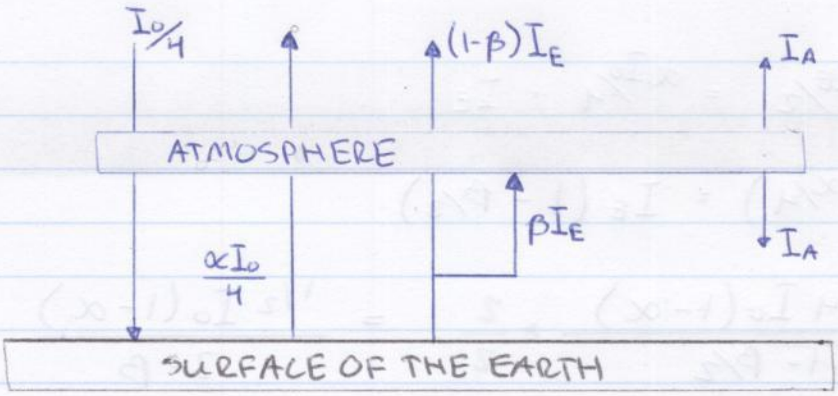
M2-1 2012-1

Solutions

PHYS 346



a) for each EM wave state its origin and wavelength.

$I_o/4$ av - solar radiation (0.5μm visible)

$\alpha I_o/4$ reflected radiation from earths surface (0.5μm visible)

I_E thermal radiation emitted from earth (10μm IR)

βI_E radiation absorbed by atmospheric gases

$(1-\beta)I_E$ the transmitted radiation

I_A thermal radiation emitted from atm. (10μm IR)

note: [text 6-6] has graph of wavelengths reaching the earth.

b) what happens to T_E as α and β are increased?

$I_E = \sigma T_E^4$ (blackbody radiator) need I_E ...

$\boxed{\text{EARTH} \quad I_{IN} = I_{OUT}}$

$I_o/4 + \boxed{I_A} = \alpha I_o/4 + I_E$

$\boxed{\text{ATM.} \quad I_{IN} = I_{OUT}}$

$\beta I_E = 2 I_A \longrightarrow \boxed{I_A} = \frac{1}{2}\beta I_E$

$$I_0/_4 + \beta I_E/_2 = \alpha I_0/_4 + I_E$$

$$I_0\left(\tfrac{1}{4} - \alpha/_4\right) = I_E\left(1 - \beta/_2\right)$$

$$I_E = \frac{\tfrac{1}{4} I_0 (1-\alpha)}{1 - \beta/_2} \times \frac{2}{2} = \frac{\tfrac{1}{2} I_0 (1-\alpha)}{2-\beta}$$

$$\boxed{T_E = \left(\frac{I_E}{\sigma}\right)^{1/4} = \sqrt[4]{\frac{\tfrac{1}{2} I_0 (1-\alpha)}{\sigma(2-\beta)}}}$$

- increasing α; reducing solar input to earth $\longrightarrow$ gets colder.
  - notice $(1-\alpha)$ decreases from $T_E(\alpha,\beta)$
- increasing β; reduce radiation into space $\longrightarrow$ earth warms up to restore equilibrium.
  - notice $(2-\beta)$ decreases $\therefore$ $1/_{2-\beta}$ increases T_E

M2-2

The Chevy volt is powered by Li-ion battery operating @ 300 V with capacity 45 A·hr

a) how much current does the battery supply at peak power output of 111 KW?

$$P = iV \longrightarrow \boxed{i = \frac{P}{V}} = \frac{111 \times 10^3 \text{ W}}{300 \text{ V}} = \boxed{370 \text{ A}}$$

b) how much energy can it store?

$$E = QV \longrightarrow E = 45 \cdot 3600 \cdot 300 = 4.86 \times 10^7 \text{ J}$$

OR $\boxed{E} = 4.86 \times 10^7 \text{ J} \times \frac{\text{KWh}}{3.6 \times 10^6 \text{ J}}$ $\boxed{= 13.5 \text{ Kwh}}$

OR $\boxed{48.6 \text{ MJ}}$

c) if the car requires 2.4 KWh to travel 10 Km, how far can it travel without re-charging?

$$\left[\frac{10 \text{ km}}{2.4 \text{ KWh}}\right] \times \underset{(\text{max})}{13.5 \text{ KWh}} \boxed{= 56 \text{ Km}}$$

d) if it cost 8¢ / KWh for energy, how much to travel 20 Km?

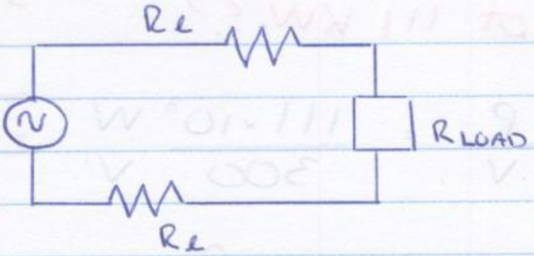
$$\frac{2.4 \text{ KWh}}{10 \text{ Km}} \times 20 \text{ Km} \times \frac{0.08 \text{ \$}}{\text{KWh}} \boxed{= \$ 0.38}$$

e) assuming a consumption of 5L / 100Km, what is the cost to run the "Volt" 20Km on gas?

$$\frac{5 \text{ L}}{100 \text{ km}} \times 20 \text{ Km} \times \frac{\$1.30}{\text{L}} \boxed{= \$ 1.30}$$

M2-3

A town is supplied by 150 kV [AC] by two lines with resistance 150 Ω each. The voltage source is initially delivering 12 MW of average power.



$V_s = 150$ kV a.c.
$R_\ell = 150\ \Omega$
$P_{AV} = 12$ MW
$R_{LOAD} = ?$

a) Find resistance accross the load.

$R_{TOTAL} = 2R_\ell + R_{LOAD}$

$P_{AV} = \frac{1}{2}\frac{V^2}{R_{TOTAL}} \longrightarrow R_{TOTAL} = \frac{V^2}{P_{AV}} \longrightarrow R_{LOAD} = \frac{V^2}{2P_{AV}} - 2R_\ell$

$\boxed{R_{LOAD} = \frac{(150\times10^3)^2}{12\times10^6} - 2(150) = 1575\ \Omega}$

b) Find voltage accross R_{LOAD}.

- one loop ∴ current is the same accross each "R"

$P = iV \longrightarrow i = \frac{P}{V} = \frac{12\times10^6}{150\times10^3} = 80$ A

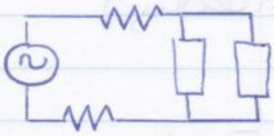
$\boxed{V_L = i_L R_L = (80)(1575) = 126\text{ kV}}$

c) how much power is lost along the transmission lines?

$\boxed{P_\ell = i_\ell^2 R_\ell = (80)^2(2\cdot150) = 1.92\text{ MW}}$

d) if a second, identical load, is placed in parallel with previous one, how much power must generator supply?

$R_T = R_{series} + R_{parallel}$



$R_{series} = 2 \cdot 150 = 300\,\Omega$

$R_{parallel} = \left(\frac{1}{1575} + \frac{1}{1575}\right)^{-1} = 788\,\Omega$

$R_T = 300 + 788 = 1088\,\Omega$

$$\boxed{P = \frac{V^2}{R} = \frac{(150 \times 10^3)^2}{1088} = 2.07\ MW}$$ average

e) if the transmission lines are made of copper, with diameter 2cm, what is their length?

$R = \frac{\rho l}{A}$

$\rho = 1.72 \times 10^{-8}$

l = length of $\underline{1}$ line

A = area = πr^2

$$l = \frac{AR}{\rho} = \frac{\pi (d/2)^2 \cdot 150}{1.72 \times 10^{-8}} = \frac{\pi (1/100)^2 \cdot 150}{1.72 \times 10^{-8}} = 2.7\,Mm$$

- each line is 2700 Km long!

M2-4

A step-up transformer boosts the voltage from 4 kV to 250 kV. If the power delivered into the transformer is 100 kW what is the primary current and secondary current?

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} \quad (100\% \text{ efficency})$$

$V_1 = 4\text{ kV}$
$V_2 = 250\text{ kV}$
$P_{IN} = 100\text{ kW}$

$P_{IN} = I_1 V_1$

$$\boxed{I_1} = \frac{P_{IN}}{V_1} = \frac{100\text{ kW}}{4\text{ kV}} = \boxed{25\text{ A}}$$

$$\boxed{I_2} = \frac{I_1 V_1}{V_2} = \frac{P_{IN}}{250\text{kV}} = \frac{100\text{ kW}}{250\text{ kV}} = \boxed{0.4\text{ A}}$$

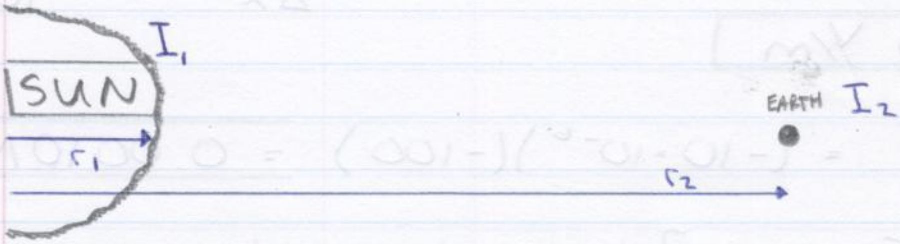
M2 - 5

The intensity of solar radiation @ earth surface is 1368 W/m², what is the surface temp of sun?

- sun is blackbody radiator

$I_{SUN} = \sigma T_{SUN}^4$, $\sigma = 5.67 \times 10^{-8}\ W m^{-2} K^{-2}$

$$\frac{I_{SUN}}{I_{EARTH}} = \left(\frac{\text{sun-earth}}{\text{sun radius}}\right)^2$$

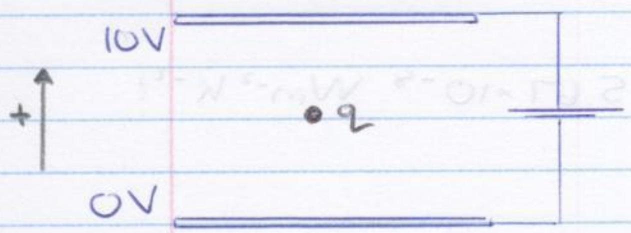


$$I_{SUN} = \left(\frac{1.5 \times 10^{11}}{6.96 \times 10^{8}}\right)^2 1368 = 6.317 \times 10^7\ W/m^2$$

$$\boxed{T_{SUN} = \left(\frac{I_{SUN}}{\sigma}\right)^{1/4} = \left(\frac{6.317 \times 10^7}{5.67 \times 10^{-8}}\right)^{1/4} = 5777°\ K}$$

M2 - 6

Two large parallel plates have a seperation of 10 cm. The upper plate is @ 10 V while the other is @ 0. What is the force on a $-10\,\mu C$ charge located between plates.



- electric field is uniform between parallel plates.

$$E = -\frac{\Delta V}{\Delta x} = \frac{-(10-0)}{10\text{cm}-0}$$

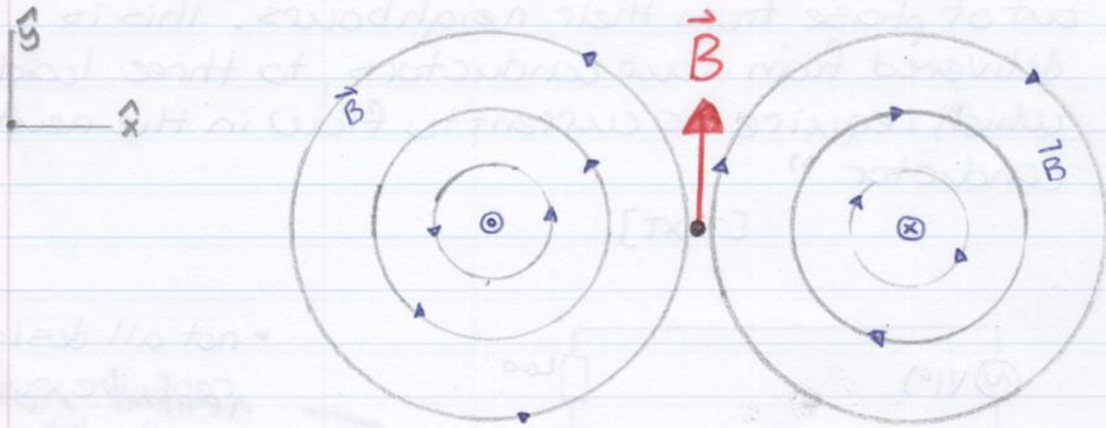
$$\boxed{E = -100\ V/m}$$

$$\boxed{\vec{F} = q\vec{E} = (-10\times10^{-6})(-100) = 0.0010\,N}$$

- force is [towards] the positive plate, in my diagram; up.

M2-7

A DC transmission line consists of two wires seperated by 2m; current is in the $\pm \hat{z}$. Each carries 100 A, what is magnetic field between the wires?



- magnetic field lines are concentric circles around current-carrying wires.

- between the wires, the B-field is pointing up [$\hat{y}$] for each ∴ total field is doubled!

$$B_{wire} = \frac{\mu_0 i}{2\pi r} = \frac{(4\pi \times 10^{-7})(100)}{2\pi(1)} = 2 \times 10^{-5}\ T$$

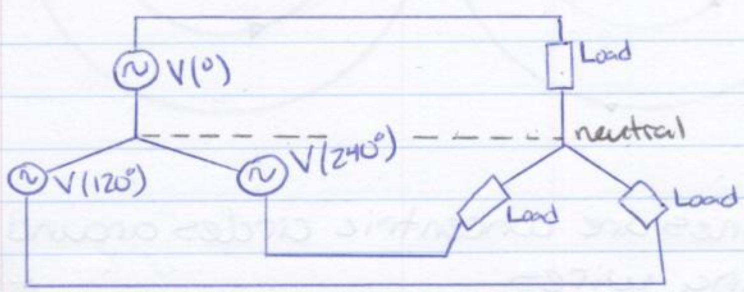
- we have TWO wires, and the point between them is affected by both.

$$\boxed{B_{TOTAL} = 2 B_{wire} = 4.0 \times 10^{-5}\ T\ [up]}$$

explain two advantages of 3 phase power, over single phase power transmission.

"Three sources, each produce 120V and are 120° out of phase from their neighbours. This is delivered from four conductors, to three loads which require no current to flow in the neutral conductor"

[TEXT]



• not all designs require a neutral wire.

- power transfer is constant.
- more transmitted power per conductor.
- Let the 3 sources be the windings of an armature on an electric motor. The change in phase can produce a rotating magnetic field inside the motor; it will rotate by itself! Called 3 phase induction motors.

M2 - 9

calculate the energy in eV of a typical x-ray phonon of 3nm. Why is this more likley to cause biological damage than 3 GHz phonon from cell phone?

- bio damage; breaking chemical bonds.
  C-C needs 3.7 eV
  C=C needs 6.2 eV
  C-H needs 4.3 eV

XRAY   (1eV = 1.602×10^{-19} J)

$E = hf$, $f = c/\lambda$

$$E = \frac{hc}{\lambda} = \frac{(6.62 \times 10^{-34})(3 \times 10^{8})}{3 \times 10^{-9}} = 6.62 \times 10^{-17} \text{ J}$$

$$\boxed{= 4. \times 10^{2} \text{ eV}}$$

PHONE

$$E = hf = (6.62 \times 10^{-34})(3 \times 10^{9}) = 1.98 \times 10^{-24} \text{ J}$$

$$\boxed{= 1 \times 10^{-5} \text{ eV}}$$

- the energy of a photon from cell phone is well below the amount needed to break simple organic bonds. The x-ray photon can easily break simple chemical bonds, even damage your DNA [journal physical chemistry, 2009]