Assignment

ELECTROTECHNOLOGY
ELTK1100
ASSIGNMENT #4
(SOLUTIONS)

1.

Series circuit, so

$I_1 = I_2 = I_3 = I_T = 5A$ [1]

	P (W)	V (V)	I (A)	R (Ω)
T	600	***120***	***5***	24 [2]
1	280	56	5 [1]	11.2 [5]
2	200	***40***	5 [1]	8 [3]
3	***120***	24	5 [1]	4.8 [4]

$$R_T = \frac{V_T}{I_T} = \frac{120\,V}{5A} = 24\,\Omega$$ [2]

$$R_2 = \frac{V_2}{I_2} = \frac{40\,V}{5A} = 8\,\Omega$$ [3]

$$R_3 = \frac{P_3}{I_T^2} = \frac{120\,W}{(5A)^2} = 4.8\,\Omega$$ [4]

$$R_1 = R_T - R_2 - R_3 = 24\,\Omega - 8\,\Omega - 4.8\,\Omega = 11.2\,\Omega$$ [5]

Alternatively:

$$V_2 = 40\,V$$

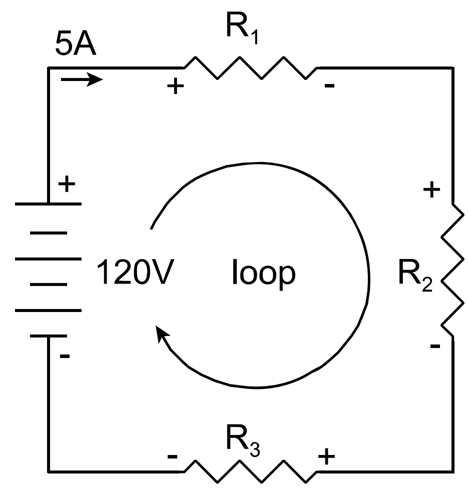
$$V_3 = \frac{P_3}{I_T} = \frac{120\,W}{5A} = 24\,V$$

KVL on loop

$$+V_T - V_1 - V_2 - V_3 = 0$$

$$V_1 = V_T - V_2 - V_3 = 120\,V - 40\,V - 24\,V = 56\,V$$

$$R_1 = \frac{V_1}{I_1} = \frac{56\,V}{5A} = 11.2\,\Omega$$



2.

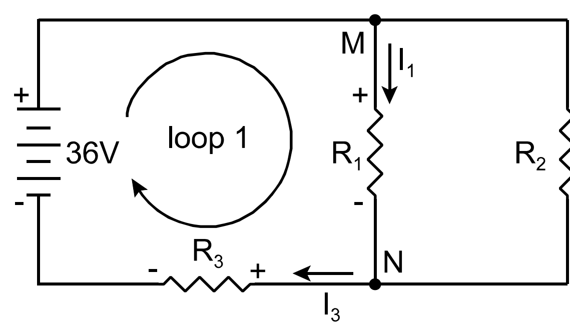
$$R_2 = \frac{1}{G_2} = \frac{1}{0.025\,S} = 40\,\Omega$$ [1]

$$KVL\ loop\ 1:\quad V_T = V_1 + V_3$$

$$V_1 = V_T - V_3 = 36\,V - 12\,V = 24\,V$$ [2]

R1 and R2 are parallel, so

$$V_2 = V_1 = 24\,V$$ [3]



$I_1 = \frac{P_1}{V_1} = \frac{33.6\,W}{24\,V} = 1.4\,A$ [4]

$R_1 = \frac{V_1}{I_1} = \frac{24\,V}{1.4\,A} = 17.1\,\Omega$ [5]

$I_2 = \frac{V_2}{R_2} = \frac{24\,V}{40\,\Omega} = 0.6\,A$ [6]

KCL on Node N

$I_T = I_3 = I_1 + I_2 = 1.4\,A + 0.6\,A = 2.0\,A$ [7]

	P (W)	V (V)	I (A)	R (Ω)
T	72	***36***	2 [7]	18
1	***33.6***	24 [2]	1.4 [4]	17.1 [5]
2	14.4	24 [3]	0.6 [6]	40 [1]
3	24	***12***	2 [7]	6 [8]

$R_3 = \frac{V_3}{I_3} = \frac{12\,V}{2\,A} = 6\,\Omega$ [8]

3.

Parallel circuit, so

$V_T = V_1 = V_2 = V_3 = 120\,V$ [1]

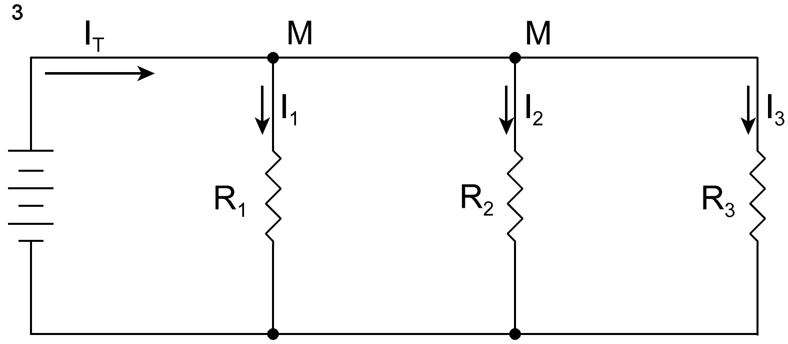
$R_1 = \frac{1}{G_1} = \frac{1}{0.0333\,S} = 30\,\Omega$ [2]

$R_2 = \frac{V_2^{\,2}}{P_2} = \frac{(120\,V)^2}{60\,W} = 240\,\Omega$ [3]

$I_1 = \frac{V_1}{R_1} = \frac{120\,V}{30\,\Omega} = 4\,A$ [4]

$I_2 = \frac{P_2}{V_2} = \frac{60\,W}{120\,V} = 0.5\,A$ [5]

	P (W)	V (V)	I (A)	R (Ω)
T	720	120 [1]	***6***	20
1	480	120 [1]	4 [4]	30 [2]
2	***60***	120 [1]	0.5 [5]	240 [3]
3	180	***120***	1.5 [6]	80 [7]



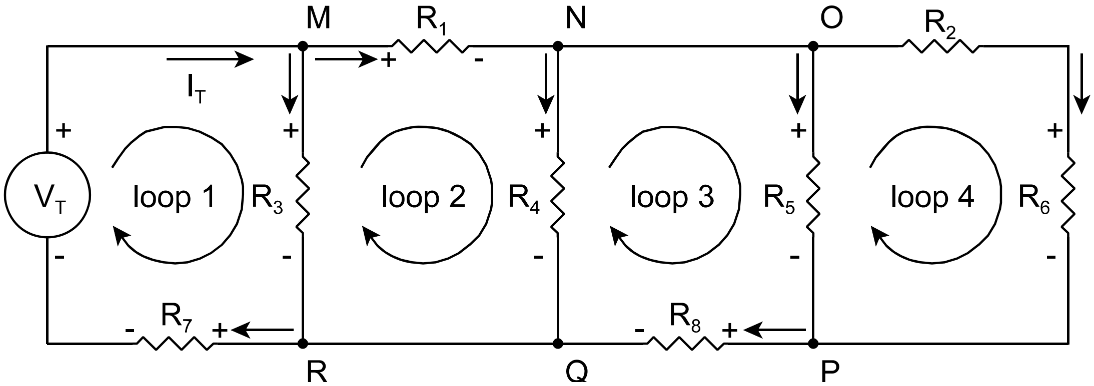
KCL on Node M

$I_T = I_1 + I_2 + I_3$

$I_3 = I_T - I_1 - I_2 = 6\,A - 4\,A - 0.5\,A = 1.5\,A$ [5]

$R_3 = \frac{V_3}{I_3} = \frac{120\,V}{1.5\,A} = 80\,\Omega$ [6]

4.



	P (W)	V (V)	I (A)	R (Ω)
T	160	***40***	***4***	10
7	80	20 [2]	4 [1]	5 [11]
3	40	***20***	2 [4]	10 [11]
1	***20***	10 [5]	2 [3]	5 [11]
4	10	10 [6]	***1***	10 [11]
8	5	5 [7]	***1***	5 [11]
5	1.67	***5***	0.333 [10]	15 [11]
2	***2***	3 [8]	0.667 [9]	4.5 [11]
6	1.33	***2***	0.667 [9]	3 [11]

$I_7 = I_T = 4A$ [1]

KVL on loop 1

$+V_T - V_3 - V_7 = 0$

$V_7 = V_T - V_3 = 40V - 20V = 20V$ [2]

KCL on node Q

$I_1 = I_4 + I_8 = 1A + 1A = 2A$ [3]

KCL on node R

$I_T = I_3 + I_1$

$I_3 = I_T - I_1 = 4A - 2A = 2A$ [4]

$V_1 = \frac{P_1}{I_1} = \frac{20W}{2A} = 10V$ [5]

KVL on loop 2

$+V_3 - V_1 - V_4 = 0$

$V_4 = V_3 - V_1 = 20V - 10V = 10V$ [6]

KVL on loop 3

$+V_4 - V_5 - V_8 = 0$

$V_8 = V_4 - V_5 = 10V - 5V = 5V$ [7]

KVL on loop 4

$+V_5 - V_2 - V_6 = 0$

$V_2 = V_5 - V_6 = 5V - 2V = 3V$ [8]

$I_2 = I_6 = \frac{P_2}{V_2} = \frac{2W}{3V} = 0.667A$ [9]

KCL on node P

$I_8 = I_5 + I_2$

$I_5 = I_8 - I_2 = 1A - 0.667A = 0.333A$ [10]

$R_7 = \frac{V_7}{I_7} = \frac{20V}{4A} = 5\Omega$ [11]

$R_3 = \frac{V_3}{I_3} = \frac{20V}{2A} = 10\Omega$

$R_1 = \frac{V_1}{I_1} = \frac{10V}{2A} = 5\Omega$

$R_4 = \frac{V_4}{I_4} = \frac{10V}{1A} = 10\Omega$

$R_8 = \frac{V_8}{I_8} = \frac{5V}{1A} = 5\Omega$

$R_5 = \frac{V_5}{I_5} = \frac{5V}{0.333A} = 15\Omega$

$R_2 = \frac{V_2}{I_2} = \frac{3V}{0.667A} = 4.5\Omega$

$R_6 = \frac{V_6}{I_6} = \frac{2V}{0.667A} = 3\Omega$

5.

$$P = 1.5\,hp = 1.5\,hp * \frac{746\,W}{hp} = 1120\,W$$

$$P = V_T\, I$$

$$I = \frac{P}{V_T} = \frac{1120\,W}{120\,V} = 9.33\,A$$

$$Energy = P\ t = 1120\,W * \frac{1\,kW}{1000\,W} * \frac{8\,hr}{day} * 50\,days = 448\,kW{\cdot}h$$

$$Cost = Energy * \frac{Cost}{kW{\cdot}h} = 448\,kW{\cdot}h * \frac{\$0.06}{kW{\cdot}h} = \$26.88$$

6.

$$I = \frac{V_T}{R_T} = \frac{240\,V}{6\,\Omega} = 40\,A$$

$$P = \frac{V_T^{\,2}}{R_T} = \frac{(240\,V)^2}{6\,\Omega} = 9.6\,kW$$

$$Energy = P\ t = 9.6\,kW * 6\,hr = 57.6\,kW{\cdot}h$$

$$Cost = Energy * \frac{Cost}{kW{\cdot}h} = 57.6\,kW{\cdot}h * \frac{\$0.06}{kW{\cdot}h} = \$3.46$$

7. **(a)**

$$P_{bulb} = \frac{P_T}{\#\ of\ bulbs} = \frac{25\,W}{50\ bulbs} = 0.5\,W$$

(b)

$$V_{bulb} = \frac{V_T}{\#\ of\ bulbs} = \frac{120\,V}{50\ bulbs} = 2.4\,V$$

(c)

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

$$R_{bulb} = \frac{V_{bulb}^{\,2}}{P_{bulb}} = \frac{(2.4\,V)^2}{0.5\,W} = 11.52\,\Omega$$

(d)

$$Energy = P\ t = 25\,W * \frac{1\,kW}{1000\,W} * \frac{6\,hr}{day} * 12\,days = 1.8\,kW{\cdot}h$$

$$Cost = Energy * \frac{Cost}{kW{\cdot}h} = 1.8\,kW{\cdot}h * \frac{\$0.08}{kW{\cdot}h} = \$0.144$$

8. If two bulbs burn out, the total resistance of the Xmas mini-light set will go down. Current is inversely proportional to resistance, so current will go up. If the current goes up, the power consumed by the individual bulb and the entire set will go up.

Therefore, the right answer is (ii), the bulbs would be brighter.

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

In fact, a 50 bulb set of Xmas mini-lights is designed with 2.5V bulbs. At 2.5V/bulb, the set requires 48 bulbs. They add 2 to decrease the current, which extends the life of the set and allows for a number of bulbs to fail as demonstrated.

9. All bulbs are identical so they have the same resistance R. We have two (B & C) in parallel connected to one (A) in series.

Current splits when it gets to a parallel circuit and B & C are equal, so they each will have 50% of the total current. Bulb A will have 100% of the total current, so the correct answer is (iii), bulb A will be brighter than bulb B.

10.

	P (W)	V (V)	I (mA)	R (Ω)
T	160	***240***	666 [2]	360 [1]
A	106.7 [5]	160	666 [3]	***240***
B	26.7 [6]	80	333 [4]	***240***
C	26.7 [6]	80	333 [4]	***240***

$$R_B \parallel R_C = \frac{240\,\Omega}{2} = 120\,\Omega$$

$$R_A \ s \ R_{B \parallel C} = 240\,\Omega + 120\,\Omega = 360\,\Omega$$

$$R_T = 360\,\Omega$$ [1]

$$I_T = \frac{V_T}{R_T} = \frac{240\,V}{360\,\Omega} = 666\,mA$$ [2]

$$I_A = 666\,mA$$ [3]

$$I_B = I_C = \frac{666\,mA}{2} = 333\,mA$$ [4]

$$P_A = I_A^2 R = (666\,mA)^2 * 240\,\Omega = 106.7\,W$$ [5]

$$P_B = P_C = I_B^2 R = (333\,mA)^2 * 240\,\Omega = 26.7\,W$$ [6]

The rated power for the light bulbs is 60W. This is the maximum power the bulb can dissipate without burning up.

In this case, when power is applied, all lights will come on. But bulb A will quickly burn out because it can only dissipate 60W of the 106.7W applied. All lights would go out when bulb A burns out.

11.

P (kW)	t (h/day)	E (kW-h/day)	E (kW-h)/month	Cost ($/month)
1.2	0.75	0.9	27	$1.62
1.492	5	7.46	223.8	$13.43
1.06	6	6.36	190.8	$11.45
0.75	0.5	0.375	11.25	$0.68
	TOTAL	15.095	453	$27.18

$$P = 2hp = 2hp * \frac{746W}{hp} = 1492W$$

$$P = 300W + 4 * 100W + 2 * 60W + 6 * 40W = 1.06kW$$

$$Cost = Energy * \frac{Cost}{kW \cdot h} = 453kW \cdot h * \frac{\$0.06}{kW \cdot h} = \$27.18$$

12.

$$P = 700W + 800W + 900W = 2400W$$

$$P_{T\,(MAX)} = V_T\, I = 120V * 25A = 3000W$$

Since we only have 600W to spare, we cannot add a 1000W hair dryer without tripping the breaker (assuming all appliances are on).

In fact, electricians wire houses so that only 80% of rated current (25A) will be used. If they cannot guarantee this safety factor, they use separate breakers to ensure it is safe.

13.

$$Q = M\ C\ \Delta T = 1kg * 1000\frac{g}{kg} * 0.8 * (50°C - 10°C) = 32kcal.$$

$$Efficiency = \frac{Q}{Heat\ Produced} * 100\%$$

$$Heat\ Produced = \frac{Q}{Efficiency} * 100\% = \frac{32kcal.}{75\%} * 100\% = 42.7kcal.$$

$$P = V_T\ I = 240V * 8A = 1920W.$$

$$Heat\ Produced = \frac{P\ t}{4.187}$$

$$t = \frac{Heat\ Produced * 4.187}{P} = \frac{42.7\ kcal. * 4.187}{1920W} = 93.1s.$$

$$P = V_T I = I^2 R = \frac{V_T^2}{R}$$

$$Q = M\,C\,\Delta T \qquad \eta = \frac{Q}{Heat\ Produced} * 100\% \qquad Heat\ Produced = \frac{P\,t}{4.187}$$

$$Energy = P\,t$$

$$Cost = Energy * \frac{Cost}{kW \bullet h}$$

$$Heat\ Produced = \frac{P\,t}{4.187} = \; = \frac{1920\,W * 2\,\text{min} * \frac{60\,s}{\text{min}}}{4.187} = 55.0\,kcal.$$

$$Efficiency = \frac{Q}{Heat\ Produced} * 100\%$$

$$Q = \frac{Efficiency}{100\%} * Heat\ Produced = \frac{75\%}{100\%} * 55.0\,kcal. = 41.3\,kcal.$$

$$Q = M\,C\,\Delta T$$

$$\Delta T = \frac{Q}{M\,C} = \frac{41.3\,kcal.}{1000g * 0.8} = 51.6^\circ C$$

$$\Delta T = T_2 - T_1$$

$$T_2 = \Delta T + T_1 = 51.6^\circ C + 10^\circ C = 61.6^\circ C$$

Since the water started out at 10°C, the final temperature of the water after 2 minutes will be 61.6°C.

$$P = V_T I = I^2 R = \frac{V_T^2}{R}$$

$$Q = M\,C\,\Delta T \qquad \eta = \frac{Q}{Heat\ Produced} * 100\% \qquad Heat\ Produced = \frac{P\,t}{4.187}$$

$$Energy = P\,t$$

$$Cost = Energy * \frac{Cost}{kW \bullet h}$$

14.

$$Cost = Energy * \frac{Cost}{kW \cdot h}$$

$$Energy = \frac{Cost}{\frac{Cost}{kW \cdot h}} = \frac{\$20.00}{\frac{\$0.08}{kW \cdot h}} = 250\,kW \cdot h$$

$$Energy = P\,t$$

$$P = \frac{Energy}{t} = \frac{250\,kW \cdot h}{5\,h} = 50\,kW$$

$$P = V_T I$$

$$I = \frac{P}{V_T} = \frac{50\,kW}{480\,V} = 104.2\,A$$

$$Heat\ Produced = \frac{P\ t}{4.187} = \frac{50000\,W * 5\,h. * \frac{3600\,sec.}{h}}{4.187} = 215\,Mcal.$$

$$Q = \frac{Efficiency}{100\%} * Heat\ Produced = \frac{75\%}{100\%} * 215\,Mcal. = 161\,Mcal.$$

$$Q = M\ C\ \Delta T$$

$$M = \frac{Q}{C\ \Delta T} = \frac{161\,Mcal.}{1 * (100°C - 25°C)} = 2150000\,g = 2150\,kg$$

$$P = V_T\ I = I^2\ R = \frac{V_T^{\,2}}{R}$$

$$Q = M\ C\ \Delta T \qquad \eta = \frac{Q}{Heat\ Produced} * 100\% \qquad Heat\ Produced = \frac{P\ t}{4.187}$$

$$Energy = P\ t$$

$$Cost = Energy * \frac{Cost}{kW\bullet h}$$

15.

$$Q = M\ C\ \Delta T = 100kg. * 1000\ \frac{g.}{kg.} * 1 * (100°C - 20°C) = 8\ Mcal.$$

$$P = \frac{V_T^{\,2}}{R} = \frac{(580V)^2}{10\Omega} = 33.64\,kW$$

$$Heat\ Produced = \frac{P\ t}{4.187} = \frac{33640\,W * 20\ min. * 60\ \frac{sec.}{min.}}{4.187} = 9.64\ Mcal.$$

$$Efficiency = \eta = \frac{Q}{Heat\ Produced} * 100\% = \frac{8\ Mcal.}{9.64\ Mcal.} * 100\% = 83\%$$

$$P = V_T\ I = I^2\ R = \frac{V_T^{\,2}}{R}$$

$$Q = M\ C\ \Delta T \qquad \eta = \frac{Q}{Heat\ Produced} * 100\% \qquad Heat\ Produced = \frac{P\ t}{4.187}$$

$$Energy = P\ t$$

$$Cost = Energy * \frac{Cost}{kW\bullet h}$$