With a silicon wafer at -60°C in the Hubble telescope

a)Calculate the intrinsic conductivity of silicon from first principles. N.b. see the data given below and the attached periodic table.
b)Calculate the extrinsic conductivity for 0.001 ppm aluminum doped silicon at -60°C. Ea=0.057 eV (taken from p. 136 of your book)
c)Calculate the extrinsic conductivity for 0.001 ppm phosphorous doped silicon at -60°C.

DATA:
Silicon, Band Gap energy, Eg=1.21 eV, effective mass of the electron, m*e/me=0.43, effective mass of hole, m*h/me=0.54, electron mobility, ìe= 0.14 m2/(V sec), hole mobility, ìh=0.05 m2/(V sec), index of refraction n=3.42.

k_B ?? 1.38?10$^{?\,23}$?$\frac{\text{joule}}{\text{K}}$

Nav ?? 6.023?10^{23}?$\frac{1}{\text{mole}}$

m_e ?? 9.11?10$^{?\,31}$?kg

e ?? 1.6?10$^{?\,19}$?coul

nm ?? 10$^{?\,9}$?m

eV ?? 1?volt?e

h ?? 6.63?10$^{?\,34}$?joule?sec

c ?? 3.00?10^{8}?$\frac{\text{m}}{\text{sec}}$

?$_o$?? 8.85?10$^{?\,12}$?$\frac{\text{farad}}{\text{m}}$

E_g ?? 1.21?eV

m'$_e$?? 0.43?m_e

m'$_h$?? 0.54?m_e

?$_e$?? 0.14?$\frac{\text{m}^2}{\text{volt?sec}}$

?$_h$?? 0.05?$\frac{\text{m}^2}{\text{volt?sec}}$

T ?? (?60 ? 273.15)?K

?Si ?? 2.34?$\frac{\text{gm}}{\text{cm}^3}$ MwSi ?? 28?$\frac{\text{gm}}{\text{mole}}$

Electrons_Si ?? 4

Index ?? 3.42

? ?? Index^2

C_o ?? Electrons_Si?Nav?$\frac{\text{?Si}}{\text{MwSi}}$

C_o ? 2.013 ? 10^{29} $\frac{1}{\text{m}^3}$

C' ?? 2??$\left(\frac{\text{m'}_e\text{?}k_B\text{?T}}{2\text{???}\left(\frac{\text{h}}{2\text{??}}\right)^2}\right)^{\frac{3}{2}}$

C' ? 4.228 ? 10^{24} $\frac{1}{\text{m}^3}$

n_{e_i} ?? C'?exp?$\left(\frac{\text{?}E_g}{2\text{?}k_B\text{?T}}\right)$

n_{e_i} ? 2.158 ? 10^{10} $\frac{1}{\text{m}^3}$

n_{h_i} ?? n_{e_i}

?$_i$?? n_{e_i}??$_e$?e ? n_{h_i}??$_h$?e

?$_i$? 6.56 ? 10$^{?\,12}$ $\frac{1}{\text{cm?ohm}}$

Answer to part A

Intrinsic Fermi Energy

E_F ?? $\frac{\left(\frac{\text{h}}{2\text{??}}\right)^2}{2\text{?}m_e}$??3??^{2}?C'?$^{\frac{2}{3}}$

E_F ? 9.557 ? 10$^{?\,3}$ eV

$E_F ?? \frac{E_g}{2} ? \frac{3}{4} ?k_B ?T ?ln ? \frac{m'_h}{m'_e} ?$

$E_F ? 0.608\,eV$

Extrinsic Fermi Energy for n-type Si

$E_d ?? \frac{? m'_e ?e^4}{8 ? ? ? ?_o ?^2 ?h^2}$

$E_d ? ?0.043\,eV$

$E_F ?? E_g ? \frac{E_d}{2}$

$E_F ? 1.189\,eV$

$\frac{E_g}{2} ? 0.605\,eV$

$? E_g ? E_F ? ?0.021\,eV$

$N_d ?? 0.001 ?10^{? 6} ?C_o$

$n_e ?? N_d ?exp ? \frac{? ? E_g ? E_F ?}{k_B ?T} ?$

$n_{e\_e} ?? n_e ? n_{e\_i}$

$n_{e\_e} ? 6.323 ? 10^{19} \frac{1}{m^3}$

$n_{h\_e} ?? \frac{n_{e\_i} ?n_{h\_i}}{n_{e\_e}}$

$n_{h\_e} ? 7.363 \frac{1}{m^3}$

$n_e ? 6.323 ? 10^{19} \frac{1}{m^3}$

$?_e ?? n_{e\_e} ?? _e ?e ? n_{h\_e} ?? _h ?e$

$?_e ? 0.014 \frac{1}{cm ?ohm}$

Answer to Part C

$E_a := 0.057 \cdot eV$ see page 136

$E_F := \frac{E_a}{2}$

$n_{h\_e} := C' \cdot \exp\left(\frac{-E_F}{k_B \cdot T}\right)$ $n_{h\_e} = 8.971 \times 10^{23} \frac{1}{m^3}$

$n_{e\_e} := \frac{n_{e\_i} \cdot n_{h\_i}}{n_{h\_e}}$ $n_{e\_e} = 5.19 \times 10^{-4} \frac{1}{m^3}$

$\sigma_e := n_{e\_e} \cdot \mu_e \cdot e + n_{h\_e} \cdot \mu_h \cdot e$

$\sigma_e = 71.765 \frac{1}{cm \cdot ohm}$ Answer to Part B