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Department of Physics
Examination paper for **FY3114 / FY8912 Functional Materials**
Examination date: **December 15, 2022**
Examination time (from-to): **15-19**

Permitted examination support material:
C: Specified printed support material is allowed. A specific basic calculator is allowed.
Allowed: Mathematical formulas (Rottmann or equivalent). English dictionary.

Academic contact during examination: Steinar Raaen, Phone: 482 96 758
Academic contact present at the exam location: NO

OTHER INFORMATION
Get an overview of the question set before you start answering the questions.
Read the questions carefully and make your own assumptions. If a question is unclear/vague, make your own assumptions and specify them in your answer. Only contact academic contact in case of errors or insufficiencies in the question set. Address an invigilator if you wish to contact the academic contact. Write down the question in advance.
Notifications: If there is a need to send a message to the candidates during the exam (e.g. if there is an error in the question set), this will be done by sending a notification in Inspera. A dialogue box will appear. You can re-read the notification by clicking the bell icon in the top right-hand corner of the screen.
Withdrawing from the exam: If you become ill or wish to submit a blank test/withdraw from the exam for another reason, go to the menu in the top right-hand corner and click “Submit blank”. This cannot be undone, even if the test is still open.
Access to your answers: After the exam, you can find your answers in the archive in Inspera. Be aware that it may take a working day until any hand-written material is available in the archive.

1 P1-h2022

Topological insulators ....
Select one alternative:

- ○ are being used in quantum computation
- ○ already have a wide range of applications
- ○ are conducting at the surface
- ○ are conducting in the bulk

Perovskite solar cells ....
Select one alternative

- ○ toxicity is not an issue as regards perovskite solar cells
- ○ have higher efficiency as compared to Si solar cells
- ○ have lower efficiency as compared to Si solar cells
- ○ presently are stable and have a long lifetime

Materials for phase change memories (PCMs)....
Select one alternative

- ○ PCMs may not be used for non-volatile memory devices
- ○ a detailed model for the amorphous state is missing
- ○ the problem of volume change between the crystalline and amorphous phases has been solved
- ○ dopants have been proved to decrease the electrical resistivity of the crystalline state

Which of the following crystal systems are uniaxial?

Select one alternative

- monoclinic
- orthorombic
- tetragonal
- cubic

Maximum marks: 4

2 P2-h2022

Which one of these elements is not ferromagnetic? ....
Select one alternative:

- Co
- Mn
- Fe
- Ni

Piezoelectric transistors...
Select one alternative

- may be made from centrosymmetric materials
- are not suitable for use in touch devices
- represent a mature technology
- may be used as strain sensors

Strain effects on transistors ....
Select one alternative

- results in increased phonon scattering
- increase leakage currents
- split degenerate energy levels
- reduce mobility of electron and holes

Which property is determined directly by the electrons and their interactions?

Select one alternative

- ferromagnetism
- elastic properties
- ferroelectricity
- piezoelectricity

Maximum marks: 4

3 P3-h2022

Spintronic transistors ....
Select one alternative

- demonstration devices exists
- use less power but are slower than ordinary transistors
- use the spin but not the charge of the electrons
- are already on the marked

Graphene ....
Select one alternative

- devices utilize high effective mass electrons
- cannot be used in lightening devices
- may be used in transparent electrodes
- devices have electron mobilities almost as high as in GaAs

Ferroelectric memory devices ....
Select one alternative

- have very high storage densities
- may be used in non-volatile memory applications
- may be made from centrosymmetric materials
- are well suited for low cost production

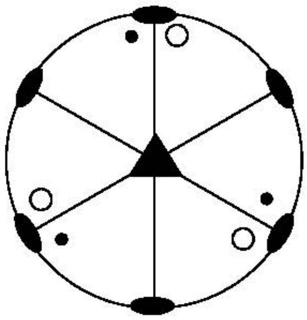
Which one of these statements is correct?

Select one alternative

- a ferroelectric material is also pyroelectric and piezoelectric
- a piezoelectric material is also ferroelectric
- a pyroelectric material is also ferroelectric
- the dielectric constant of a ferroelectric material is low

Maximum marks: 4

4 # P4-h2022



To which point group does the stereogram above correspond?
Select one alternative:

- 32
- $3m$
- $\bar{6}m2$
- $\bar{3}2/m$

Maximum marks: 4

5 P5-h2022

Identify the stereograms (2D pointgroup projections) by placing the relevant point group notations on top of the stereograms (-4 means $\bar{4}$)

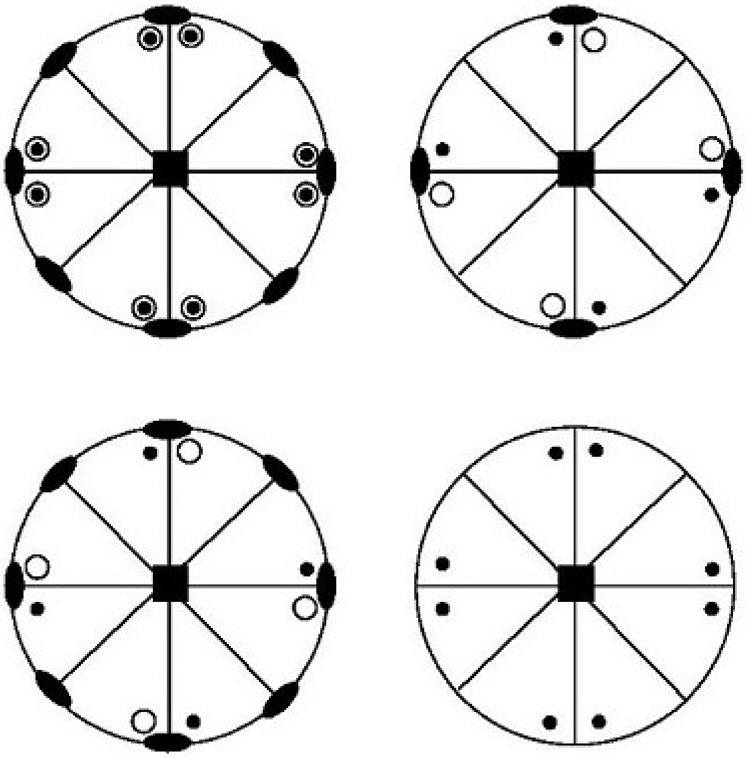
Move the point group notations listed on the left on top of the relevant stereogram

4mm

4/m 2/m 2/m

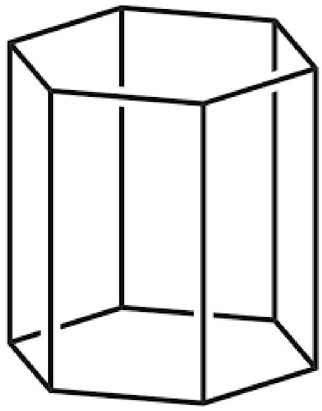
-42m

422



Maximum marks: 4

6 P6-h2022



Regular hexagonal prism

How many symmetry elements are contained in the point group of the triangular prism as shown in the figure above?

Select one alternative:

- 24
- 36
- 12
- 18
- 32

Which one of the following symmetry elements is not contained in the point group?

Select one alternative

- $\bar{6}$
- $\bar{1}$
- $\bar{3}$
- 4

Maximum marks: 4

7 P7-h2022

Which ones of the points groups **422**, **32**, $\mathbf{\overline{4}2m}$, $\mathbf{\overline{3}}$, **622**, **4/m**, $\mathbf{\overline{6}}$,**6/m** are centrosymmetric?
Select one or more alternatives:

- ☐ $\mathbf{422}$
- ☐ $\mathbf{32}$
- ☐ $\mathbf{6/m}$
- ☐ $\mathbf{\overline{3}}$
- ☐ $\mathbf{\overline{4}2m}$
- ☐ $\mathbf{622}$
- ☐ $\mathbf{4/m}$
- ☐ $\mathbf{\overline{6}}$

(1 points for correct answer, -1 point for wrong answer, 0 points for no answer, minimum score is 0 points)

Maximum marks: 3

8 P8-h2022

The resistivity tensor of a monoclinic crystal is given by:

$$\rho = \begin{bmatrix} 3.9 & 6.5 & 0 \\ 6.5 & 1.3 & 0 \\ 0 & 0 & 4.7 \end{bmatrix},\ in\ units\ of\ 10^{-8}\,\Omega m$$

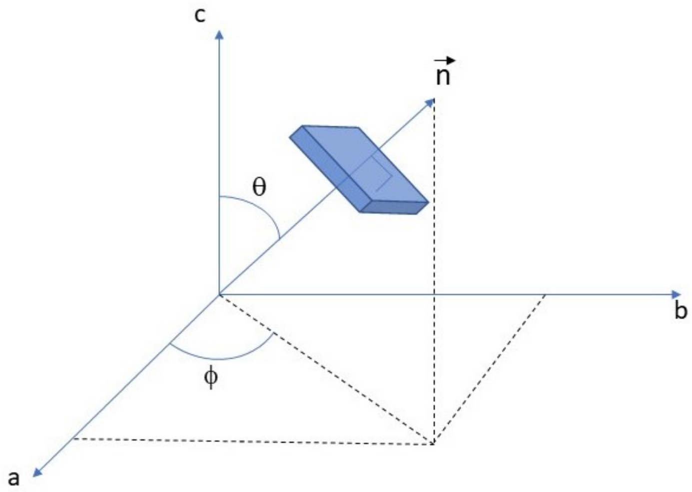
This tensor can be diagonalized by rotation by an angle θ around the z-axis.
Find the angle θ.

The angle is:
Select one alternative:

- 42.2^o
- 53.6^o
- 19.7^o
- 39.3^o
- 78.6^o

Maximum marks: 4

9 P9-h2022



An orthorhombic crystal is cut in a thin slab where the surface normal is at an angle θ = 45^o with the c-axis, and the angle between the a-axis and the projection of the surface normal in the ab-plane is ϕ = 30^o.

There is a temperature gradient across the thin slab. The temperature difference between the big faces of the thin slab is 2 K, and the thickness of the slab is L = 10 mm. The components of the thermal conductivity tensor is: k_{11}, k_{22}, k_{33} = 6, 5 , 1 [W/mK]; respectively.

Find the absolute value of the heat flow across the crystal in the direction of the surface normal.

Select one alternative

- $800W/m^2$
- $700W/m^2$
- $900W/m^2$
- $675W/m^2$
- $775W/m^2$

Maximum marks: 4

10 P10-h2022

Find the energies of the electron and the hole relative to the respective band edges when a **2.0 eV** photon is adsorbed in the semiconductor **InP**.

The energy of the electron is:
Select one alternative:

- 0.22
- 0.62
- 0.45
- 0.78
- 0.16

The energy of the hole is:

Select one alternative

- -0.06
- -0.09
- 0.11
- -0.13
- -0.11

Maximum marks: 4

11 P11-h2022

The average electric field in a Si device of length $L = 3\mu m$ is $E = 20kV/cm$. The temperature is assumed to be $T = 300K$.

Find the transit time of an electron through the device using the low field value of the mobility.
Select one alternative:

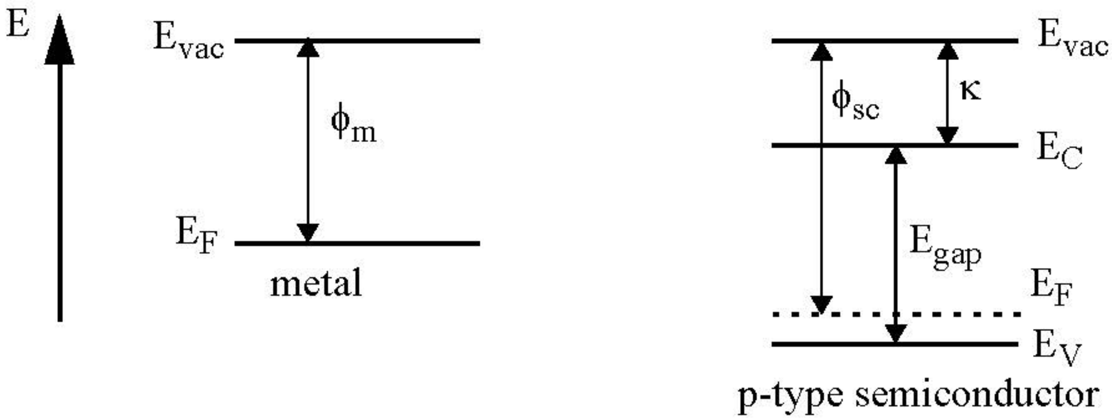
- $3.0 \cdot 10^{-13}s$
- $1.5 \cdot 10^{-13}s$
- $1.5 \cdot 10^{-12}s$
- $1.5 \cdot 10^{-11}s$
- $3.0 \cdot 10^{-11}s$

Find the electron transit time using the saturation value of the drift velocity $v_d = 1 \cdot 10^7 cm/s$.
Select one alternative

- $3.0 \cdot 10^{-11}s$
- $1.5 \cdot 10^{-13}s$
- $1.5 \cdot 10^{-12}s$
- $1.5 \cdot 10^{-11}s$
- $3.0 \cdot 10^{-13}s$

Maximum marks: 4

12 P12-2022



Schematic representations of the energy levels of a metal and a p-doped semiconductor are showed in the figure above. The work functions of metal and semiconductor are given by $\phi_M = 4.0$ and $\phi_{SC} = 4.8eV$; respectively. The energy gap of the semiconductor is $E_{gap} = 1.1eV$, and the electron affinity is $\kappa = 3.9eV$.

When the metal and semiconductor are contacted a Schottky junction forms.

The barrier height at the junction becomes:

Select one alternative:

- + 1.0 eV
- - 0.2 eV
- + 0.8 eV
- + 0.2 eV
- - 1.0 eV

Maximum marks: 4

13 P13-h2022

A p-doped Si sample is kept at temperature 300 K. The density of holes is $5 \cdot 10^{17} cm^{-3}$. Use the law of mass action to find the conductivity due to the electrons.

The conductivity due to the electrons is:

Select one alternative

- $14.0 \frac{1}{\Omega cm}$
- $7.2 \cdot 10^{-12} \frac{1}{\Omega cm}$
- $3.6 \cdot 10^{-14} \frac{1}{\Omega cm}$
- $28.0 \frac{1}{\Omega cm}$
- $7.2 \cdot 10^{-14} \frac{1}{\Omega cm}$

The conductivity due to the holes is:

Select one alternative

- $28.0 \frac{1}{\Omega cm}$
- $14.0 \frac{1}{\Omega cm}$
- $7.2 \cdot 10^{-14} \frac{1}{\Omega cm}$
- $3.6 \cdot 10^{-14} \frac{1}{\Omega cm}$
- $3.6 \cdot 10^{-14} \frac{1}{\Omega cm}$

The conductivity of an undoped sample would be:

Select one alternative:

- $2.4 \cdot 10^{-6} \frac{1}{\Omega cm}$
- $3.2 \cdot 10^{-6} \frac{1}{\Omega cm}$
- $2.6 \cdot 10^{-6} \frac{1}{\Omega cm}$
- $2.2 \cdot 10^{-6} \frac{1}{\Omega cm}$
- $1.6 \cdot 10^{-6} \frac{1}{\Omega cm}$

Maximum marks: 3

14 P14-h2022

A solar cell consists of a GaAs pn-diode of area $A = 2cm^2$. The temperature is 300 K.
The total current when the diode is connected to an external load is given by

$$I = I_L - I_0(e^{eV/k_BT} - 1)$$

where $I_L$is the photocurrent and $I_0$is the diffusion current of electrons and holes.
Find the open circuit $(I = 0)$ voltage V_{OC} for the solar cell.
Parameter values are:

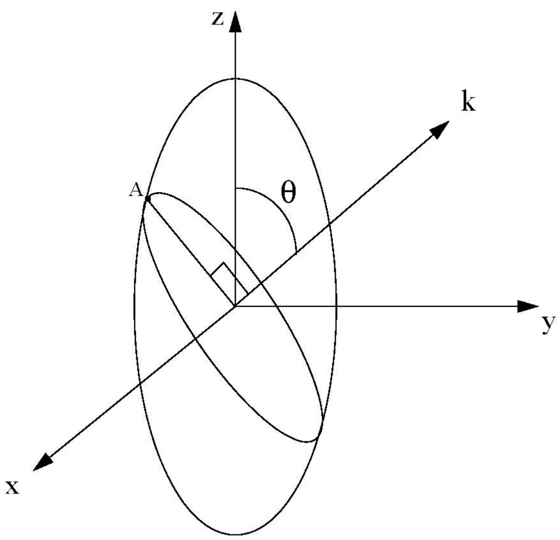
Density of electrons and holes: $n_n = 1 \cdot 10^{17} cm^{-3}$ and $p_p = 5 \cdot 10^{17} cm^{-3}$
Electron diffusion coefficients: $D_n = 25cm^2/s$ and $D_p = 16cm^2/s$
Electron and hole recombination times: $\tau_n = 4 \cdot 10^{-7} s$ and $\tau_p = 2 \cdot 10^{-7} s$
Photocurrent: $I_L = 25mA$

The open circuit voltage V_{OC} is:
Select one alternative:

- 0.97 V
- 1.03 V
- 0.89 V
- 0.65 V
- 1.12 V

Maximum marks: 4

15 P15-h2022



The figure above shows the index ellipsoid of a uniaxial optical active material. The propagation direction of the light is perpendicular to the ellipse as shown. The wave vector ***k*** is in the yz-plane. The point A is located in the yz-plane and on both the ellipsoid and the ellipse. The angle $\theta = 35^0$, and the ordinary and extraordinary indices of refraction are $n_o = 1.87$ and $n_e = 1.69$.

The index ellipsoid is given by $\frac{x^2}{n_o^2} + \frac{y^2}{n_o^2} + \frac{z^2}{n_e^2} = 1$

What is the refractive index $n_e(\theta = 35^0)$?

Enter the answer here: [ ] .

Maximum marks: 4

16 P16-h2022

The **Pockels** tensor elements (contracted notation) for the tetragonal electroactive material BTO are as follows:

$r_{13} = r_{23}$ = 8 pm/V
r_{33} = 23 pm/V
$r_{42} = r_{51}$ = 820 pm/V
other **r_{ij} = 0**

Refractive indices are **n_e = 2.18** and **n_o = 2.44**
An electric field **$E_3 = 1 \cdot 10^8$ V/m** is applied in the z-direction.

The impermeability tensor elements are given by $\eta_{ij}(E) = \eta_{ij}(0) + \sum_k r_{ijk} E_k$

Estimate the change in the difference in the refractive indices $\Delta n = \Delta n_o(E) - \Delta n_e(E)$ due to the electric field.

Select one alternative:

- 0.003
- 0.012
- 0.009
- 0.006
- 0.015

Maximum marks: 4

17 P17-h2022

The piezoelectric tensor of the tetragonal material PZT-5H (point group 4mm) is given by:

$$d = \begin{bmatrix} 0 & 0 & 0 & 0 & 735 & 0 \\ 0 & 0 & 0 & 735 & 0 & 0 \\ -263 & -263 & 515 & 0 & 0 & 0 \end{bmatrix} \text{ in units of } 10^{-12} C/N$$

The polarization along the y-axis for a shear stress $\sigma = 3 \cdot 10^4 Nm^{-2}$ around the x-axis is:

Select one alternative

- 0
- $2.21 \cdot 10^{-5} Cm^{-2}$
- $1.55 \cdot 10^{-5} Cm^{-2}$
- $1.55 \cdot 10^{-6} Cm^{-2}$
- $-7.89 \cdot 10^{-6} Cm^{-2}$

Maximum marks: 4

18 P18-h2022

Soft ferromagnetic materials may be used for:
Select one or more alternatives:

- ☐ Flux guides
- ☐ Motors
- ☐ Magnetic recording devices
- ☐ Transformers
- ☐ Permanent magnets
- ☐ Induction ovens
- ☐ Magnetic shielding

(1 point for correct answer, -1 point for wrong answer, 0 points for no answer, minimum score is 0 points)

Maximum marks: 3

19 P19-h2022

Consider a ferromagnetic material in which the exchange field is proportional to the magnetization: $B_E = \lambda \mu_0 M$, where $\lambda = 850$ is a dimensionless constant. The curie constant $C = 0.82K$.

Derive the expression for the ferromagnetic susceptibility to find the Curie temperature for the ferromagnetic material:

Select one alternative:

- 1037 K
- 770 K
- 697 K
- 648 K
- 850 K

Maximum marks: 4

1 P1-h2022

Topological insulators ....
Select one alternative:

- ○ are being used in quantum computation
- ○ already have a wide range of applications
- ○ are conducting at the surface
- ○ are conducting in the bulk

Perovskite solar cells ....
Select one alternative

- ○ toxicity is not an issue as regards perovskite solar cells
- ○ have higher efficiency as compared to Si solar cells
- ○ have lower efficiency as compared to Si solar cells
- ○ presently are stable and have a long lifetime

Materials for phase change memories (PCMs)....
Select one alternative

- ○ PCMs may not be used for non-volatile memory devices
- ○ a detailed model for the amorphous state is missing
- ○ the problem of volume change between the crystalline and amorphous phases has been solved
- ○ dopants have been proved to decrease the electrical resistivity of the crystalline state

Which of the following crystal systems are uniaxial?

Select one alternative

- monoclinic
- orthorombic
- tetragonal
- cubic

Maximum marks: 4

2 P2-h2022

Which one of these elements is not ferromagnetic? ....
Select one alternative:

- ◯ Co
- ◯ Mn
- ◯ Fe
- ◯ Ni

Piezoelectric transistors...
Select one alternative

- ◯ may be made from centrosymmetric materials
- ◯ are not suitable for use in touch devices
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Strain effects on transistors ....
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- ◯ results in increased phonon scattering
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Which property is determined directly by the electrons and their interactions?

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3 P3-h2022

Spintronic transistors ....
Select one alternative

- ◯ demonstration devices exists
- ◯ use less power but are slower than ordinary transistors
- ◯ use the spin but not the charge of the electrons
- ◯ are already on the marked

Graphene ....
Select one alternative

- ◯ devices utilize high effective mass electrons
- ◯ cannot be used in lightening devices
- ◯ may be used in transparent electrodes
- ◯ devices have electron mobilities almost as high as in GaAs

Ferroelectric memory devices ....
Select one alternative

- ◯ have very high storage densities
- ◯ may be used in non-volatile memory applications
- ◯ may be made from centrosymmetric materials
- ◯ are well suited for low cost production

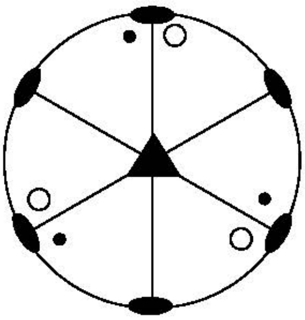
Which one of these statements is correct?

Select one alternative

- a ferroelectric material is also pyroelectric and piezoelectric
- a piezoelectric material is also ferroelectric
- a pyroelectric material is also ferroelectric
- the dielectric constant of a ferroelectric material is low

Maximum marks: 4

4 P4-h2022



To which point group does the stereogram above correspond?

Select one alternative:

- 32
- $3m$
- $\bar{6}m2$
- $\bar{3}2/m$

Maximum marks: 4

Exam December 15, 2022 FY3114/FY8912 Funksjonelle materialer.

Problems 1-3: multiple choice questions at the end of document

Problem 4: point group 32

Problem 5: see lecture notes

Problem 6:

24 symmetry elements in point group: 1, -1, 2 x 6, 1/m, m x 6, 6, 6^2, 6^3, 6^4, 6^5, -6, -6^5, -3, -3^5

Problem 7: centrosymmetric point groups: -3, 4/m, 6/m

Problem 8:

Rotation around the z-axis gives

$A'_{12} = (A_{22} - A_{11})\frac{1}{2}sin2\theta + A_{12}cos2\theta = 0$, therefore $tan2\theta = \frac{2A_{12}}{A_{11}-A_{22}} = \frac{2\ 6.5}{3.9-1.3} = 5$

θ = 39.3°

Problem 9:

The temperature gradient has components along the a-, b-, and c- axes given by

$\left(\frac{\delta T}{\delta x}\right) = \frac{\Delta T}{L} sin\theta cos\varphi, \quad \left(\frac{\delta T}{\delta y}\right) = \frac{\Delta T}{L} sin\theta sin\varphi, \quad \left(\frac{\delta T}{\delta z}\right) = \frac{\Delta T}{L} cos\theta$

The heat flow is given by $\vec{h} = -k\nabla T$, or $h_i = -\sum_j k_{ij}\left(\frac{\delta T}{\delta x_j}\right)$

which gives $h_1 = -k_{11}(\frac{\delta T}{\delta x})$, $h_2 = -k_{22}(\frac{\delta T}{\delta y})$, $h_3 = -k_{33}(\frac{\delta T}{\delta z})$ (since other $k_{ij} = 0$).

Since $\vec{h} = -k\nabla T$ the magnitude of h along the surface normal is given by

$$h_n = \frac{\vec{h}\cdot\nabla T}{|\nabla T|} = \sum_i h_i\left(\frac{\delta T}{\delta x_j}\right) /|\nabla T| = \sum_i h_i\left(\frac{\delta T}{\delta x_j}\right)\frac{L}{\Delta T} = -\sum_{ij} k_{ij}\left(\frac{\delta T}{\delta x_j}\right)\left(\frac{\delta T}{\delta x_i}\right)\frac{L}{\Delta T}$$

$$h_n = -k_{11}\left(\frac{\delta T}{\delta x_1}\right)^2\frac{L}{\Delta T} - k_{22}\left(\frac{\delta T}{\delta x_2}\right)^2\frac{L}{\Delta T} - k_{33}\left(\frac{\delta T}{\delta x_3}\right)^2\frac{L}{\Delta T}$$

$$h_n = -k_{11}\left(\frac{\Delta T}{L}sin\theta cos\varphi\right)^2\frac{L}{\Delta T} - k_{22}\left(\frac{\Delta T}{L}sin\theta sin\varphi\right)^2\frac{L}{\Delta T} - k_{33}\left(\frac{\Delta T}{L}cos\theta\right)^2\frac{L}{\Delta T}$$

$$h_n = -k_{11}\frac{\Delta T}{L}sin^2\theta cos^2\varphi - k_{22}\frac{\Delta T}{L}sin^2\theta sin^2\varphi - k_{33}\frac{\Delta T}{L}cos^2\theta$$

$$h_n = -k_{11}\frac{2}{0.01}\frac{1}{2}\frac{3}{4} - k_{22}\frac{2}{0.01}\frac{1}{2}\frac{1}{4} - k_{33}\frac{2}{0.01}\frac{1}{2}$$

h_n= 675 W/m^2

Problem 10:

We have $\hbar\omega = E_e - E_h = E_{gap} + \frac{\hbar^2 k^2}{2m_r^*}$ which gives $\frac{\hbar^2 k^2}{2m_r^*} = \hbar\omega - E_{gap}$

Therefore $E_e - E_c = \frac{m_r^*}{m_e^*}(\hbar\omega - E_{gap})$ and $E_h - E_v = -\frac{m_r^*}{m_h^*}(\hbar\omega - E_{gap})$

E_e = 0.62 eV, and E_h = -0.11 eV

Problem 11:

$$Low\ field\ approx: v = \mu E\ and\ \tau = \frac{L}{v} = \frac{L}{\mu E} = 1.5 \cdot 10^{-11} s$$

$$Saturation\ velocity: \tau = \frac{L}{v} = 3.0 \cdot 10^{-11} s$$

Problem 12:

$$V_B = \Phi_M - \chi - E_{gap} = -1.0\ eV$$

Problem 13:

$$\sigma = n_p e\mu_n + p_p e\mu_n\ \ using\ law\ of\ mass\ action\ n_i^2 = n_n p_n = n_p p_p\ \ gives\ n_p = \frac{n_i^2}{p_p}$$

$$\sigma_n = n_p e\mu_n = \frac{n_i^2}{p_p} e\mu_n = 7.2 \cdot 10^{-14} \frac{1}{\Omega cm}$$

$$\sigma_p = p_p e\mu_p = 28.0 \frac{1}{\Omega cm}$$

$$\sigma_{intrinsic} = n_i e\mu_n + n_i e\mu_p = 3.2 \cdot 10^{-6} \frac{1}{\Omega cm}$$

Problem 14:

$$Open\ circuit\ voltage\ for\ solar\ cell: I = I_L - I_0\left(e^{\frac{eV}{k_B T}} - 1\right) = 0$$

$$Diffusion\ currents:\ J_n = eD_n \frac{dn}{dx} = eD_n \frac{n_p}{L_n}\ \ and\ :\ J_p = eD_p \frac{dp}{dx} = eD_p \frac{p_n}{L_p}$$

$$Law\ of\ mass\ action:\ n_i^2 = n_n p_n = n_p p_p$$

$$Total\ diffusion\ current\ \frac{I_0}{A} = eD_n \frac{n_p}{L_n} + eD_p \frac{p_n}{L_p}\ \ where\ L_n = \sqrt{D_n \tau_n}\ and\ L_p = \sqrt{D_p \tau_p}$$

$$Open\ circuit\ voltage\ V_{oc} = \frac{k_B T}{e} \ln\left(1 + \frac{I_L}{I_0}\right) = 1.03\ V$$

Problem 15:

Uniaxial optic active material $\frac{1}{n_e(\theta)^2} = \frac{cos^2\theta}{n_o^2} + \frac{sin^2\theta}{n_e^2}$

We get $n_e(\theta) = 1/\sqrt{\frac{cos^2\theta}{n_o^2} + \frac{sin^2\theta}{n_e^2}}$ = 1.805 (n_o= 1.87 and n_e=1.69)

Problem 16:

Electroactive optic material BTO

Impermeability tensor elements $\eta_{ij} = \eta_{ij}{}^{0} + r_{ij3}E_3$

Index ellipsoid given by $\sum_{ij} \eta_{ij}\, x_i x_j = 1$

This gives $\eta_{11}{}^{0}x^2 + \eta_{22}{}^{0}y^2 + \eta_{33}{}^{0}z^2 + r_{113}E_3x^2 + r_{223}E_3y^2 + r_{333}E_3z^2 = 1$

Therefore $\left(\frac{1}{n_o{}^2} + r_{13}E_3\right)x^2 + \left(\frac{1}{n_o{}^2} + r_{13}E_3\right)y^2 + \left(\frac{1}{n_e{}^2} + r_{33}E_3\right)z^2 = 1$

And change in refractive index in the E-field is $\Delta\left(\frac{1}{n_o{}^2}\right) = r_{13}E_3$ and $\Delta\left(\frac{1}{n_e{}^2}\right) = r_{33}E_3$

Which gives $\Delta n_o = -\frac{1}{2}n_o{}^3 r_{13}E_3$ and $\Delta n_e = -\frac{1}{2}n_e{}^3 r_{33}E_3$

And $\Delta n = \Delta n_o - \Delta n_e = -\frac{1}{2}E_3(n_o{}^3 r_{13} - n_e{}^3 r_{33})$

Δn = 0.006

Problem 17:

Piezoelectric tensor for tetragonal PZT-5H (pg 4mm)

$$\textit{Shear stress around } x\text{: } \sigma_{23} = \sigma_4 \Rightarrow P_2 = d_{24}\sigma_4 = 735 \cdot 10^{-12} \cdot 3 \cdot 10^4 \frac{C}{m^2} = 2.21 \cdot 10^{-5} \frac{C}{m^2}$$

Problem 18:

Soft magnetic materials may be used for: Transformers, Flux guides, Magnetic shielding

Problem 19:

$$\textit{Ferromagnet}\text{: } \mu_0 M = \chi_P(B_a + B_E) = \chi_P(B_a + \lambda\mu_0 M) \Rightarrow \chi = \frac{\mu_0 M}{B_a} = \frac{\chi_P}{1 - \chi_P\lambda}$$

$$\textit{Paramagnetic susceptibility } \chi_P = \frac{C}{T} \textit{ gives } \chi = \frac{C}{T - C\lambda} \textit{ and } T_C = C\lambda = 697\ K$$