HW 4 Solutions

Ch 17

P32) Q = CV, so V = Q/C=16.5×10^{-8} C/9500×10^{-12} F = 17 V.

P39) E = V/d. Know d, but need V. Use Q = CV so V = Q/C = 72×10^{-6} C/0.80×10^{-6} F = 90 V. Thus E = 90 V/0.002 m = 45,000 V /m.

P46) PE = $1/2CV^2$ = 0.5 · 2200×10^{-12} F · $(650\ V)^2$ = 0.00046 J.

P48) Energy in field = $\frac{1}{2}\varepsilon_o E^2 V$,
where V is the volume = 0.08 m × 0.08 m × 0.0015 m = $9.6\times10^{-6}m^3$.

$$E = \frac{V}{d} = \frac{\frac{Q}{C}}{d} = \frac{Q}{Cd} = \frac{Q}{\frac{\varepsilon_o A}{d}d} = \frac{Q}{\varepsilon_o A} = \frac{42\times10^{-9}C}{8.85\times10^{-12}\frac{C^2}{N\cdot m^2}\cdot(0.08m)^2} = 7.4\times10^5\frac{N}{C}$$

$$\text{Energy} = \frac{1}{2}\left(8.85\times10^{-12}\frac{C^2}{N\cdot m^2}\right)\left(7.4\times10^5\frac{N}{C}\right)^2 9.6\times10^{-6}m^3 = 2.3\times10^{-5}\,joule$$

Or you could just use $PE = \frac{1}{2}\frac{Q}{C^2}$ along with $C = \frac{\varepsilon_o A}{d}$

Ch. 18

Q10) When a light bulb burns out the filament breaks so that there is no longer a complete conducting path.

Q12) To answer this question you have to assume that the light bulbs are all designed to operate at the same voltage, presumably 120 V. In that case, the one with the higher power will "draw" more current (P = IV, so I = P/V) and thus have a smaller resistance (R = V/I).

P7) I = V/R = 240 V/9.6 Ω = 25 Amps. Q = I · t = 25 coulombs/s · 50 min · (60 s/1 min) = 75000 C.

P8) I = V/R = 9.0 V/1.6 Ω =5.6 amps = 5.6 C/s. Q = I · t = 5.6 C/s · 60 s = 337.5 C

340 C · (1 electron/1.6×10^{-19} C) = 2.1×10^{21} electrons.

P9) The resistance between the bird's feet is 2.5×10^{-5} Ω/m · 0.040 m = 1.0×10^{-6} Ω. The potential difference between the bird's feet is V = IR = 2800 A · 1.0×10^{-6} Ω = 2.8×10^{-3} V.

Thus the bird does not have to worry about getting electrocuted. Now on the other hand the bird better not get too close to that pole in the picture because it would be at ground potential while the wire is probably at thousands of volts relative to ground. That is why there is the big insulator between the pole and the wire. If the bird touched the pole while sitting on the wire then that would be it for the bird.

P13) $R = \dfrac{\rho l}{A} = \dfrac{(1.68\times 10^{-8}\Omega\cdot m)\cdot(3.5m)}{\pi\left(\dfrac{.0015m}{2}\right)^2} = 0.033\Omega$

P20) $R = \dfrac{\rho l}{A} = \dfrac{(1.68\times 10^{-8}\Omega\cdot m)\cdot(26m)}{\pi\left(\dfrac{.001628m}{2}\right)^2} = 0.21\Omega$; V=IR=(12 amps)(.21Ω)=2.5 V. In this case the voltage drop is pretty small, which is a good thing. If one uses a really long extension cord, for example for an electric lawnmower, the voltage drop could get big enough that it would actually reduce the power of the lawnmower.

P28) $P = IV = V^2/R$. Solving for V gives $V = (PR)^{0.5} = (0.25\text{ watts}\cdot 2700\text{ ohms})^{0.5} = 26$ V. If the voltage exceeds this value, more heat will be produced in the resistor than the resistor can get rid of, and the resistor will overheat and be ruined. Actually resistors are usually rated pretty conservatively so going a little over 26 V would probably not damage the resistor.

P30) P = IV so I = P/V = 110 W/115 V = 0.96 amps

V = IR so R = V/I = 115 V/0.96 amps = 120 ohms.

P34) 25 W = 0.025 kW. 1 year = 365 days = 365 x 24 hours = 8760 hours.

Energy used = P x t = 0.025 kW x 8760 h = 219 kWh. At 9.5 cents per kWh the cost is 219 x 9.5 = 2080 cents = $20.80.

AP1) a) $Q = CV = (47\times10^{-12}\text{ F})\cdot(15\text{ V}) = 7.1\times10^{-10}$ C

b) $PE = QV/2 = (7.1\times10^{-10}\text{ C})\cdot(15\text{ V})/2 = 5.3\times10^{-9}$ J

c) $C = K\varepsilon_o A/d$ so $d = K\varepsilon_o A/C = (3.7)\cdot(8.85\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}^2)\cdot(0.000718\text{ m}^2)/(47\text{x}10^{-12}\text{F}) =$ 0.00050 m = 0.5 mm. Amazingly these units do work out. Putting in 1 F = 1 C/V and 1V = 1J/C = 1N·m/C gives $(\text{C}^2/\text{N}\cdot\text{m}^2)\cdot(\text{m}^2)/(\text{C}^2/\text{N}\cdot\text{m}) = \text{m}$

AP2) a) $P = I_{rms}\cdot V_{rms}$ so I_{rms} = 1500 W/120V = 12.5 A

b) $I_{peak} = \sqrt{2}\, I_{rms} = 17.7$ A

c) Energy = P · t = (1.5 kW) · (3/60 h) · ($0.15/kWh) = $0.011 or 1.1 cents.

AP3) a) Make a Gaussian surface centered at the center of the sphere that has a radius greater than R. By symmetry, the electric field is everywhere perpendicular to the surface of the sphere. Thus the flux through the surface is just E · A where $A = 4\pi r^2$. By Gauss's Law the flux equals

$Q_{enclosed}/\varepsilon_o$. But the charge enclosed is just Q, the charge on the sphere. Thus $E = Q/4\pi\varepsilon_o r^2$, which is the same as the expression for a point charge located at the center of the sphere.

b) Since the field outside the sphere is exactly the same as that of a point charge, the work required to move a positive test charge from infinity to some distance r must be the same as it would be for a point charge. But that means the potential must be the same too. Therefore, $V = kQ/r$ outside the sphere, and at the surface the potential is kQ/R. This is a little subtle, because I am saying that the surface is outside the sphere, but one can imagine getting infinitely close to the surface and the potential must then approach kQ/R.

c) The electric field inside the sphere is 0 because the sphere is a conductor. The potential inside the sphere must be constant because by $\Delta V = E \cdot d$, if E is 0 then $\Delta V = 0$, which means that V is constant. But we know that $V = kQ/R$ at the surface of the sphere, so it must also have this value on the inside of the sphere.

Suppose that R = 9 cm, and $Q = 1 \times 10^{-10}$ C. Then the potential vs. distance from the center of the sphere would look as shown below. This graph should seem reasonable. It shows a constant potential inside the sphere, corresponding to zero electric field, and then a potential which decreases in the exact same way as the potential of a point charge located at the center of the sphere.