V battery and four light bulbs $R_1=R_2=R_3=R_4=300\ \Omega$,



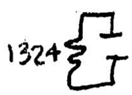
$\nearrow I$

(a) Calculate the total current provided by the battery *[8 points]*



$R_{13} = 300\ \Omega + 300\ \Omega = 600\ \Omega$

$\frac{1}{R_{132}} = \left(\frac{1}{600}\right) + \left(\frac{1}{300}\right) = 0.005 \rightarrow R_{132} = 200\ \Omega$



$R_{eq} = 200\ \Omega + 300\ \Omega = 500\ \Omega$

$I = \frac{V}{R} = \frac{9V}{500\ \Omega} = \boxed{0.018\ A}$

(b) Calculate the electric power dissipated in R_3. *[10 points]*

1324: $R = 500\ \Omega$, $I = 0.018\ A$, $V = 9\ V$

132: $R = 200\ \Omega$, $I = 0.018\ A$, $V = 3.6\ V$

4: $R = 300\ \Omega$, $I = 0.018\ A$, $V = 5.4$

13: $R = 600\ \Omega$, $I = 0.006$, $V = 3.6\ V$

2: $R = 300\ \Omega$, $I = 0.012$, $V = 3.6\ V$

1: $R = 300\ \Omega$, $I = 0.006$, $V = 1.8\ V$

3: $R = 300\ \Omega$, $I = 0.006$, $V = 1.8\ V$

$V = I \cdot R$

$3.6 = (0.018)(200)$

$5.4 = (0.018)(300)$

$I = \frac{V}{R}$ $\quad 0.006 = \frac{3.6}{600}$

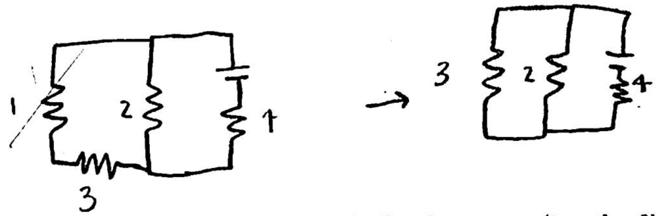
$0.012 = \frac{3.6}{300}$

$V = I \cdot R$

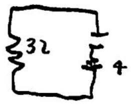
$1.8 = (0.006)(300)$

$P_3 = I \cdot V = (0.006)(1.8) = \boxed{0.0108\ W}$

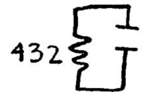
(continued on next page)



(c) What happens to the brightness of each bulb if bulb 1 burns out (i.e. the filament breaks)? Explain your answer. *[7 points]*



$R_{32} = 150\ \Omega$



$R_{eq} = 450\ \Omega$

$P = I \cdot V$

total $I = 0.02$ A

4: $300\ \Omega$, 0.02 A, 6 V $\quad P_4 = 0.12$ W

32: $150\ \Omega$, 0.02 A, 3 V $\quad P_3 = 0.03$ W

3: $300\ \Omega$, 0.01 A, 3 V $\quad P_2 = 0.03$ W

2: $300\ \Omega$, 0.01 A, 3 V

without bulb 1

W/out 1

$P_4 \downarrow$

$P_3 \downarrow$

$P_2 \uparrow$

With bulb 1: $P_4 = 0.097$, $P_3 = 0.0108$, $P_2 = 0.0432$

If bulb 1 burns out bulb 4 and 3 will get dimmer and bulb 2 will get brighter.

Bulb 3 & 4 were in series with bulb 1 and by losing it the Req decreases so using $P = I^2 R$ we know that if R decreases, so does P which lowers brightness.

Bulb 2 was parallel to 1 & 3 but now would only be parallel to 3 so the Req decreases and with $P = \frac{V^2}{R}$ we know that decreasing R increases P which increases brightness.