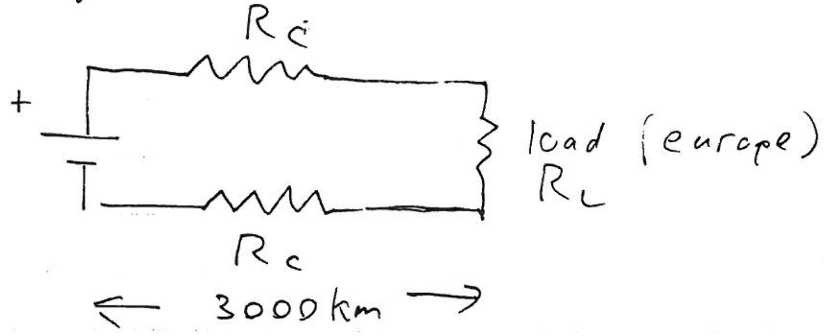
Assignment #5 Physics 346

① Equivalent circuit:



delivered voltage across R_L is 800 kV

(a) Delivered power across R_L is 5×10^9 W
delivered voltage across R_L is 800 kV
∴ current through R_L is $\frac{P_{delivered}}{V_{delivered}} = \frac{5\times10^9\,W}{8\times10^5\,V}$

$\therefore I = 6250A$

There are 2 cables each having resistance R_c

Power lost to cables is $I^2(2R_c)$ (2 cables)

We need $I^2(2R_c) < 5\times10^8$ W (10% of delivered power)

$$\therefore R_c < \frac{5\times10^8\,W}{(6250A)^2\,2} = \underline{\underline{6.4\,\Omega}}$$

$$R_c = \rho\frac{L}{A} = \frac{\rho L}{\pi(D/2)^2}$$ where D = cable diameter

Rearrange $D = 2\sqrt{\frac{\rho L}{\pi R_c}} = 2\sqrt{\frac{(1.72\times10^{-8}\,\Omega\,cm)\,3\times10^6\,m}{\pi\;6.4\,\Omega}}$

∴ Must have $D \geq$ $\underline{\underline{10\text{ cm}}}$

(6) What voltage must be generated in Africa?

Voltage dropped across each wire is

$V_c = IR_c$

total voltage dropped is $2V_c = 2IR_c$

$= 2(6250A)(6.4\,\Omega)$

$= 80,000V$

$\therefore$ Voltage in Africa must be 880,000V

(old midterm question)

(2)

An electric car requires 15 kWh of electrical energy to travel 100 km. The car must have a design range of 300 km. It is designed to run on Pb acid batteries which have a voltage of 12 V and a capacity of 90 A-hr.

(a) (2 marks) What is the total stored charge required to achieve this range?

Total energy $E = 15\,\text{kwhr} \times 3 = 45\,\text{kwh} = VQ$ $(= 1.62 \times 10^{8}$

$\therefore Q = \frac{E}{V} = \frac{(45\,\text{kWh})(3.6 \times 10^{6}\,\text{J/kWh})}{(12\,\text{V})}$

$= 1.35 \times 10^{7}\,\text{C} \times \frac{1\,\text{A-h}}{3600\,\text{C}} = \underline{3.75 \times 10^{3}\,\text{Ah}}$

(b) (1 mark) how many batteries will be necessary to achieve this range?

$\#$ of batteries $= \frac{3.75 \times 10^{3}\,\text{Ah}}{90\,\text{Ah/batt.}} = \underline{42}$ batt.

8. Microwave radiation from a cell phone with a wavelength of 16 cm is incident on a surface with an intensity of 0.01 W/cm^2.

(a) (2 marks) How many microwave photons pass through 1 cm^2 of this surface each second?

Energy per photon $E = hf = h\frac{c}{\lambda} =$ 1.242

In 1 cm^2: Power $P = \frac{NE}{\Delta t}$ where $N = \#$ of photons

$\therefore N = \frac{P}{E}\Delta t = \frac{(0.01\,\text{J/s})(1\,\text{s})}{1.242 \times 10^{-24}\,\text{J}} = 8.0 \times 10^{21}\,\text{phot/s}$

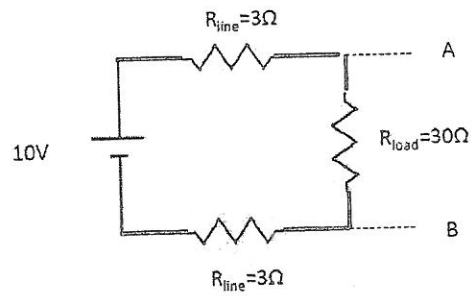
(b) (1 mark) What is the primary physical effect of these photons on human tissue?

Heating, via excitation of rotational motion of H_2O molecules.

Old Midterm question

(3)

9. The circuit below is a simple model of a fictitious town that runs on low voltage DC power. The power is generated by a DC power facility at a voltage of 10V and deliver by two power lines with resistance R_{line}. The maximum power the voltage source can deliver is 5 W.



$R_{series} = 36\,\Omega$

(a) (1 mark) Find the total power delivered by the DC voltage source.

$$P = \frac{V^2}{R} = \frac{(10V)^2}{36\,\Omega} = 2.78\ W$$

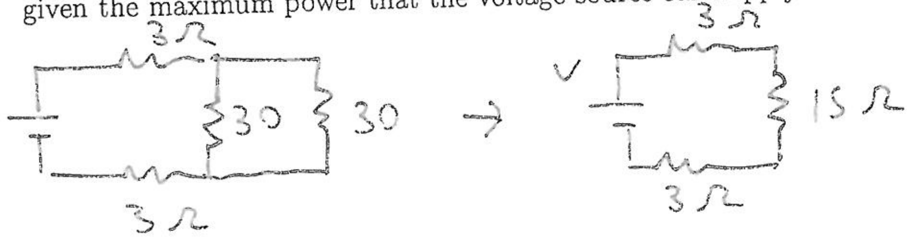
(b) (2 marks) Find the power lost to resistance heating in the wires.

$$P = I^2 2R_{line} = \left(\frac{V_{supp}^2}{R_{series}^2}\right)(2R_{line})$$

$(I = .278A)$

$$= \left(\frac{100V^2}{36^2\,\Omega^2}\right)(2\times 3) = 0.463\ W$$

(c) (2 marks) It is proposed that a second town of resistance 30 Ω be connected in parallel to the town (across points A and B in the diagram). Will this be possible given the maximum power that the voltage source can supply?



$$P = \frac{V^2}{R_{tot}} = \frac{(10V)^2}{21\,\Omega} = 4.76\ W$$

∴ It is possible

(c) (2 marks) Using your knowledge of Faraday's law and magnetic induction briefly explain how this field could cause problems for very sensitive electrical circuits.

~~A circuit is a closed loop. A changing field due to AC power lines will induce an emf in the circuit which may affect certain sensitive electric circuits~~

Old Midterm Question

12. Near the surface of the earth the electric potential V decreases by ≈ 120 V for every meter of elevation increase.

(4)

(a) (1 marks) What is the magnitude and direction of the electric force on a 10 nC charge near the surface of the earth?

Direction: down

direction of increasing V ↓

$E = -\frac{\Delta V}{\Delta x}$ ∴ ↑ E points up

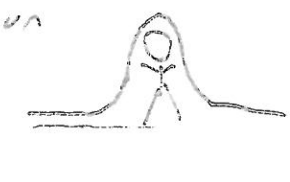
↓ $\vec{F} = q\vec{E}$, $q < 0$

$|F| = (10^{-8}\,C)(120\,V) = 1.2 \times 10^{-6}\,N$

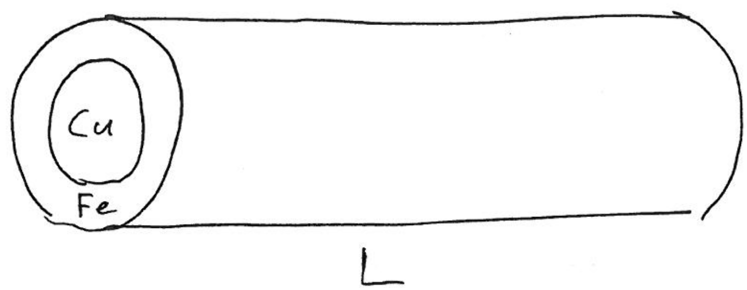
(b) (1 marks) Why do humans not observe this voltage in everyday life? (After all, 110V from an outlet can kill)

- Humans are relatively good conductors. An external electric field cannot induce appreciable internal field in a good conductor (surface charges are set up which oppose any internal field.

- Humans are usually in decent electrical contact w/ the ground. The effect is to deform the lines of constant voltage around the person



7 - 20



(a)

$$R_{Cu} = \frac{\rho_{Cu} L}{A_{Cu}}$$

$$R_{Fe} = \frac{\rho_{Fe} L}{A_{steel}}$$

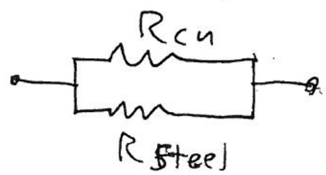
$A_{Cu} + A_{steel}$ = crossectional area of copper and iron

Resistance of copper core =

$$R_{Cu} = \frac{(1.72\times10^{-8}\ \Omega m)(10^3 m)}{(\pi (.005m)^2)} = 0.219\Omega$$

$$R_{Fe} = \frac{(29\times10^{-8}\ \Omega m)(10^3 m)}{\pi(.01^2 - .005^2)} = 1.23\Omega$$

we add the resistances in parallel!



$$\frac{1}{R_{total}} = \frac{1}{R_{Cu}} + \frac{1}{R_{steel}} = 5.39\ \Omega^{-1} \quad \therefore R_{total} = 0.186\Omega$$

(b) Ratio of currents : Since V is same for each cable

$$I_{Cu} = \frac{V}{R_{Cu}},\ I_{steel} = \frac{V}{R_{steel}} \qquad \frac{I_{Cu}}{I_{steel}} = \frac{R_{steel}}{R_{Cu}} = \frac{1.23}{.219} = \underline{\underline{5.61}}$$

(c) Ratio of powers: $P = V^2/R$

$$\therefore \frac{P_{Cu}}{P_{steel}} = \frac{R_{steel}}{R_{Cu}} = \underline{\underline{5.61}}$$

8-16

An electric kettle of 7 Ω contains 500 cm³ of H_2O at 10°C is connected to 110 V supply. If 10% of electrical energy is wasted (bad insulation) how long does it take to convert all water into steam?

- how much energy is required to convert water to steam...

NOTE: 1 g H_2O = 1 cm³ H_2O ($\rho_{H2O} = 1$)

$$Q = mc\Delta T + mL_v$$
$$= (.5)(4189)(100-10) + (.5)(2.26\times10^6)$$
$$Q = 1.3\times10^6 \text{ J}$$ (1 mark)

- power produced (usable) from kettle

$$P = \frac{(0.9)V^2}{R} = \frac{(0.9)(110)^2}{7} = 1.6\times10^3 \text{ W}$$ (1 mark)

- time needed...

$$t = \frac{\text{Joules}}{\text{Joules/s}} = s = \frac{J}{W} = \frac{Q}{P}$$

$$t = \frac{1.3\times10^6 \text{ J}}{1.6\times10^3 \text{ W}} = 8.1\times10^2 \text{ s}$$

$$= 14 \text{ min}$$ (1 mark)

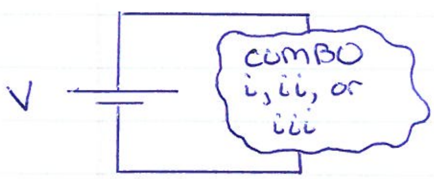
) either is fine

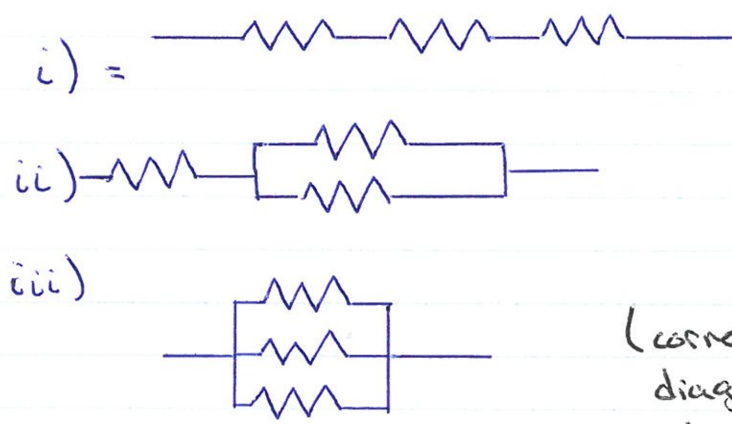
8-17

The stove has three settings for its resistors:

i) in series
ii) 2 parallel, 1 in series
iii) all parallel

step 1: DIAGRAM





- voltage drop accross battery is V...

(correct diagrams 1 mark)

a) which combination gives HIGH, MED, LOW

- refers to heat ~ Power
- total voltage stays the same, but "R" can vary

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

∴ low R ⟶ high P
big R ⟶ low P

HIGH	is	iii)
MED	is	ii)
LOW	is	i)

(1 mark)

b) what is R_{TOTAL} for each case?

i) $R_T = 3R$

(1 mark)

ii) $R_T = \left(\frac{2}{R}\right)^{-1} + R = \frac{3R}{2}$

iii) $R_T = \left(\frac{1}{R} + \frac{1}{R} + \frac{1}{R}\right)^{-1} = \left(\frac{3}{R}\right)^{-1} = \frac{R}{3}$

c) if HIGH setting provides 1000 W, what is the power of the other two?

- use P_{HIGH} to get "R" for each resistor...

$$P_{HIGH} = \frac{V_{TOTAL}^2}{R_{TOTAL}} = 1000\ W$$

<u>NOTE:</u> if R_{TOTAL} increases by factor of "A", the power decreases by factor of "1/A".

- the R_{TOTAL} (HIGH) is $R/3$
- R_{TOTAL} (MED) $= 3R/2$
  - increased by $\frac{3R}{2} / R/3 = \frac{9}{2}$
  - Power (MED) $= 1000 \frac{2}{9} = 222\ W$ (1 mark)
- R_{TOTAL} (LOW) $= 3R$
  - increased by $\frac{3R}{R/3} = 9$
  - Power (LOW) $= 1000 \cdot 1/9 = 111\ W$ (1 mark)
- not really a good set of values, linear scale is prefered.