2019 Fall, Electrical and Electronic Circuits (4190.206A 002)

Homework #1

Due date: Oct. 7, 2019 3:15pm

> If you hand-in after the due date, your score will be deducted by 20%.
>
> No more submission will be accepted after Oct. 9, 2019. 3:15am, it

Name : ____________________ Solution.

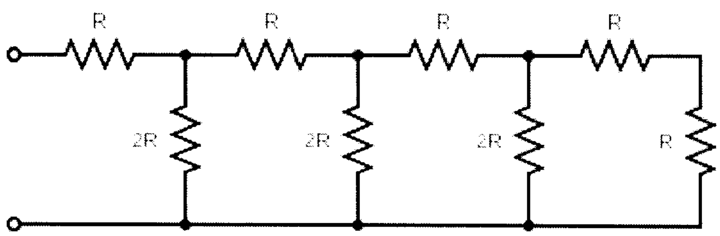
Student ID Number : ____________________

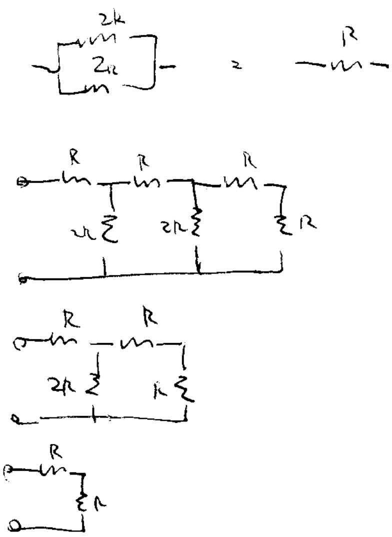
1 (4)	2 (4)	3 (4)	4 (8)	5 (10)	6 (5,2)		7 (8)	8 (6)
					a	b		

9 (6)	10 (6,3)		11 (4,6,5)			12 (6,3,3)			13 (2,2,2,2,3,2,2,2)								Total (110)
	a	b	a	b	c	a	b	c	a	b	c	d	e	f	g	h	

[Equivalent Resistance]

1-1. (point 4) Find the equivalent resistance from the indicated terminal pair of the network.

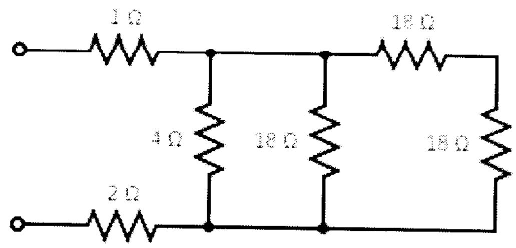




= 2R

Answer : 2R

1-2. (point 4) Find the equivalent resistance from the indicated terminal pair of the network.



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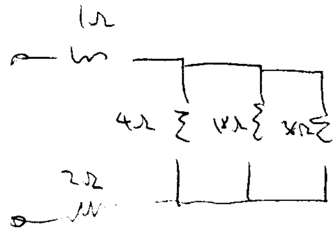
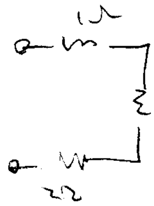


Answer : 6Ω

=

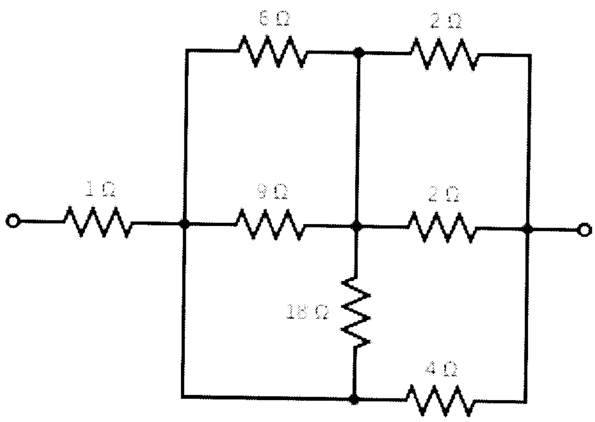


$\frac{1}{\frac{1}{4}+\frac{1}{18}+\frac{1}{36}} = 3\Omega$

$= 6\Omega$

1-3. (point 4) Find the equivalent resistance from the indicated terminal pair of the network.

$\frac{1}{\frac{1}{6}+\frac{1}{9}+\frac{1}{18}} = 3\Omega$



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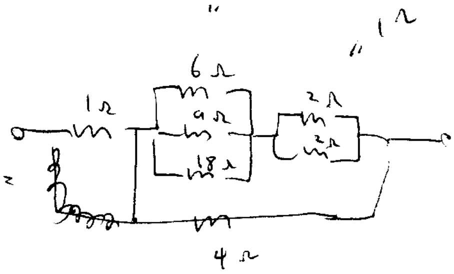

Answer : 3Ω

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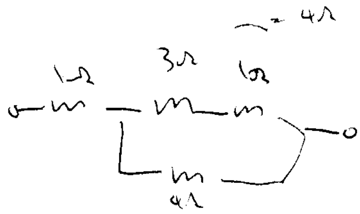

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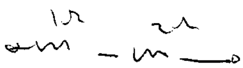
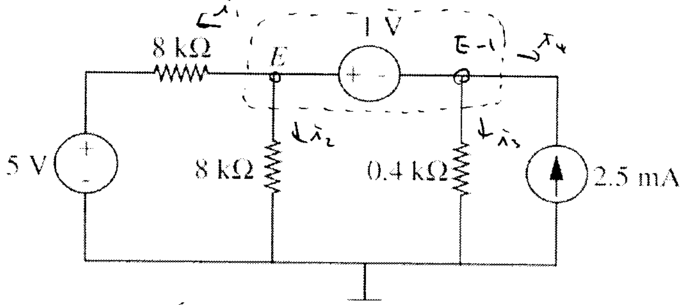


$= 3\Omega$

[Node Analysis]

1-4. (point 8) Find the node potential E in the following figure using node analysis. (Hint: consider using a super node.)



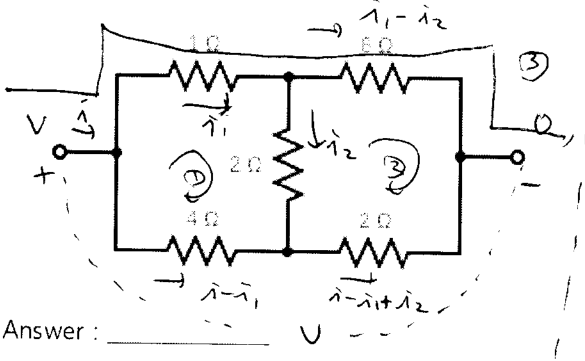
$i_1 + i_2 + i_3 + i_4 = 0$

$\Rightarrow \dfrac{E-5}{8k\Omega} + \dfrac{E}{8k\Omega} + \dfrac{E-1}{0.4k\Omega} - 2.5mA = 0$

$\Rightarrow E = \dfrac{45}{22} V$

Answer : $\dfrac{45}{22}$ V

1-5. (point 10) Find the equivalent resistance from the indicated terminal pair of the network. (Hint : Imagine that we applied a voltage source with V_0 between the two indicated terminals. Using the node analysis method, you can find out all the voltages at the nodes in terms of V_0. Then you can find out the currents flowing in the 1Ω resistor and the 4Ω resistor in terms of V_0, and therefore you can find out the total current coming out of the voltage source in terms of V_0. This should be enough information to find out the total resistance.)



Answer : ______ Ω

① set v, i, i_1, i_2

② KVL (loop ①)

$i_1 + 2i_2 - 4(i - i_1) = 0$

③ KVL (loop ②)

$6(i_1 - i_2) - 2(i - i_1 + i_2) - 2i_2 = 0$

②, ③ $\Rightarrow$ $i_1 = \frac{2}{3} i$, $i_2 = \frac{1}{3} i$

④ Voltage drop along path ③

$V = v = \frac{2}{3} i + 2i = \frac{8}{3} i = R i$

$\boxed{R = \frac{8}{3} \Omega}$

$5i_1 + 2i_2 = 4i$

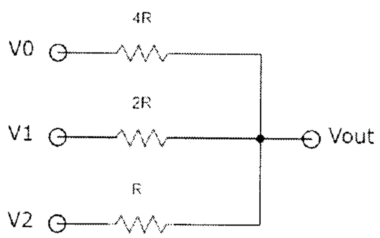
$8i_1 - 10i_2 = 2i$

$4i_1 - 5i_2 = i$

$33 i_1 = 22 i$

$2i - \frac{5}{2} \cdot \frac{2}{3} i$

1-6. (point 7) In the following circuit, V0, V1, and V2 are controlled by digital outputs from some digital processor. Assume that the output voltage of this digital processor is either 0V or 1V.



a) (point 5) Find out the Vout in terms of V0, V1, and V2. (Hint : Treat V0, V1, V2 as separate voltage sources, then you can use node analysis to find out Vout.)

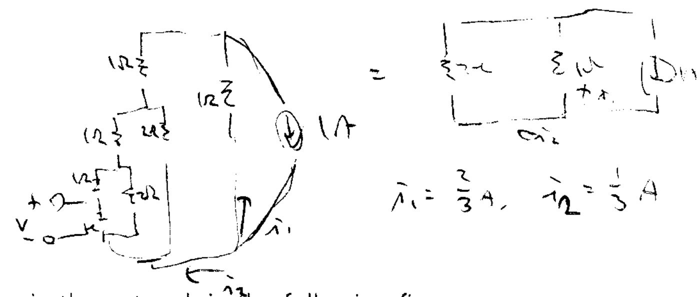
Answer : _____

$$\frac{V_{out}-V_0}{4R}+\frac{V_{out}-V_1}{2R}+\frac{V_{out}-V_2}{R}=0$$

$$\Rightarrow V_{out}=\frac{4V_2+2V_1+V_0}{7}$$

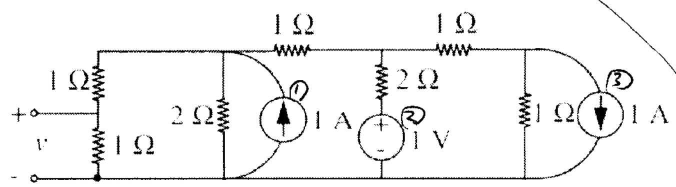
b) (point 2) Fill out the following table. You don't need to calculate the fraction into a decimal number. Can you tell the function of the above circuit? Answer: DAC

V2 (V)	V1 (V)	V0 (V)	Vout (V)
0	0	0	0
0	0	1	$\frac{1}{7}$
0	1	0	$\frac{2}{7}$
0	1	1	$\frac{3}{7}$
1	0	0	$\frac{4}{7}$
1	0	1	$\frac{5}{7}$
1	1	0	$\frac{6}{7}$
1	1	1	1



[Superposition Method]

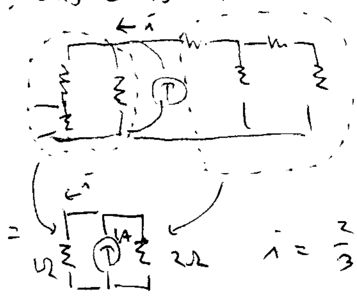
1-7. (point 8) Use superposition to find the voltage v in the network in the following figure.



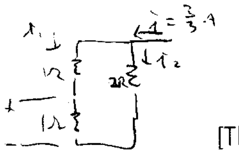
$\Rightarrow i_3 = i_4 = \frac{1}{6}A$

Answer : $\frac{1}{3}V$

1. Only ① is on.



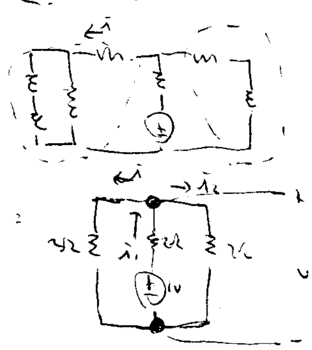
$i = \frac{2}{3}A$



$i_1 = i_2 = \frac{1}{3}A$

$v_1 = \frac{1}{3}V$

2. only ② is on



$v = 2i = 2i_2$

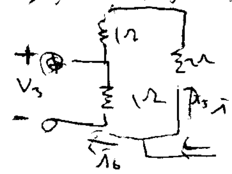
$\Rightarrow i_2 = i,\ i_1 = 2i$

KVL $\Rightarrow$ $1v = 6i,\ i = \frac{1}{6}A$

$i_3 = i_4 = \frac{1}{12}A$

$\Rightarrow V_2 = \frac{1}{12}V$

3. only ③ is on.



$\Rightarrow i_6 = \frac{1}{12}A$

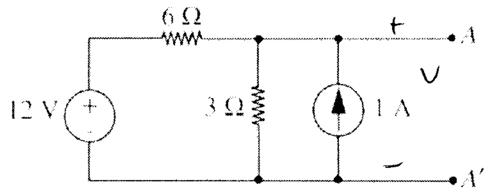
$-V_3 = \frac{1}{12}V$

$V_3 = -\frac{1}{12}V$

$V = V_1 + V_2 + V_3 = \frac{1}{3}V$

[Thevenin and Norton Method]

1-8. (point 6) Find the Thevenin equivalent for circuit in the following figure at the terminal AA'.

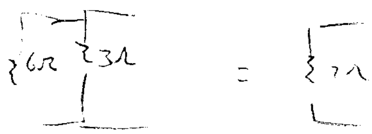


Answer :

$R_{Th} = 2\Omega$

$V_{Th} = 6V$

$R_{Th} = 2\Omega$

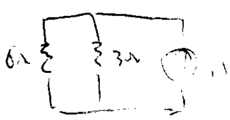


V_{Th} : superposition method

① 12V is on

$V_① = 12 \times \frac{3}{9} = 4V$

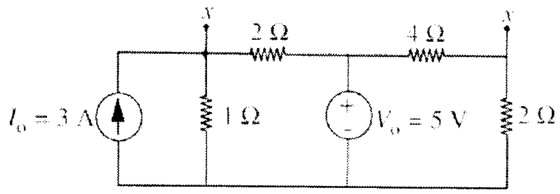
② 1A is on



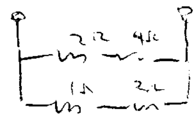
$V_② = 2V$

$V_{Th} = 4V + 2V = 6V$

1-9. (point 6) Find the Norton equivalent at the terminals marked x-x in the circuit in the following figure.



R_{Th} =



= 2 Ω

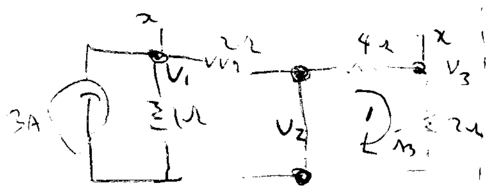
V_{TH} : Superposition

$I_N = 1A$

Answer : ___________

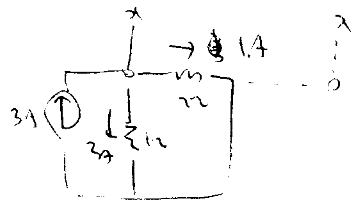
I_o

① 3A is on



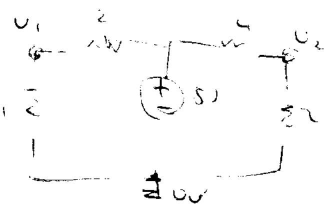
KVL along loop 1

$6\Omega \times i_3 = 0$, $i_3 = 0$ ⇒ $V_3 = V_2$



$V_{\textcircled{1}} = 2V$

② 5V is on

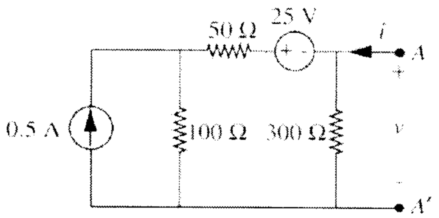


$V_{\textcircled{2}} = 0$

$V_T = V_{\textcircled{1}} + V_{\textcircled{2}} = 2V$

$I_N = \frac{V_{Th}}{R_{Th}} = 1A$

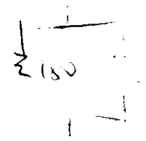
1-10. (point 9) Consider the circuit in the figure below.



a) (point 6) Find a Norton equivalent circuit for this circuit at terminals A-A′

Answer : ___________

R_{Th} =

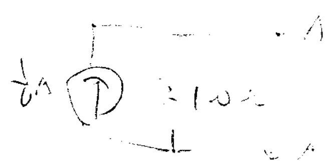


= 100Ω

$V_{Th} = \frac{50}{3}V$

$I_N = \frac{V_{Th}}{R_{Th}} = \frac{1}{6}A$

⇒

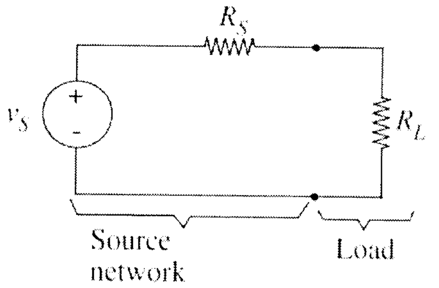


b) (point 3) Find the Thevenin equivalent circuit corresponding to your answer in a).

Answer : ___________

[Power]

1-11. (point 15) Consider the network in the figure below, in which a non-ideal battery drives a load resistor R_L. The battery is modeled as a voltage source V_S in series with a resistor R_S. The following are some proofs about power transfer:



a) (point 4) Prove that for R_S variable and R_L fixed, the power dissipated in R_L is maximum when $R_S = 0$. (Hint: Plot the power dissipated in R_L as a function of R_S.)

$$P_{R_L} = \left(\frac{V_S}{R_L+R_S}\right)^2 \times R_L$$

P_{R_L} is maximum when $R_S = 0$

b) (point 6) Prove that for R_S fixed and R_L variable, the power dissipated in R_L is maximum when $R_S = R_L$. (Hint: Find out P_{R_L} which is the power dissipated in R_L in terms of R_S and R_L. Differentiate P_{R_L} with respect to R_L. Find out R_L which will make the differentiation zero, i.e. find out the extremum point.)

$$P_{R_L} = f(R_L) = \left(\frac{V_S}{R_L+R_S}\right)^2 R_L$$

$$f'(R_L) = 0 \rightarrow R_L = R_S$$

c) (point 5) Prove that for R_S fixed and R_L variable, the condition that maximizes the power delivered to the load R_L requires that an equal amount of power be dissipated in the source resistance R_S.

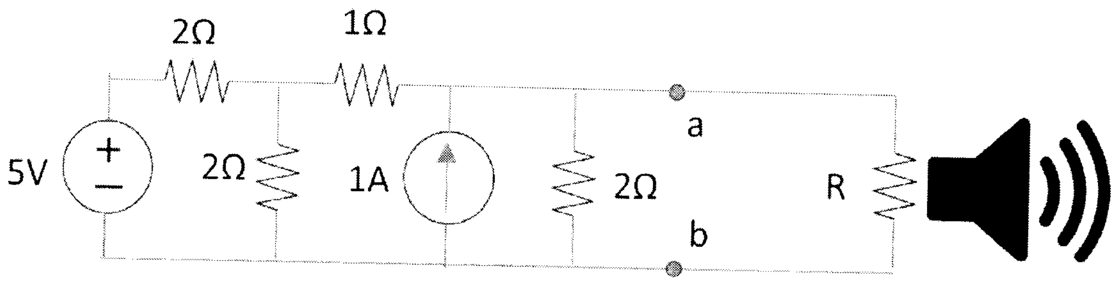
$$R_S = R_L$$

$$\Rightarrow P_{R_S} = \left(\frac{V_S}{R_L+R_S}\right)^2 R_S$$

$$P_{R_L} = \left(\frac{V}{R_L+R_S}\right)^2 R_L$$

$$P_{R_S} = P_{R_L}$$

1-12. (point 12) We have an audio system as shown in the below. We want to deliver the maximum power to the speaker. In the following, we assumed that the speaker can be modelled as simple resistor R, and all the power is converted into sound. Let's find out a requirement for speaker.



a) (point 6) Calculate the Thevenin equivalent circuit on the left side of a-b.

Answer : ____

$R_{Th} = 1\Omega$

$V_{Th} = \frac{9}{4} V$

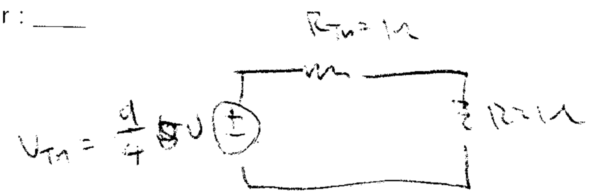
b) (point 3) To deliver the maximum power from the Thevenin source to the speaker (modeled as the resistance R), what is the optimal resistance for the speaker?

Answer : ____

$R = 1\Omega$

c) (point 3) What is the maximum power delivered to the speaker?

Answer : ____



$P_R = I^2 R$

$= \left(\frac{9}{8} A\right)^2 1\Omega$

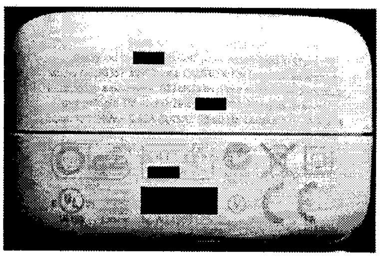
$= \frac{81}{64} W$

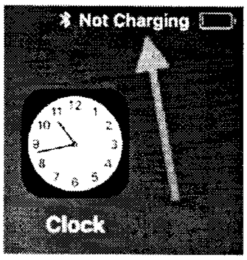
1-13. (point 17) Nowadays, many of the small electric devices use USB power adapter as its power source. Let's calculate how much power these USB power adapters can handle and think how does it affect our daily lives. In the following calculation, we will assume that there is no power loss in the conversion.

a) (point 2) USB interface has a long history with multiple versions, but when the early generation of the smartphones and tablets started to adopt USB power adapter, the most popular USB version was either 1.1 or 2.0, and the maximum current the typical USB ports on PC can provide was limited to 500 mA. What is the maximum power these USB ports can supply? (Hint: the voltage of the USB standard is always 5.0V except the power delivery (USB PD) specs which is not quite popular yet.)

Answer: 2.5 W

b) (point 2) The first *pad released in 2010 from A* company was shipped with USB power adapter that can provide up to 2.1A of current. However, people also used to connect this device to the USB ports on the PC or tried to charge it with other USB power adapters because the power adapter sold from A* company was too expensive. And in most of the case, *pad showed a warning message "Not Charging", even though in many cases it was being charged slowly. Assume that it used to take about 2 hours to charge *pad to 100% with the original charger (assume 2.0A for simple calculation) when it is off, then how long would it have taken to charge it with the typical USB port on PC in those days?

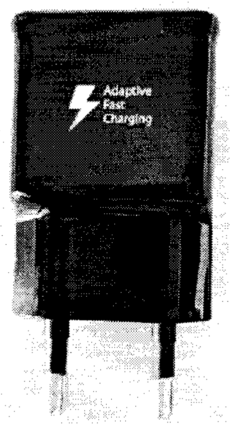


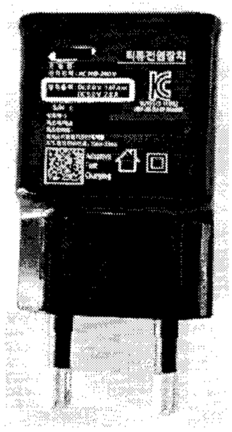


Answer: 8 hours

(FYI, USB ports on the recent computers support USB 3.0, and it can provide more than 0.5A.)

c) (point 2) For example, my USB power supply can support either 9.0V 1.67A mode or 5.0V 2.0A mode. As its marking on the front face says, it can adjust the output power level for faster charging. Fast charging or quick charging is a new standard to shorten the charging time and it became popular only around mid-2010s. It can charge your smartphone faster only when your smartphone supports such a mode. My phone shows that it is in a "faster charging mode" when it is connected to such a power supply. Assuming there is no power loss during conversion, which mode will charge the smartphone faster and how many times is it faster?





Answer: 9 V 1.67 A mode, 1.5 times faster

d) (point 2) Check your own USB power supply for your smartphone, and find out how much current it can support. If your USB power supply can support multiple modes, please list all those modes.

Answer: model name or No.: ____________

Voltage and current: 9V , 1.67A

e) (point 3) Check your own smartphone model name or number and find out the capacity of the battery in your smartphone from the internet. Battery capacity is generally specified in terms of mAh. 100 mAh means it can provide 100 mA for 1 hour or 10 mA for 10 hours. And if the specification of the battery capacity does not say anything, it is probably using Lithium-ion battery and the output voltage can be between 3.6V and 3.85V. Let's assume that its nominal output voltage is 3.7V. Calculate the total amount of energy stored in your battery when it is fully charged. (Hint: 1 J (Joule) is the amount of energy when 1W (watt) of power is spent for 1 second. Therefore, if 1 Wh (watt-hour) is stored, it can do a work of 3600 J. If you are not familiar with the power conversion, please re-read section 1.5.1 of the textbook.)

Answer: Phone model name or No. (manufacturer): ____________(____________)

Battery capacity (mAh): 3500 mAh (If it is written in other units, please specify it.)

Maximum amount of energy stored in your device (J): 46620 J

(FYI, according to some reference, an average man with 60kg of weight needs roughly $9\text{x}10^6$ J of energy per day.)

f) (point 2) Based on the answers from d) and e), how long should it take to charge your smartphone to its full capacity theoretically? If your power supply and phone support multiple charging mode, choose the fastest option. Assume that there is no power loss during conversion.

Answer (min or hour): 51 min. $\frac{46620\text{ J}}{9\text{V} \times 1.67\text{A}} \times \frac{1\text{ min}}{60\text{ s}}$

g) (point 2) Nowadays, many people carry the portable phone charging battery. If you have your own portable battery, please find out its specification. If you do not own one, you can use the specification of mine (3.6V/10400mAh). Find out the maximum energy it can contain, and also calculate how many times it can charge your phone from empty to full.

Answer: maximum energy stored in the portable battery (J): 134784 J

Number of time it can charge your phone: 2 (truncate to integer.)

h) (point 2) According to FAA (US Federal Aviation Administration) regulation, "A device with a lithium ion battery that exceeds 160 watt hours (Wh) is prohibited as carry-on or checked baggage". Is your smartphone allowed on board according to this regulation?

Answer: Yes