Note

- (1) Probability of electron occupying an energy level is given by f(E) = 1.
- (2) Probability of electron not occupying an energy level is given by 1 f(E).
- (3) Relation between fermi energy E_F , fermi velocity V_F and temperature T_F , is g

$$V_F = \sqrt{\frac{2E_F}{m}}$$
 $T_F = \frac{E_F}{K_B}$

Numericals

(12) Evaluiate fermi function for an energy k_BT above fermi energy.

$$E - E_F = k_B T , \quad f(E) = ?$$

$$f(E) = \frac{1}{1 + e^{(E - E_F)/K_B T}}$$

$$\frac{1}{1+e^{K_BT/K_BT}} = \frac{1}{1+e^{K_BT/K_BT}} = \frac{1}$$

$$f(E) = 0.269$$

Answer

(13) Use fermi function to obtain the value of f(E) for $E - E_F = 0.010$ eV at 200K.

$$E - E_F = 0.01 \text{ eV} = 0.01 \times 1.6 \times 10^{-19} J$$

$$T = 200 \text{ K}, \quad f(E) = ?$$

$$f(E) = \frac{1}{1 + e^{(E - E_F)/k_B T}}$$

$$= \frac{1}{1 + e^{\left(\frac{0.01 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23} \times 200}\right)}} = 3.0 \text{ M}$$

As temperature 'T' increases, electron may get an each by of an pixler 4,74, and

$$\therefore f(E) = \frac{1}{1+1.784} = \frac{1}{2.784} \cdot (A-B) \text{ and thus } AB \text{ woled so green entropy}$$

$$f(E) = 0.35913$$

Answer

As a result of this, the fermi function falls.

(14) Calculate the fermi velocity and mean free path for conduction electrons, given that its fermi energy is 11.63 eV and relaxation time for electrons is 7.3×10^{-15} $E_F = 11.63 \text{ eV} = 11.63 \times 1.6 \times 10^{-19} J$ sec.

$$E_F = 11.63 \text{ eV} = 11.63 \times 1.6 \times 10^{-19} J$$

$$T = 7.3 \times 10^{-15} \text{ sec}$$

$$V_F = ?, \quad \lambda = ?$$

Fermi velocity

 $V_F = \sqrt{\frac{2E_F}{m}}$ stode $V_B \lambda$ (grows as not not small terral tender (21)

$$\therefore V_F = \sqrt{\frac{2 \times 11.63 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}}$$

$$=\sqrt{4.085\times10^{12}}$$

:
$$V_F = 2.02 \times 10^6 \, m/\text{sec}$$

The mean free path

$$\lambda = \tau V_F$$
= $(7.3 \times 10^{-15})(2.02 \times 10^6)$

$$\lambda = 1.47 \times 10^{-8} m$$

$$\lambda = 14.75 nm$$

Answer

Vr = 1.06×100 m/sec (15) Calculate the fermi energy and fermi temperature in a metal. The fermi veocity of electrons in the metal is 0.86×10^6 m/sec.

$$V_F = 0.86 \times 10^6 \, m/\text{sec}$$

$$E_F = ?$$
, $T_F = ?$

We know,
$$E_F = \frac{1}{2} m V_F^2$$

$$T_{cr} = 3.7 \times 10^4 \text{ K}$$

(17) Using form function, evaluate the $(2^6)^{100} \times (10^6)^{110} \times (10^6)^{110} = \frac{1}{2} = \frac{1}{2} \times (10^6)^{110} \times (10^6)$ that an electron in a solid will have an energy 0.5 eV above collection.

$$E_F = 3.36 \times 10^{-19} J$$

$$E_F = 2.105 eV$$

 $E - E_F = 0.5 \times 1.6 \times 10^{-19} J$

Answer

Fermi temperature,

$$T_F = \frac{E_F}{k_B}$$

$$=\frac{3.36\times10^{-19}}{1.38\times10^{-23}}$$

E=5.5 eV. Er = 5 ev

$$C = A$$

$$(DA = 2b, C = (DA))$$

Answer

 $T_F = 24.41 \times 10^3 K$

(16) Calculate the fermi temperature and fermi velocity for sodium whose fermi level is 3.2 eV. 1 /1E)+ (18) + (31) A

$$E_F = 3.2 \, eV = 3.2 \times 1.6 \times 10^{-19} \, J$$

 $\therefore V_F = 2.02 \times 10^6 \text{ m/sec}$

$$T_F = ?, \quad V_F = ?$$

$$V_F = \sqrt{\frac{2E_F}{m}}$$

$$=\sqrt{\frac{2\times3.2\times1.6\times10^{-19}}{9.11\times10^{-31}}}$$

$$\therefore V_F = \sqrt{1.12 \times 10^{12}}$$

:
$$V_F = 1.06 \times 10^6 \, m/\text{sec}$$

leulate the formi energy and fermi temperature in a

Fermi temperature

of electrons in the metal is
$$0.86 \times 10^{\circ}$$
 m/sec.
$$V_F = 0.86 \times 10^{\circ}$$
 m/sec

$$=\frac{3.2\times1.6\times10^{-19}}{1.38\times10^{-23}}$$

$$T_F = 3.7 \times 10^4 K$$

We know, $E_F = \frac{1}{2} m V_F^2$ Answer

(17) Using fermi function, evaluate the temperature at which there is 1% probability that an electron in a solid will have an energy 0.5 eV above E_F of 5 eV.

$$E = 5.5 \text{ eV}, \quad E_F = 5 \text{ eV}$$

$$E - E_F = 5.5 - 5 = 0.5 \text{ eV}$$

$$E - E_F = 0.5 \times 1.6 \times 10^{-19} J$$

$$f(E) = 1\% = 0.01$$

$$T = ?$$

We know,

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{k_B T}\right)}}$$

 $V_E = 0.86 \times 10^6 \, m/sec$

(16) (alculate the ferm) temperature and form $u = \left[\frac{E - E_E}{k_B T}\right] = 1$ (are level form) (alculate the ferm) temperature and form)

$$f(F) + f(F) \cdot e^{\left(\frac{E - E_F}{k_B T}\right)} = 1$$

$$\therefore f(E)e^{\left(\frac{E-E_F}{k_BT}\right)} = 1 - f(E)$$

$$\therefore e^{\left(\frac{E-E_F}{k_BT}\right)} = \frac{1-f(E)}{f(E)}$$

Taking logarithm on both sides

$$\frac{E - E_F}{k_B T} = \ln \left[\frac{1 - f(E)}{f(E)} \right]$$
$$= \ln[1 - f(E)] - \ln[f(E)]$$

$$\therefore \frac{1}{k_B T} = \frac{\ln[1 - f(E)] - \ln[f(E)]}{(E - E_F)}$$

$$\therefore k_B T = \frac{(E - E_F)}{\ln[1 - f(E)] - \ln[f(E)]}$$

$$(E - E_F)$$

$$(E - E_F)$$

$$(E - E_F)$$

$$\frac{1}{\ln[1-f(E)]-\ln[f(E)]}$$

$$T = \frac{(E - E_F)}{k_B \ln[1 - f(E)] - \ln[f(E)]}$$

$$\ln[-f(E)] - \ln[f(E)]$$

$$= \frac{0.5 \times 1.6 \times 10^{-19}}{(1.38 \times 10^{-23})[\ln(1-0.01) - \ln(0.01)]}$$

$$=\frac{8\times10^{-20}}{(1.38\times10^{-23})[-0.01005-(-4.6051)]}$$

$$=\frac{8\times10^{-20}}{(1.38\times10^{-23})(4.595)}$$

$$=\frac{8\times10^{-20}}{6.341\times10^{-23}}$$

$$T = 1261.597$$

$$\therefore T = 1.261 \times 10^3 K$$

Answer

(18) The fermi level in potassium is 2.1 eV. What are the energies for which the probabilities of occupancy at 300K are 0.99, 0.01 and 0.5?

$$E_F = 2.1 \text{ eV} = 2.1 \times 1.6 \times 10^{-19} J$$

(2) = (3) \

/(aj) = 0.99 ; [a] = 9

Man Bally Ball

/(E2)=0.01. B2="

$$I = \left(1 + \left(\frac{1}{18^{3}}\right)^{2}\right) (2) \left(\frac{1}{18^{3}}\right)^{2}$$

Thank I occurrence both sides

$$\frac{E - F}{1 - \beta} = \ln[1 - f(E)] - \ln[J(E)]$$

$$E - E_E = k_B T (\ln(1 - f(E)))$$

$$E_t = E_F + k_B T || \ln U - V$$

$$=(2.1\times1.6\times10^{-10})$$

$$E_1 = 3.36 \times 10^{-19} + 4$$

$$=3.36\times10^{-19} +4.14\times10^{-21}(-4.595)$$

$$T = 300 \text{ K}$$

 $f(E_1) = 0.99, E_1 = ?$
 $f(E_2) = 0.01, E_2 = ?$
 $f(E_3) = 0.5, E_3 = ?$

We know,

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{k_B T}\right)}}$$

$$\therefore f(E) \left(e^{\left(\frac{E - E_F}{k_B T} \right)} + 1 \right) = 1$$

Taking Logarithm on both sides,

$$\frac{E - E_F}{k_B T} = \ln[1 - f(E)] - \ln[f(E)]$$

$$\frac{E - E_F}{k_B T} = \ln[1 - f(E)] - \ln[f(E)]$$

$$\therefore E - E_F = kBI \left(\inf(I - J(E)) - \inf(J(E)) \right)$$

 $\therefore E = E_F + k_B T[\ln(1 - f(E)) - \ln(f(E))]$

To find E_1, E_2, E_3

(1) At
$$f(E_1) = 0.99$$

$$E_{1} = E_{F} + k_{B}T[\ln(1 - f(E)) - \ln(f(E))] = \frac{0.5 - 0.1 \times 8}{(1.200 \text{ k} - 1) - 200 \times 0 - 100} = \frac{(1.200 \text{ k} - 1) - 200 \times 0 - 100}{(1.38 \times 10^{-23})300[\ln(1 - 0.99) - \ln(0.99)]}$$

$$E_1 = 3.36 \times 10^{-19} + 4.14 \times 10^{-21} [-4.6051 - (-0.01005)]$$

$$= 3.36 \times 10^{-19} + 4.14 \times 10^{-21} (-4.595)$$

$$\therefore E_1 = 3.36 \times 10^{-19} - 1.902 \times 10^{-20}$$

$$E_1 = 3.16 \times 10^{-19} J$$

TOWARK

$$(E)_{e}^{\left(\frac{L-E_{F}}{L_{B}T}\right)} = 1 - f(E)$$

fulding logarithm on both sides

$$\frac{e - \varepsilon_{\ell}}{\epsilon_{n} \tau} = \ln \left[\frac{1 - f(E)}{f(E)} \right]$$

 $|(3)\backslash |m-|(3)\backslash -|m|=$

$$\frac{1}{k_BT} = \frac{\ln(1 - f(E)) - \ln[f(E)]}{(E - E_E)}$$

$$\therefore k_B T = \frac{(E - E_F)}{\ln[1 - f(E)] - \ln[f(E)]}$$

$$\therefore E - E_F = k_B T [\ln(1 - f(E)) - \ln(f(E))] \frac{(\sqrt{3} - 3)}{\ln(-1/3) \sqrt{-1} \ln(\sqrt{3})} = T$$

$$\frac{0.5 \times 1.6 \times 10^{-19}}{0.5 \times 10^{-23}) [in(1-0.01) - ln(0.01)]}$$

$$= \frac{8 \times 10^{-20}}{(1.38 \times 10^{-23})[-0.01005 \text{ (-4.6051)}]}$$

 $T = 1.261 \times 10^3 \text{ K}$

level in potassium is 2.1 eV. What are the VasQue in level in which the probabilities of occupancy at 300K are 0.90, 0.01 and 0.5 ? (2) For f(E) = 0.01

$$E_F = 2.1 \,\text{eV} = 2.1 \times 1.6 \times 10^{-19} \,\text{J}$$

 $E_3 = 2.1 \ eV$

to want

218.0 = (317 ... Answer

$$E_2 = E_F + k_B T \left[\ln(1 - f(E)) - \ln(f(E)) \right]$$

$$= 3.36 \times 10^{-19} + 4.14 \times 10^{-21} \left[\ln(0.99) - \ln(0.01) \right]$$

$$= 3.36 \times 10^{-19} + 4.14 \times 10^{-21} \left[-0.01005 - (-4.605) \right]$$

$$= 3.36 \times 10^{-19} + 4.14 \times 10^{-21} (4.595)$$

$$= 3.36 \times 10^{-19} + 1.902 \times 10^{-20}$$

$$\therefore E_2 = 3.55 \times 10^{-19} J$$
or
$$\therefore E_2 = 2.21eV$$

$$(3) \text{ for } f(E) = 0.5$$

$$E_3 = E_F + k_B T \left[\ln(1 - f(E)) - \ln(f(E)) \right]$$

$$= 3.36 \times 10^{-19} + 4.14 \times 10^{-21} \left[\ln 0.5 - \ln 0.5 \right]$$

$$= 3.36 \times 10^{-19} + 4.14 \times 10^{-21} \left[\ln 0.5 - \ln 0.5 \right]$$

(19) In a solid, consider an energy level lying 0.1 eV above fermi level. What is the probability of this level not being occupied by an electron at room temperature.

$$E - E_F = 0.1 \text{ eV} = 0.1 \times 1.6 \times 10^{-19} J$$

$$T = 300 \text{ K}$$

The probability of unoccupancy is given by

$$1 - f(E) = 1 - \left[\frac{1}{1 + e^{\left(\frac{E - E_F}{k_B T}\right)}} \right]$$

$$= 1 - \left[\frac{1}{1 + e^{\left(\frac{0.1 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23} \times 300}\right)}} \right] = 1 - \left(\frac{1}{1 + e^{3.864}} \right)$$

$$= 1 - \left(\frac{1}{1 + 47.69} \right) = 1 - \frac{1}{48.69}$$
Almost the first the second solution of the second solution o

((E) = fermi function

$$1 - f(E) = 1 - 0.0205$$

$$1 - f(E) = 0.9794$$

10 0mi - (00 0mil) 15 018 11.4 + 01 018 8 E = Answe (20) Find the probability with which an energy level 0.02 eV above fermi level will be occupied at room temperature of 300 K and at 1000 K.

$$E - E_F = 0.02eV = 0.02 \times 1.6 \times 10^{-19} J_{\perp}^{15} \text{ mag. f.}$$

Probability of occupancy at 300 K

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{K_B T}\right)}}$$

Ainswer

$$=\frac{1}{1+e^{\left(\frac{0.02\times1.6\times10^{-19}}{1.38\times10^{-23}\times300}\right)}}$$

$$=\frac{1}{1+e^{0.7729}}$$

$$=\frac{1}{1+2.166}$$

f(E) = 0.315

$$E_{1} = 2.21eV$$

: E1 = 3.55×10-19 J

(3) for
$$f(E) = 0.5$$

$$E_3 = E_F + k_B T \{ \ln(1 - f(E)) - \ln(f(E)) \}$$

 $=3.36 \times 10^{-19} + 1.902 \times 10^{-2}$

$$=3.36\times10^{-19} +4.14\times10^{-21}[\ln 0.5 - \ln 0.5]$$

$$=3.36\times10^{-19}$$
 J

add at Probability of occupancy at 1000 Knivl lavel (green our rebisnes, biles and (%1) probability of this level not being occupied by an electron at room is appendent.

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{k_B T}\right)}}$$
$$= \frac{1}{\left(\frac{0.02 \times 1.6 \times 10^{\circ}}{1 + e^{\left(\frac{E - E_F}{k_B T}\right)}}\right)}$$

$$= \frac{1 + e^{\left(\frac{0.02 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23} \times 1000}\right)}$$

$$=\frac{1}{1+e^{0.2318}}=\frac{1}{1+1.2609}$$

$$\therefore f(E) = 0.442$$

The probability of unoccupancy is given by
$$1 - f(E) = 1 - \left(\frac{1}{1 + e^{\left(\frac{E-E_{p}}{E}\right)}}\right)$$

 $E - E_F = 0.1 \text{ eV} = 0.1 \times 1.6 \times 10^{-19} \text{ J}$ T = 300 K