Q1) A wire whose diameter is 0.20 cm must carry a 20 A current. The maximum power dissipation along the wire is 4 W/m.

Which materials in the Table can be used for this application?

Electrical conductivities of some metals and nonmetals at room temperature

Metals and alloys	$\sigma\ (\Omega \cdot m)^{-1}$	Nonmetals	$\sigma\ (\Omega \cdot m)^{-1}$
Silver	6.3×10^7	Graphite	10^5 (average)
Copper, commercial purity	5.8×10^7	Germanium	2.2
Gold	4.2×10^7	Silicon	4.3×10^{-4}
Aluminum, commercial purity	3.4×10^7	Polyethylene	10^{-14}
		Polystyrene	10^{-14}
		Diamond	10^{-14}

$P = 4\ W\ for\ 1\ m\ (l = 1\ m)$

$P \leq 4\ W$

$P = i.V = i^2R$

$$P = i^2\rho\frac{l}{A} = i^2\frac{l}{\sigma A}$$

$\frac{i^2 l}{\sigma A} \leq 4\ W \quad \rightarrow \quad \sigma \geq \frac{i^2 l}{4A}$

$$\sigma \geq \frac{20^2(1)}{4\pi(\frac{(0.2x10)^{-2}}{2})^2}$$

$\sigma \geq 3.18x10^7\ (ohm.m)^{-1}$

Candidate materials are **aluminum, gold, copper and silver**

Q2) If a copper wire of commercial purity is to conduct 10 A of current with a maximum voltage drop of 0.4 V/m, what must be its minimum diameter? (σ for copper is $5.85x10^7\ (\Omega.m)^{-1}$)

$\Delta V\ per\ 1\ m\ wire\ is\ 0.4\frac{v}{m} \quad \rightarrow \quad l = 1\ m\ and\ \Delta V \leq 0.4\ V$

$V = iR \quad \rightarrow \quad V = i\frac{\rho l}{A} \leq 0.4\ V \rightarrow \frac{il}{\sigma A} \leq 0.4\ V \quad \rightarrow \quad \frac{il}{\sigma\pi\left(\frac{d}{2}\right)^2} \leq 0.4\ V$

$(\frac{d}{2})^2 \geq \frac{il}{\sigma\pi(0.4)} \quad \rightarrow \quad (\frac{d}{2})^2 \geq \frac{(10)(1)}{5.85x10^7(\pi)(0.4)} \quad \rightarrow d \ \geq\ 7.37x10^{-4}\ m$

Q3) A simple parallel-plate capacitor is to be made to store $5.0x10^{-6}$ C at a potential of 8000 V. The seperation distance between the plates is to be 0.3 mm. Calculate the area that the plates must have if dielectric between the plates is (a) a vacuum (κ =1) and (b) alümina (κ =9) (ε_o = $8.85x10^{-12}$ F/m).

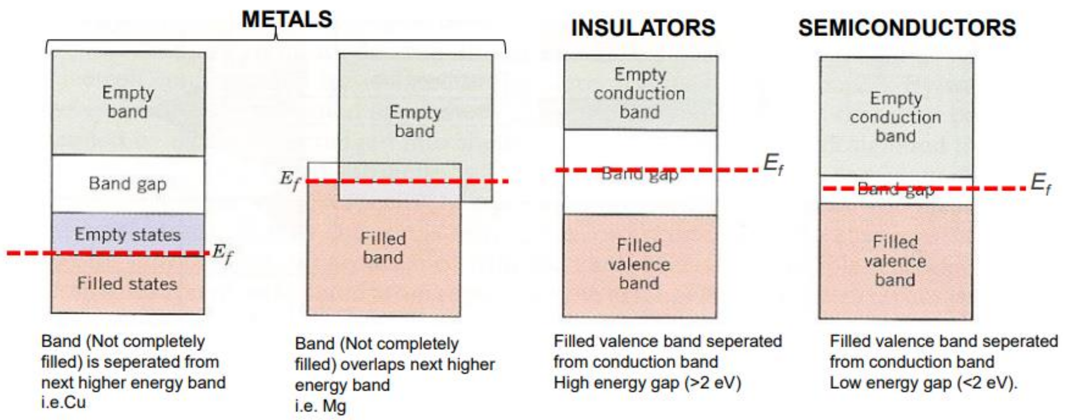
$$q = CV \rightarrow C = \frac{q}{V} = \frac{5.0x10^{-6}\,C}{8000\,V} = 6.25x10^{-10}\,F$$

$$C = K\varepsilon_o\frac{A}{d} \rightarrow A = \frac{Cd}{\varepsilon_o K} \rightarrow A = 0.021\,m^2\,(If\ K = 1) \quad A = 2.35x10^{-3}\,m^2\,(If\ K = 9)$$

Q4) A simple plate capacitor stores $6.5x10^{-5}$ C at a potential of 12.000 V. If the area of the plates is $3x10^{-5}$ m^2 and the distance between the plates is 0.18 mm, what must be the dielectric constant of the material between plates?

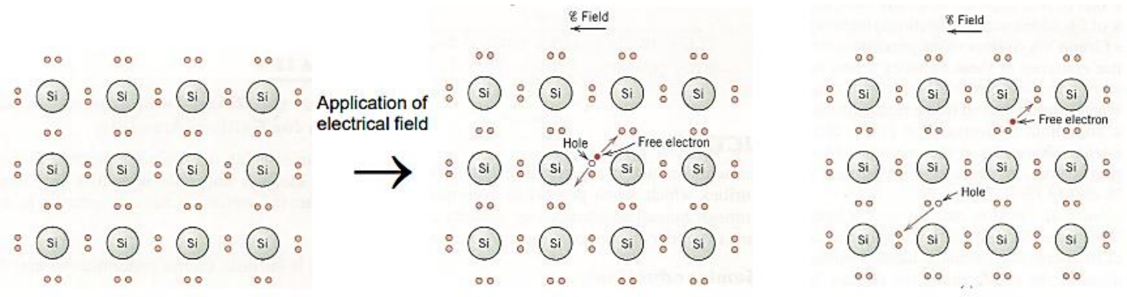
OR which of the following materials will be the candidate materialas?

Q5) Explain the electrical conductivity of metals, insulators and semiconductors by use of proper energy band diagrams.



Q6) How conductivity occurs in intrinsic and extrinsic semicnductor materials (both n- and p-type semiconductors). Explain using schematic drawings? Also compare conductivities by use of conductivity equation.

Intrinsic semiconductor



time= t1 time= t2

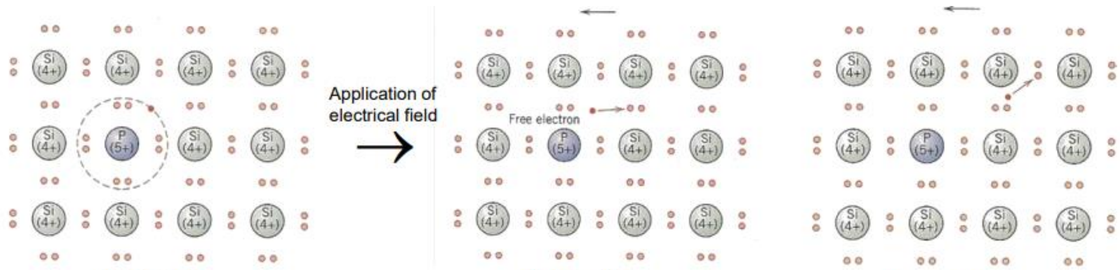
$$\sigma = n|e|\mu_e + p|e|\mu_h$$

n: number of electrons/m^3
p: number of protons/m^3
μ_e: electron mobility
μ_h: hole mobility
|e|: Charge of electron/proton1.6x10^{-19} C

- **For an intrinsic semiconductor n=p**

$$\sigma = n|e|(\mu_e+\mu_h)$$

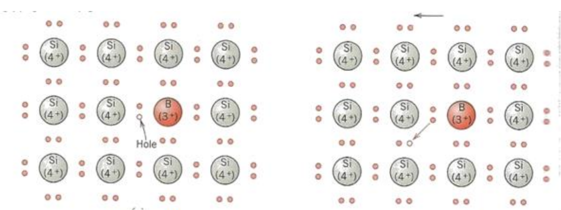
n-type semiconductor



time= t0 time= t1 time= t2

$$n \gg p \rightarrow \sigma \approx n|e|\mu_e$$

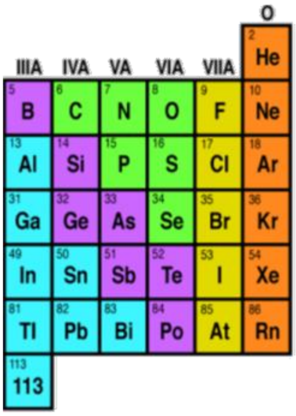
p-type semiconductor



time= t0 time= t1

p$\gg n \rightarrow \sigma \approx p|e|\mu_e$

Q7) A semiconductor is made by adding boron to silicon to give an electrical resistivity of 1.90 Ω.m. Calculate the concentration of charge carriers per cubic meter in the material. Assume $\mu_s = 0.048 \frac{m^2}{V.s}$



$\rho = 1.90\ ohm.m \quad \rightarrow \quad \sigma = \frac{1}{\rho} \cong 0.53\ (ohm.m)^{-1}$

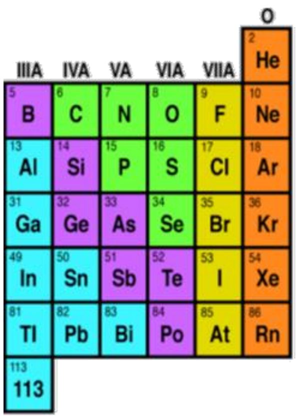
$\sigma = p|e|\mu_e \ \rightarrow \ 0.53 = p|-1.6x10^{-19}|0.048$

$p = \ 6.9x10^{19}\ holes/m^3$

Q8) Germanium doped with 10^{24} m^{-3} Boron atoms is an extrinsic semiconductor at room temperature and virtually all the B atoms may be thought of as being ionized (i.e. one charge carrier exists for each B atom).

a) Is this material is n- or p-type?
b) Calculate the room temperature electrical resistivity of this material.
c) What would be the resistivity at the same temperature when the same amount of P (Phouphorous) atomsa re added instead of B?

(a)



Boron is in 3A group so that addition of each B atom creates one hole in the structure. Therefore, resultant semiconductor is p-type.

(b)

$$\sigma = p|e|\mu_p \quad \rightarrow \quad At\ 298\ K, hole\ mobility = 0.01\frac{m^2}{Vs} \quad \rightarrow \quad \sigma = 1600\ (ohm.m)^{-1}$$

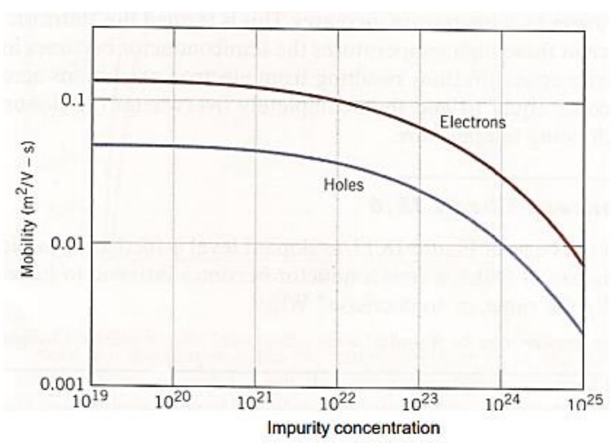
$$\rho = \frac{1}{\sigma} = \frac{1}{1600} = 6.25x10^{-4}\ ohm.m$$

(c)

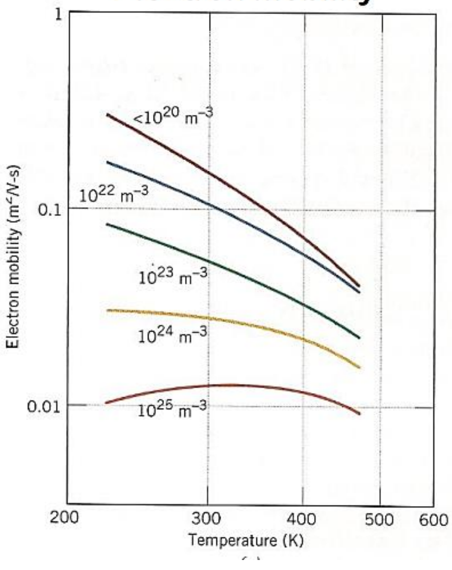
P is in 5A group so that it results in n-type semiconductor. In this case electrons are charge carrriers. From the graph, at room temperature mobility of electrons is 0.03 m^2/V.s.

$$\sigma = 10^{24}|1.6x10^{-19}|(0.03)$$

$$\sigma = 4800\ (ohm.m)^{-1} \quad \rightarrow \ \rho = \frac{1}{\sigma} = \frac{1}{4800} = 2.08x10^{-4}\ \text{ohm.m}$$



Electron mobility



Hole mobility