Week 4 Homework

Physics 1B

January 31, 2007

1 Serway C17.2

The fundamental idea about a conductor is that charges in a conductor are free to move. This can allow them to position themselves such that the electric field they cause is opposite in direction but equal in magnitude within the conductor to any electric field externally caused. However, it takes time for them to move to these positions (the better the conductor, the less time it takes the charge carriers to move).

In a current-carrying wire, charges are being added to and taken away from a given portion of wire. So before the charges can position themselves to cancel the electric field, some are taken away and some are added to the portion of wire. The charge carriers aren't able to cancel the external electric field due to this problem.

2 Serway C17.3

The charge carriers don't fall because gravity is not the only force acting on them. Their masses are small, so gravitational effects are not as large the repulsion the electrons feel from the presence of the other free electrons.

Charges reside on the surface of a conductor with a net charge. If the conductor does not have a net charge, the charges remain uniformly distributed throughout the metal. If the charges in a neutral conductor went to the surface, they would leave a net positive charge inside the conductor.

3 Serway C17.8

If you only have one hand out, you have less opportunity to touch two parts of the circuit at once. If you touched two parts of the circuit at once, you would connect the circuit and current would flow through you. No fun!

4 Serway C17.13

Resistance is caused by collisions between charge carriers and other atoms. In the absence of these collisions, which slow down drift velocity, drift velocity would increase. This would cause current to increase since current and drift velocity are proportional (assuming n, q, and A are unchanged).

5 Serway P17.2

5.1 Concepts

The drift speed of electrons in a conductor is given by

$$I = nqv_dA \tag{1}$$

where I is the current through the conductor, n is the number of free charge carriers in the conductor, q is the charge of an individual charge carrier, v_d is the drift velocity of a charge carrier within the conductor (the effective velocity of the charge carriers, taking collisions into account), and A is the cross-sectional area of the conductor.

5.2 Application

$$\begin{aligned}
n &= \textit{number of free electrons}/m^3 && (2)\\
&= 7.50 \times 10^{28}/m^3 && (3)\\
A &= \textit{cross sectional area of conductor} && (4)\\
&= 4.00 \times 10^{-6} m^2 && (5)\\
I &= \textit{current through conductor} && (6)\\
&= 2.50A && (7)
\end{aligned}$$

Solving for v_d and substituting (looking only at one cubic meter of the conductor so that the number of charge carriers is the number given above, and noting that the charge carriers, either protons or electrons, have charge e),

$$\begin{aligned}
v_d &= \frac{I}{nqA} && (8)\\
&= \frac{2.50A}{(7.50 \times 10^{28})(1.60 \times 10^{-19}C)(4.00 \times 10^{-6}m^2)} && (9)\\
&= 5.2 \times 10^{-5} m/s && (10)
\end{aligned}$$

6 Serway P17.4

6.1 Concepts

Current is charge moved per unit time:

$$I = \frac{Q}{\Delta t} \tag{11}$$

The SI unit of current is an ampere (A), which is 1 C/s.

6.2 Application

We are given that the current of $60.0 \times 10^{-6} A$. Solving the above for Q,

$$\begin{aligned}
Q &= I\Delta t && (12)\\
&= (60.0 \times 10^{-6} C/s)(1s) && (13)\\
&= 60.0 \times 10^{-6} C && (14)\\
& && (15)
\end{aligned}$$

Knowing that each electron has charge $e = 1.60 \times 10^{-19} C$,

$$\begin{aligned}
n &= \textit{number of electrons hitting screen in 1 s} && (16)\\
&= (60.0 \times 10^{-6} C)(\frac{1 electrons}{1.60 \times 10^{-19} C}) && (17)\\
&= 3.75 \times 10^{14} electrons && (18)
\end{aligned}$$

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12. From table 17.1, the resistivity ρ of copper is $\rho = 1.7\times10^{-8}\ \Omega\cdot m$

- The density of copper is $\delta = 8.92\times10^{6}\ g/m^3$ so $1.0\ g$ of copper has volume $\frac{1.0\,g}{\delta} = 1.12\times10^{-7}\ m^3$

- A cylindrical wire has volume $\pi r^2 l$.

- $R = \rho\frac{l}{A}$ where A is the area of the cross-section (a circle of radius r)

$$l = \frac{AR}{\rho} = \frac{\pi r^2 R}{\rho}$$

- The volume of the wire must equal the volume of Cu we have if we are to use all the copper $\pi r^2 l = 1.12\times10^{-7}\ m^3$

$\therefore \pi r^2 = \frac{1.12\times10^{-7}\ m^3}{l}$

$$l^2 = \frac{(1.12\times10^{-7}\ m^3)R}{\rho} = \frac{(1.12\times10^{-7}\ m^3)(0.500\ \Omega)}{1.7\times10^{-8}\ \Omega m}$$

$\boxed{l = 1.8\ m}$

Using $\pi r^2 l = 1.12\times10^{-7}\ m^3$

$\boxed{r = 1.4\times10^{-4}\ m} \Rightarrow \boxed{d = 2.8\times10^{-4}\ m}$

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34. Assuming the transmission lines are made of materials which obey ohm's law,

$V = IR$.

- The total resistance R of a line 160 km long is $(0.31\ \Omega/km)(160\ km)$ $= 49.6\ \Omega$. Using this and the given current $I = 1000\ A$,

$$V = (1000\ A)(49.6\ \Omega).$$
$$= 4.96 \times 10^4\ V.$$

- This is the voltage drop across the 160 km transmission line.
- Power dissipated can be found in general from $P = IV$.

$$P = (1000\ A)(4.96 \times 10^4\ V)$$
$$\boxed{P = 5.0 \times 10^7\ W}$$

b) Power output at the station is (from $P = IV$)

$$P_{station} = (1000\ A)(700 \times 10^3\ V)$$
$$= 7 \times 10^8\ W$$

Therefore $\frac{5.0 \times 10^7}{7 \times 10^8} = \boxed{0.071}$ is the fraction of power lost.

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4. Total power used by alarm clocks

$P = \left(\frac{\text{power}}{\text{clock}}\right)\left(\frac{\text{clocks}}{\text{person}}\right)(\#\ \text{people})$

$= (2.50\ W/\text{clock})(1\ \text{clock/person})(270000000\ \text{people})$

$= 6.75 \times 10^8\ W$ (where $1 W = 1\ J/s$)

$= 6.75 \times 10^8\ \frac{J}{s} \times \frac{3600\ s}{1\ h}$

$= 2.43 \times 10^{12}\ J/h$

$= 2.43 \cdot 10^6\ MJ/h$

In one hour, we would need $2.43 \cdot 10^6$ MJ to run our clocks. Given that coal releases 330 MJ/kg, we need

$\frac{2.43 \cdot 10^6\ MJ}{330\ MJ/kg} = 7.4 \cdot 10^4\ kg$ coal (per hour).

This is how much we would need if we could use all the energy from burning coal. However, since our power plants are 25% efficient ($\frac{1}{4}$), we must burn four times this amount:

$2.95 \cdot 10^5\ kg/h = \boxed{295\ \text{metric tons/hr}}$ (1000 kg = 1 metric ton)

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61. Given the resistivity ρ, length l, and inner and outer radii, from which we can find the cross sectional area A, we can calculate the resistance R.

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

$$A = \pi r_{out}^2 - \pi r_{in}^2$$

$\rho = 3.5 \times 10^5\ \Omega \cdot m$

$r_{out} = 1.2\ cm = 1.2 \times 10^{-2}\ m$

$r_{in} = 0.50\ cm = 5.0 \times 10^{-3}\ m$

$l = 4.0\ cm = 4.0 \times 10^{-2}\ m$

$$R = \frac{(3.5 \times 10^5\ \Omega \cdot m)(4.0 \times 10^{-2}\ m)}{\pi \left[(1.2 \times 10^{-2}\ m)^2 - (5.0 \times 10^{-3}\ m)^2 \right]}$$

$$\boxed{R = 3.7 \times 10^7\ \Omega}$$

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62. Equation 17.3 is ohm's law, $\Delta V = IR$

a) The graph is approx linear between $-1.5\ V \le V \le 0\ V$.

$$R = \frac{\Delta V}{I} = \frac{[0-(-1.5)]\,V}{[0-(-2.5\times10^{-5})]\,A}$$

$$= 6.0\times10^{4}\ \Omega$$

→ Note that the graph's scaling changes below the V axis.

Between $0\ V \le V \le 0.25\ V$

$$R = \frac{[0.25-0]\,V}{[0.005-0]\,A}$$

$$= 50\ \Omega$$

Between $0.25\ V \le V \le 0.50\ V$

$$R = \frac{[0.50-0.25]\,V}{[0.02-0.005]\,A}$$

$$= 17\ \Omega$$

Between $0.5\ V \le V \le 0.75\ V$

$$R = \frac{[0.75-0.5]\,V}{[0.10-0.02]\,A}$$

$$= 3.1\ \Omega$$

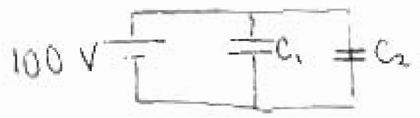
b) The diode's resistance is very large if you try to run a negative current through it, but the resistance becomes very small for large positive currents.

Week 4 Homework

Ch. 16 #44

$C_1 = 25.0\ \mu F$

$C_2 = 5.00\ \mu F$



a) Find equivalent capacitance

$C_{eq} = C_1 + C_2 = 30.0\ \mu F$

Using $PE = \frac{1}{2} C (\Delta V)^2$

$= \frac{1}{2}(30.0 \times 10^{-6}\ F)(100\ V)^2$

$\boxed{PE = 0.15\ J}$

b) Find V necessary for $PE = 0.15\ J$ in this configuration

Find C_{eq}: $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow C_{eq} = 4.17\ \mu F$

$PE = \frac{1}{2} C_{eq} (\Delta V)^2$

$(\Delta V) = \sqrt{\frac{2 PE}{C_{eq}}}$

$= \sqrt{\frac{2(0.15\ J)}{(4.17 \times 10^{-6}\ \mu F)}}$

$\boxed{\Delta V = 270\ V}$

Since equivalent capacitance is less than part (a), more potential difference required for same potential energy.