Electric current and resistance

$I = \frac{dQ}{dt} = \rho_q \frac{d}{dt} \; Adx \;$;

$I = \vec{j} \cdot \vec{A} = \underbrace{n_V q}_{\rho_q} \underbrace{A \frac{dx}{dt}}_{\frac{dV}{dt}} = \frac{\text{number of charges}}{\text{volume}}$ elementary charge $\cdot$ cross-section=$\rho_q A \text{v}_\text{d}$

$I = n_V q v_d A$ where v_d is the drift velocity of the charges due to $\vec{\text{E}}$

1. (1) In a particular cathode ray tube, the measured current is 30.0μA. How many electrons strike the tube screen in 40.0s? (7.50E15 electrons.)

2. (3) Suppose that the current in a conductor decreases exponentially with time according to $I(t) = I_0 e^{-t/\tau}$ where I_0 is the initial current and τ is the time constant. Consider a fixed observation point within the conductor.
a) How much charge passes this point between t=0 and t= τ ? b) How much charge passes this point between t=0 and t=10 τ ? c) What is the total charge passing?
a) 0.632 b)0.99995;c)1 (all in units of $\text{I}_0 \tau$)

3. In the Bohr model of the H-atom, an electron in the lowest energy state follows a circular path with radius 0.529E-10m around the central proton. a) Show that the speed of the electron is 2.19E6m/s. b) What is the effective current associated with this orbiting electron? (1.05mA)
4. (8) A circular conductor with varying cross-section carries a current of 5.00 A. If the radius of the cross-section at location (1) is 0.400cm, a) find the magnitude of the current density passing through A_1.b) If the radius at a location (2) is four times the radius at (1) what is the current density at (2)?
a) 10A/cm^2, b) 1/16 of j_1

5. (6) An electric current is given by $I(t) = 100 \sin(120\pi t)$ in SI units. What is the total charge carried by the current from t=0 to t=1/240 s? (0.265C)

6. (10) An aluminum wire having a cross-sectional area of 4.00E-6m^2 carries a current of 5.00A. Find the drift speed of the electrons in the wire. The density of aluminum is 2.70g/cm^3. Assume that one conduction electron is supplied by each atom. (0.130mm/s)

Resistance:

$\vec{j} = \sigma \vec{E} = conductivity \cdot \vec{E}$; Ohm's law $\text{R}=\rho_\Omega \frac{l}{A}$ $\Delta\text{V}=\text{RI}$

$\vec{E} = \rho \vec{j} = resistivity \cdot \vec{E}$

7. (12) A light bulb has a resistance of 240 when operating at 120V across it. What is the current in the light bulb? (500mA)

8. (13) Suppose that you wish to fabricate a uniform wire out of 1.00g of copper. If the wire is to have a resistance of 0.500Ω ,and if all of the copper is to be used, what will be the a) length and b) diameter of the wire.

a) 1.82m b) 280μm

9. (15) A current density of 6.00E-13A/m^2 exists in the atmosphere at a location where the electric field is 100V/m. Calculate the electrical conductivity of the atmosphere at that location. (6.00E-15(Ωm)$^{-1}$)

Model of electric conduction:

$$j = \sigma E = n_V q \mathrm{v_d} = \frac{nq^2 E}{m}\tau$$

$$I = jA = n_V q \mathrm{v_d} A \Rightarrow \mathrm{v_d} = \frac{I}{n_V qA}$$

10. (17) If the magnitude of the drift velocity of free electrons in a copper wire is 7.84E-4m/s, what is the electric field in the conductor? (0.181 V/m)

Resistance and temperature:

11. (18) A certain light bulb has a tungsten filament with a resistance of 19.0Ω when cold and 140 Ω when hot. Assume a) that the resistivity of tungsten varies linearly with temperature even over the large temperature range involved here, and find the temperature of the hot filament. a) 1.44E3°C

b) Assume that the resistivity varies exponentially $\alpha = \frac{1}{\rho}\frac{d\rho}{dT} \Rightarrow \rho = \rho_0 e^{\alpha\,T-T_0}$ and find the temperature of the hot filament. α=4.50E-3/C° at 20°C. (See problem 43 b) 463°C

12. (19) An aluminum wire with a diameter of 0.100 mm has a uniform electric field of 0.200V/m imposed along its entire length. The temperature of the wire is 50.0°C. Assume one free electron per atom

a) Determine the resistivity (α=3.9E-3/C° at 20°C; ρ=2.82E-8Ωm)
b) What is the current density in the wire?
c)What is the total current in the wire?
d) What is the drift speed of the electrons?
e) What potential difference must exist between the ends of the 2.00m long wire to produce the static electric field?
a) 3.15E-8 Ωm; b) 6.35E6 A/m^2; c)49.9mA; d) 659μm/s; e) 0.400V

Electric power: RI^2

13. What is the required resistance of an immersion heater that increases the temperature of 1.50kg of water from 10.0 to 50.0°C in 10.0 min while operating at 110V? (28.9Ω)
14. (30) A coil of Nichrome wire is 25.0m long (ρ=1.50E-6Ωm at 20°C) The wire has a diameter of 0.400mm and is at 20.0°C. If it carries a current of 0.500A, what are a) the magnitude of the electric field in the wire, b) the power delivered to it?. c)What power will coil of part a) actually deliver if the wire is heated to 340°C and the voltage across the wire is maintained constant? a) 5.97V/m b) 74.6W c) 66.1W.
15. (43) Prove that the more general definition of temperature dependence leads to the exponential expression below:

$$\alpha = \frac{1}{\rho}\frac{d\rho}{dT} \Rightarrow \rho = \rho_0 e^{\alpha\,T-T_0}$$