P1-1 If $\vec{j} = \sigma \vec{E}$ then 7.6 gives

a) $$\sigma = \frac{(nf)q^2\lambda}{2mv} = \frac{(nf)q^2\tau}{2m}$$

$$\tau = \frac{2m}{(nf)q^2\rho}$$

b) $q = 1.6\times10^{-19}$ C $\quad m = 9.1\times10^{-31}$ kg

$nf = 8.5\times10^{28}$ m^{-3} $\quad \rho = 1.68\times10^{-8}$ Ω-m

$\tau = 4.9\times10^{-14}$ s

c) $\frac{3}{2}kT = \frac{1}{2}mv^2 \qquad v^2 = \frac{3kT}{m} \qquad v = \sqrt{\frac{3kT}{m}}$

$k = 1.38\times10^{-23}$ J/K

$T = 300$ K

so $v = 1.17\times10^{5}$ m/s

d) $\lambda = v\tau = 5.75\times10^{-9}$ m

e) Take $v = 3\times10^{8}$ m/s $/200 = 1.5\times10^{6}$ m/s

$\lambda = 7.38\times10^{-8}$

f The lattice constant $a = 3.6$ Å $= 3.6\times10^{-10}$ m

(In fcc, nearest neighbors are at $a/\sqrt{2} =$

so λ_d is 23 nn distances

λ_e is 280 nn distances

2a) Eq 5.29 is continuity equation: $-\frac{\partial \rho}{\partial t} = \nabla \cdot \vec{J}$

Now use Ohm's law $\vec{J} = \sigma \vec{E}$. Then

$$\frac{\partial \rho}{\partial t} = -\sigma \nabla \cdot \vec{E}$$

Use Gauss' law $\nabla \cdot \vec{D} = \rho$ $\quad \vec{D} = \epsilon \vec{E}$

Hence $\epsilon \nabla \cdot \vec{E} = \rho$ $\quad$ Note $\epsilon = \epsilon_r \epsilon_0$!

$$\frac{\partial \rho}{\partial t} = -\sigma \frac{\rho}{\epsilon}$$

Solution $\rho = \rho_0 e^{-t/\tau}$

b) $-\frac{1}{\tau}\rho = -\frac{\sigma}{\epsilon}\rho$ $\quad$ substituting

charge density

$\tau = \frac{\epsilon}{\sigma} = \epsilon \rho$ resistivity

or $\tau = \epsilon_r \epsilon_0 \rho$

c) Copper $\quad \tau = 1.49 \times 10^{-19}$ s

d) Silicon $\quad \tau = 2.59 \times 10^{-7}$ s

e) Teflon $\quad \tau = 2.66 \times 10^{+11}$ s

3. a) If $\rho = 0$, $\sigma = \infty$ Ohms law becomes
$\vec{J} = \sigma \vec{E}$ or $\rho \vec{J} = \vec{E}$.

Hence $\vec{E} = 0$

b) Faraday's law: $\nabla \times E = -\frac{\partial \vec{B}}{\partial t}$. But $\vec{E} = 0$.
Hence $\frac{\partial \vec{B}}{\partial t} = 0$, B is constant

c) In integral form $\oint_{loop} \vec{E} \cdot d\ell = -\frac{\partial \Phi}{\partial t}$

But $\vec{E} = 0$. Hence $\frac{\partial \Phi}{\partial t} = 0$. Φ = constant

4.a) The induced EMF is $\mathcal{E} = vBh$ and also $\mathcal{E} = -L\frac{dI}{dt}$. So $vBh = -L\frac{dI}{dt}$

The loop experiences a force (Lorentz force) from the moving charges that make up the current

$$F = IhB$$

Newton

$$F = ma = m\frac{dv}{dt}$$

Equate

$$\frac{dv}{dt} = \frac{IhB}{m}$$

so

$$\frac{d^2v}{dt^2} = \frac{hB}{m}\frac{dI}{dt}$$

$$= -\frac{hB}{m}\frac{vBh}{L}$$

or

$$\frac{d^2v}{dt^2} = -\frac{h^2B^2}{mL}v \equiv -\omega_0^2 v$$

Soln:

$$v(t) = v_0 \sin \omega_0 t$$

$$\omega_0 = \frac{hB}{\sqrt{mL}}$$