Solution Key

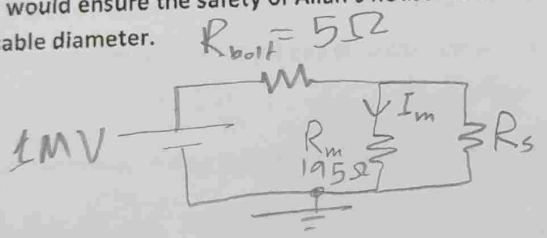
MEU جامعة الشرق الأوسط MIDDLE EAST UNIVERSITY Amman - Jordan

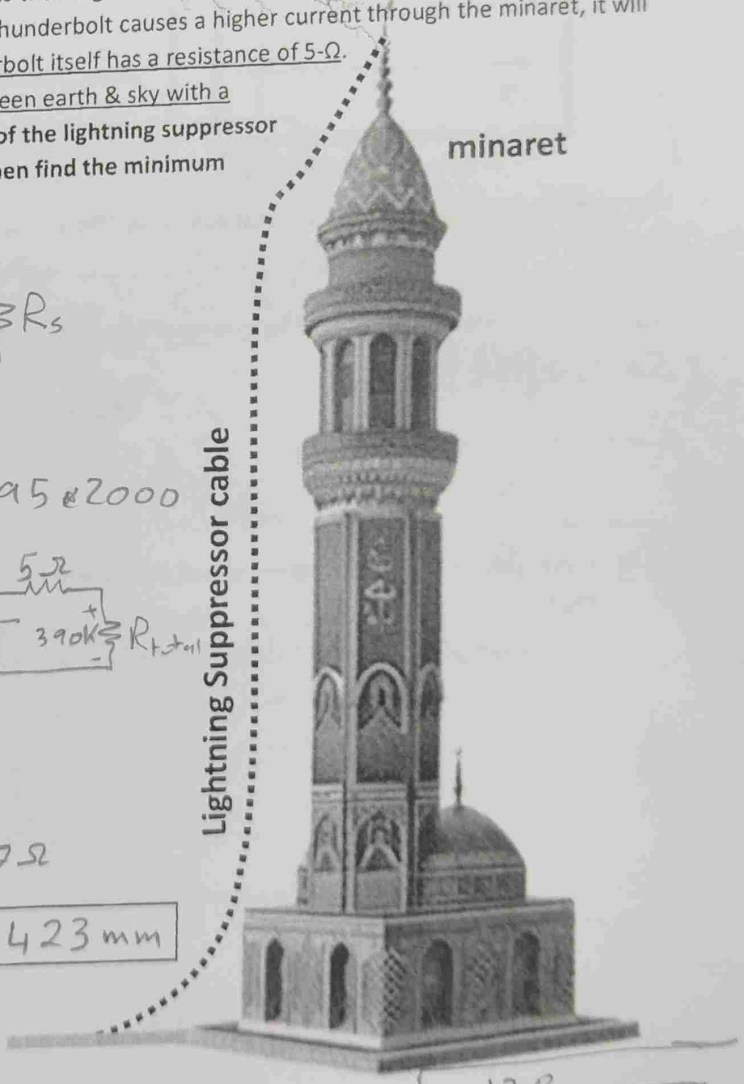
كلية الهندسة Engineering

Faculty: Engineering	Department: Renewable Energy Engineering
Academic Year: 2024/2025	Semester: 1st Semester
Course Name and Number: Electrical Circuits I (0952501)	
Instructor Name: A. Jayyousi	Midterm Exam ■
Exam Date: 4/12/2024	Exam Time: 12:00-13:00
Student Name:	ID Number:

Problem 1 (CLO1) — 8 Points

A minaret has a height of 30-meters from ground to its highest point. The minaret has a total electric resitance of 195-Ω (from tip to earth). To protect the minaret from thunderbolts (صواعق), a **lightning suppressor** system (مانع صواعق) is installed. The system is a simple copper cable ($\sigma=5.8\times10^6$S/m) extending from the highest point of the minaret to ground. The cable has approximately the same length as the height of the building. The minaret can withstand (تحتمل) a maximum of 2000A when hit by thunderbolts. If the thunderbolt causes a higher current through the minaret, it will catch fire, explode or get heavily damaged. The thunderbolt itself has a resistance of 5-Ω. The cloud can be modelled as a DC voltage source between earth & sky with a voltage of 1 MillionVolt. **Find the maximum resistance of the lightning suppressor cable that would ensure the safety of Allah's house. Then find the minimum required cable diameter.**





$I_{minaret,max.}=2000A$

$V_{minaret,max}=R_{minaret}*I_{minaret,max}=195*2000$

$V_{minaret,max}=390,000\ V$

$R_{total}=R_{minaret}\ //\ R_{suppressor}$

Voltage Division Rule:

$V_{R_{total}}=1M*\frac{R_{total}}{5+R_{total}}=390k$

$R_{total}=0.39*5+0.39*R_{total}$

$0.61R_{total}=1.95\Rightarrow R_{total}\simeq3.1967\Omega$

$R_{minaret}*R_{sup}=3.1967$

$R_{minaret}-R_{sup}$

$195R_{sup}=3.1967*195+3.1967*R_{sup}$

$R_{sup}\simeq3.25\Omega$

$R_{suppressor}=3.25\Omega$

$R=\frac{L}{\sigma A}=\frac{30}{5.8\times10^6*\frac{\pi}{4}D^2}=3.25$

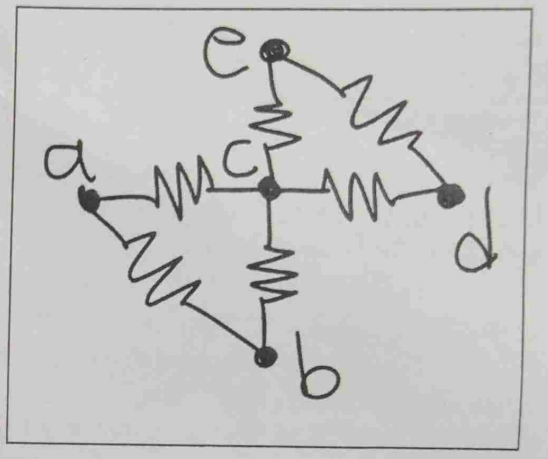
$\rightarrow D=\sqrt{\frac{120}{5.8\times10^6*\pi*3.25}}$

$D=1.423$ mm

$D_{cable}=1.423$ mm

Problem 2 (CLO1)	4 Points

Look at the 6 resistors shown on the right. The resistors are identical. Each one has a value of 3-Ω and **a maximum power rating of 12-Watts**. Find the following:



a) R_{ad} $= (3//(3+3)) + (3//(3+3))$
$= 4$

R_{ad}= 4 Ω

b) R_{ab}

R_{ab}= 2 Ω

c) What is the maximum voltage that can be applied across terminals (a) and (d) without damaging the resistors?

$$\frac{(V_{max})^2}{3} = 12 \Rightarrow V_{max} = \sqrt{1243} = 6\,V$$

$$V_{ac,max} + V_{cd,max} = 6 + 6 = 12 = V_{ad,max}$$

$V_{ad,max}$= 12 V

d) If the resistor connecting points (c) and (b) is burnt and becomes an open-circuit, what is the new value of R_{ad} then?

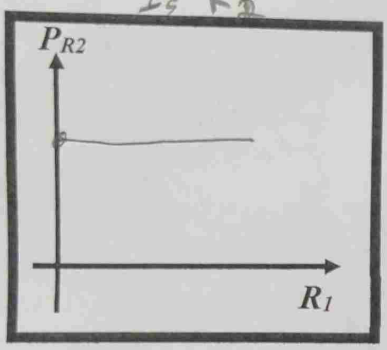
$$R_{ac} + R_{cd}//(R_{ce}+R_{ed}) = 3 + 3//6 = 3+2 = 5$$

R_{ad}= 5 Ω

Problem 3 (CLO1) — **3 Points**

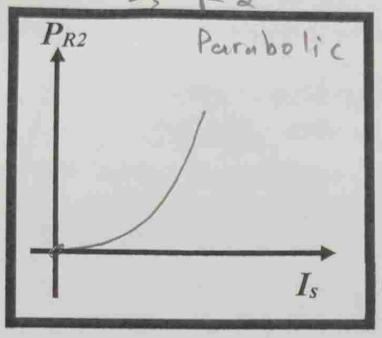
An independent current source, I_s, is connected in series with two resistors, R1 and R2. Draw a rough plot of the power consumed by resistor R_2 versus the following: the value of R_1, the value of I_s, and the value of R_2. No exact values are required, but you need to show the correct form of the plot (linear rising, linear falling, quadratic, exponential, etc..). Also, the graph should show P_{R2} when the x-axis variable is zero.

$I_s^2 R_2$



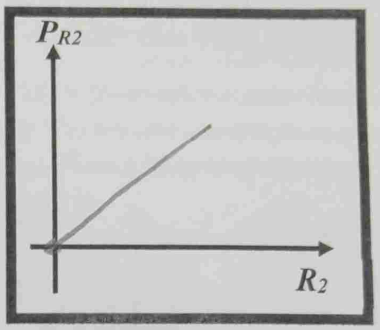
(I_s and R_2 constant)

$I_s^2 R_2$



(R_1 and R_2 constant)

$I_s^2 R_2$



(I_s and R_1 constant)

Problem 4 (CLO1) — **6 Points**

A bulb consumes 60 Watts to produce a certain amount of light when operated from 240VDC.

a) **What operating voltage is needed to make the bulb give half the amount of light?**

$P = 30$ Watts

$\frac{V^2}{R} = 30$

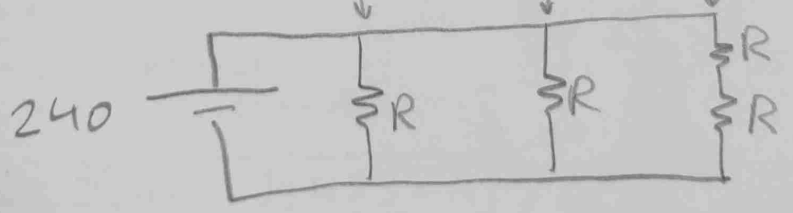
$\frac{240^2}{R} = 60 \Rightarrow R = 960\ \Omega$

$V = \sqrt{30 \cdot R} = \sqrt{30 * 960} = 169.7$ V

V= 169.7 V

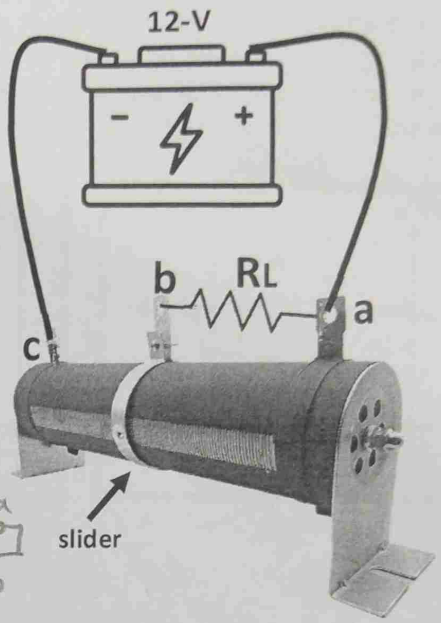
b) **If you have an infinite quantity of this type of bulb, what combination of bulbs should you use to achieve a total power consumption of 150-Watts when operating from a 240-V source? Draw the combination.**

150W = 60W + 60W + 30W



Problem 5 (CLO1) — **6 Points**

The image on the right shows a potentiometer (a variable resistor). The potentiometer has three terminals: a, b & c. The full resistance of this potentiometer is Rac=1kΩ. The ring-shaped slider is connected to terminal (b) and provides a variable resistance (Rab & Rbc). A load, RL, can be connected between terminals (a) and (b), while a 12-V battery is connected between terminals (a) and (c). Assuming the slider is placed exactly in the middle of the potentiometer, find the following:

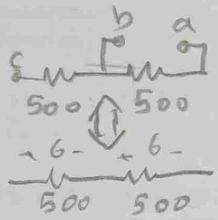


a) Range of voltage which any load (R_L) could experience (loads assumed to extend from zero resistance to infinity). Give your answer in the form of $[V_{minimum}, V_{maximum}]$.

Range is limited by $R_L=0$ and $R_L=\infty$

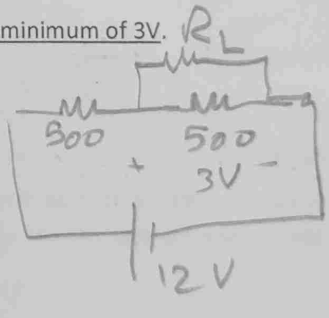
when $R_L = 0 \Rightarrow V_{ab} = 0$

When $R_L = \infty \Rightarrow V_{ab} = 6\ V$



$[V_{min}, V_{max}] = [\ 0\ ,\ 6\ ]$

b) What is the minimum load resistance, R_L, that would ensure the load gets a minimum of 3V.



$$3 = 12 \times \frac{R_L // 500}{500 + R_L // 500}$$

$$1500 + 3R_T = 12R_T$$

$$R_T = \frac{1500}{9} = 166.\bar{6}$$

$R_L = 250\ \Omega$

$$\frac{500R_L}{500+R_L} = 166.\bar{6}$$

$$500R_L = 83,333.\bar{3} + 166.\bar{6}R_L \Rightarrow R_L = \frac{83,333.\bar{3}}{333.\bar{3}} = 250\ \Omega$$