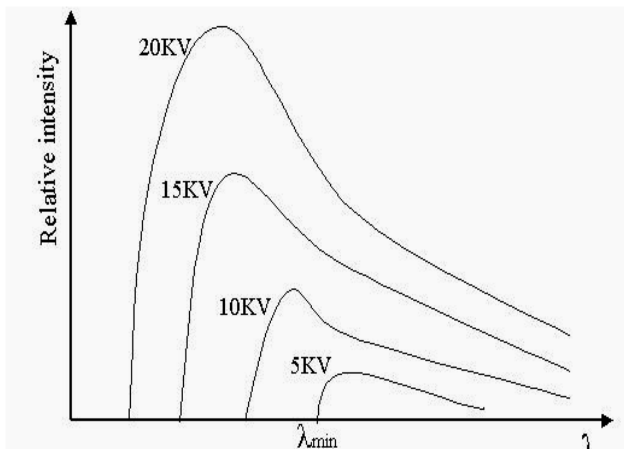
Benha University **Faculty of Engineering – Shoubra** **Renewable Energy Program** **Second Term (2018-2019)**		**Final Term Exam** **Physics 3** **Date: 26 / 5 / 2019** **Duration: 2 hours**

- Answer all the following question
- Illustrate your answers with sketches when necessary
- No. of questions: 4 questions
- Total Mark: 40 Marks

Question (1) (10 marks)

1-a) Discuss the properties of the continuous x-ray spectrum and how can quantum theory explains it?

Answer



Continuous x-rays spectra has the following properties

1- it is electromagnetic waves with very short wavelength in the range 0.1-100 Å

2- at fixed applied potential V on x-ray tube the intensity of the continuous spectrum gradually increase with decreasing the wavelength up to reach maximum intensity and suddenly drop at short wave boundary or minimum wavelength

3- with increasing the applied potential V the same behavior is observed the intensity is distributed over different values of wavelength but at higher intensities than before

4- the intensity increase to reach maximum and suddenly drop is at short wavelength smaller than before

5- the short wave boundary λ_{min} is inversely proportional with applied potential V where

$$\lambda_{min} = \frac{constant}{V}$$

The quantum theory explain the continuous spectrum as follow

1- the electrons gain kinetic energy K due to the potential difference V between cathode (filament) and anode (target) where

$K = eV \ \ Joule$

2- When electrons bombarded by solid target a part of K will lost in a form of electromagnetic radiation appear as continuous of x-ray spectrum with photon energy $h\nu$.

3- The photons energies(intensities) are distributions over different values of frequencies or different values of corresponding wavelength

4- At points of minimum wavelength all electron will lost by photons with maximum frequency or shot wave boundary $\lambda_{\min}$ where

$$h\nu_{\max} = eV$$

$$h\frac{c}{\lambda_{\min}} = eV$$

$$V\lambda_{\min} = h\frac{c}{e} = constant$$

$$\lambda_{\min} = \frac{constant}{V}$$

The magnitude of the constant is agree with the experimental results

1-b) Find the wavelength of short-wave boundary of continuous x-ray spectrum if the applied voltage to the x-ray tube is 50 KV? Calculate the electric potential on the x-ray tube to give a minimum wavelength 1 A^o?

Solution

$$\lambda_{\min} = h\frac{c}{Ve} = \frac{6.625\times10^{-34}\ j.s\times3\times10^{8}\ m/s}{50000V\times1.6\times10^{-19}\ C} = 2.48\times10^{-11} m$$

$$\lambda_{\min} = 0.249 \ \text{Å}$$

$$V = h\frac{c}{e\lambda_{\min}} = \frac{6.625\times10^{-34}\ j.s\times3\times10^{8}\ m/s}{1.6\times10^{-19}\ C\times1\times10^{-10}\ m} = 12421.67V = 12.421\ KV$$

<u>Question (2) (10 marks)</u>

2-a) Explain the method of polarization of natural light by reflection? Derive the relation between polarizing and refraction angles?

Answer

There are three methods to obtain polarized light

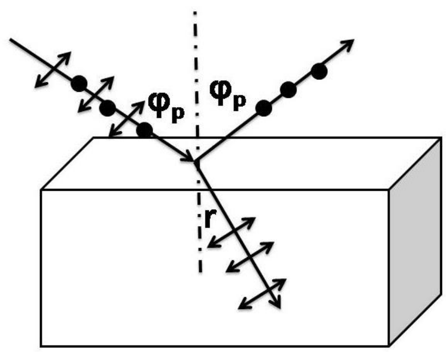
1- polarization by reflection

2- polarization by refraction

3- polarization by double refraction

to explain the method by reflection consider a beam of natural light incident on a sheet of glass by angle of incident φ the reflected light is partly polarized light and the degree of polarization depends on the angle of incidence. When the reflected light is completely polarized the angle of incidence is called polarizing angle and depends on the absolute refractive index of the material where

$$\tan\varphi_p = \mu$$

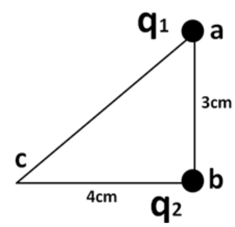


But $\mu = \dfrac{\sin\varphi_p}{\sin r}$

$$\cos\varphi_p = \sin r = \cos(90^\circ - r)$$

$$\varphi_p + r = 90^\circ$$

2-b) Two charges q_1 = -1 μC and q_2 = - 2 μC are place on the vertices of right angle triangle as shown in figure. Calculate the magnitude and direction of the electric field intensity at point c. If a charge +5 C placed at point c, calculate the magnitude and direction of the electric force acting on it there.

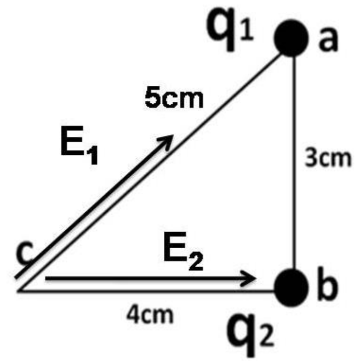


Solution

The magnitude of the electric field at a point dueto point charge at distance r is calculated from the equation

$$E = K\frac{q}{r^2}$$

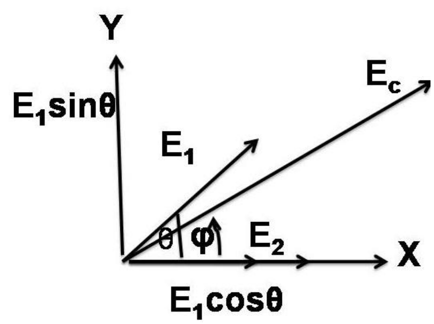
Apply the equation for point c due to two charges q_i and q_2



$$E_1 = K\frac{q_1}{r_1^2} = 9\times10^9 \frac{1\times10^{-6}}{(0.05)^2} = 3.6\times10^6 \ N/C$$

And also for q_2

$$E_2 = K\frac{q_2}{r_2^2} = 9\times10^9 \frac{2\times10^{-6}}{(0.04)^2} = 11.25\times10^6 \ N/C$$



Since the two charges are negative the direction of electric field st point c id directed towards points a and b.
To calculate the resultant field use the XY plane and analyze the field E_1

$$E_X = E_2 + E_1 \cos\theta$$

$$E_X = 11.25\times10^6 \ N/C + 3.6\times10^6 \ N/C \times (\frac{4}{5}) = 14.12\times10^6 \ N/C$$

$$E_Y = E_1 \sin\theta = 3{,}6\times10^6 \times (\frac{3}{5}) = 2.16\times10^6 \ N/C$$

The resultant field at point c is

$$E_c = \sqrt{E_x^2 + E_y^2} = \sqrt{(14.12\times10^6)^2 + (2.16\times10^6)^2} = 14.28\times10^6 \ N/C$$

The direction of the resultant field makes angle φ measured from +Ve X-axis anti clockwise where

$$\varphi = \tan^{-1}(\frac{E_Y}{E_X}) = \tan^{-1}(\frac{2.16}{13.12}) = 9^{\circ}\ 20^{-}\ 56$$

The direction of the resultant field E_c makes angle φ= $9^{\circ}\ 20^{-}\ 56$ measured from +Ve X-axis anti clockwise

The force acting on charge +5C placed at point c is

$$F = qE = 5C\times14.28\times106 \ N/C = 71.42\times10^6 \ N$$

The direction of this force takes the same direction of E_c makes angle φ= $9^{\circ}\ 20^{-}\ 56$ measured from +Ve X-axis anti clockwise

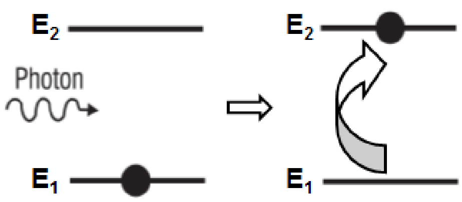
Question (3) (8 marks)

3-a) What does the word "LASER" mean? Explain with schematic diagrams the main characteristics of stimulated absorption, stimulated emission and spontaneous emission of light?

LASER word comes from:

Light **A**mplification by **S**timulated **E**mission of **R**adiation

Stimulated absorption is the process in which an atom absorbs the energy of an incident photon. This causes an electron transition from a lower energy state to a higher energy state.



The rate of stimulated absorption can be given as:

With, $\frac{dN_1}{dt} \alpha N_1$ and, $\frac{dN_1}{dt} \alpha \ \rho$

So, $$\frac{dN_1}{dt} = B_{12} N_1 \rho$$

Where,

N_1 : number of atoms in the lower energy state.

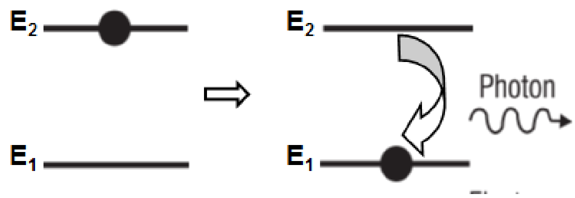
$\rho = \frac{I(v)}{4 \pi c}$ is called the energy density of radiation,

with $I(v)$ is the intensity of the incident radiation.

B_{12} : Stimulated absorption rate coefficient, or,

Einstein coefficient of stimulated absorption.

Spontaneous emission is the process in which an atom undergoes an electron transition from a higher energy state to a lower energy state spontaneously. This causes an emission of a light photon.



The rate of spontaneous emission can be given as:

With, $\frac{dN_2}{dt} \alpha N_2$

So, $$\left.\frac{dN_2}{dt}\right|_{sp} = A_{21} N_2$$

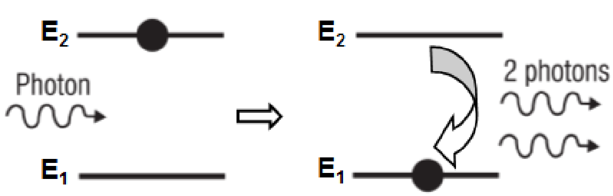
Where,

N_2 : number of atoms in the higher energy state.

$A_{21} = \frac{1}{\tau_{21}}$: Spontaneous emission rate coefficient,
or,
Einstein coefficient of spontaneous emission.

With, τ_{21} is the transition life time from the higher to the lower level.

Stimulated emission is the process in which an atom interacts with the energy of an incident photon. This causes an electron transition from a higher energy state to a lower energy state. Two photons with the same frequency are produced in phase.



The rate of stimulated emission can be given as:

With, $\frac{dN_2}{dt} \alpha N_2$ **and,** $\frac{dN_2}{dt} \alpha \rho$

So, $\frac{dN_2}{dt}\Big|_{st} = B_{21} N_2 \rho$

Where,

N_2 : number of atoms in the higher energy state.

$\rho = \frac{I(v)}{4 \pi c}$ **is called the energy density of radiation,**

with $I(v)$ is the intensity of the incident radiation.

B_{21} : Stimulated emission rate coefficient, or,

Einstein coefficient of stimulated emission.

3-b) If 10 percent of the total population is considered as an "appreciable fraction". What temperature would be needed to obtain such a population if the absorption through these states is in the visible region of yellow light with 600 nm? [$c = 3 \times 10^{8}$ m/s, $h = 6.6 \times 10^{-34}$ J.s, $k = 1.38 \times 10^{-23}$ J/K]

Answer:

$N_2/N_1 = 10\% = 0.1$

$c = 3 \times 10^{8}$ m/s

$h = 6.6 \times 10^{-34}$ J.s

$k = 1.38 \times 10^{-23}$ J/K

$\lambda = 600$ nm $= 600 \times 10^{-9}$ m

$$\frac{N_2}{N_1} = e^{-\frac{h\nu}{kT}}$$

$$\frac{N_2}{N_1} = e^{-\frac{h\,c}{\lambda\,k\,T}}$$

$$\text{Ln}\,(N_2/N_1) = -\,(h\,c / \lambda\,k\,T)$$

$$\text{Ln}\,(0.1) = -\,(6.6 \times 10^{-34} \times 3 \times 10^{8} / 600 \times 10^{-9} \times 1.38 \times 10^{-23}\ T)$$

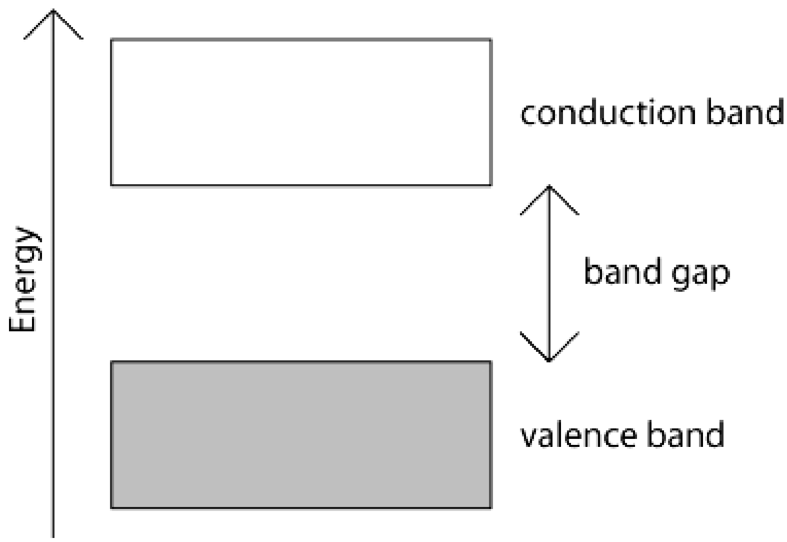
$$T = 10385\ K$$

Question (4) (12 marks)

4-a) Discuss the concept of energy bands to explain the main difference between insulators, semiconductors, and conductors

In case of a single isolated atom an electron in any orbit has definite energy. When atoms are brought together and combine to form molecules as in solids, an atom is influenced by the forces from other atoms. Hence an electron in any orbit can have a range of energies rather than single energy. The range of the energetic levels of atoms is represented by a near-continuum of levels called *energy band*. The energetic levels are occupied by the electrons (distributed according to Pauli Exclusion Principle), starting with the lowest energy value level.

The electrons that contribute to the electrical conduction occupy the higher (partially filled) energy band which is called *the conduction band*. The highest energy band that is fully occupied with electrons is called *the valence band*. The Valence band and conduction band are separated by an energy gap in which no electrons normally exist this gap is called the *forbidden gap*. A conventional form of the energy bands in a solid material is indicated in figure

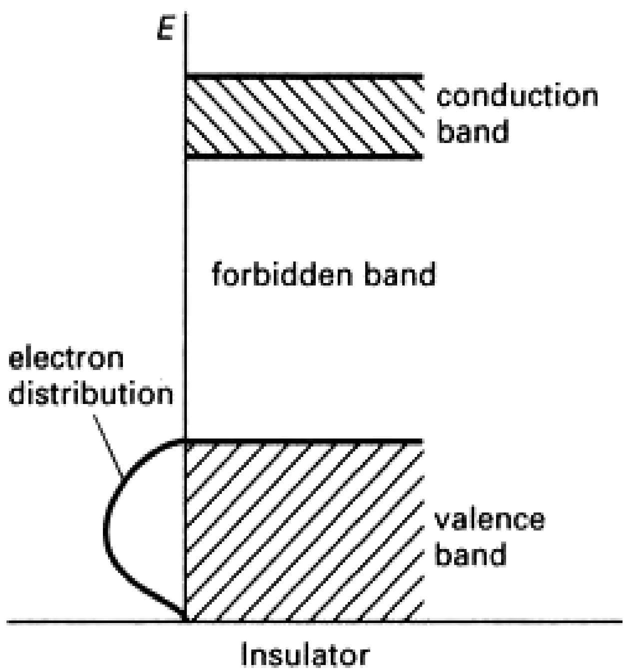


Electrons in conduction band are either escaped from their atoms (free electrons) or only weakly held to the nucleus. Thereby by the electrons in conduction band may be easily moved around within the material by applying relatively small amount of energy; (either by increasing the temperature or by focusing light on the material etc….). This is the reason why the conductivity of the material increases with increase in temperature. But much larger amount of energy must be applied in order to extract an electron from the valence band because electrons in valence band are usually in the normal orbit around a nucleus.

For a given material, the forbidden gap may be large, small or non-existent. According to energy bands, materials can be classified as:

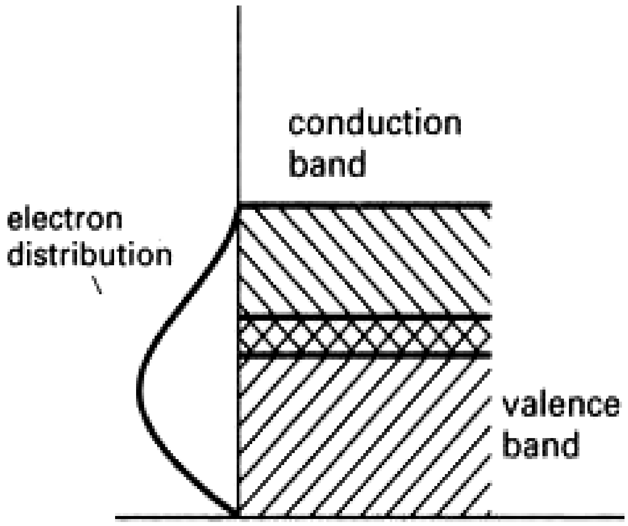
Insulators

In case of insulators, the forbidden energy gap is extremely high. On the other hand its valence band is fully filled with the electrons, whereas its conduction band is empty. For example, in diamond, the approximate value of forbidden energy gap is nearly 6 eV. In normal case, electrons would not acquire enough energy (thermally or optically) to cross the large energy gap of such materials. Thus electrons can not jump into the conduction band, and as a result these materials are insulators.



Conductors

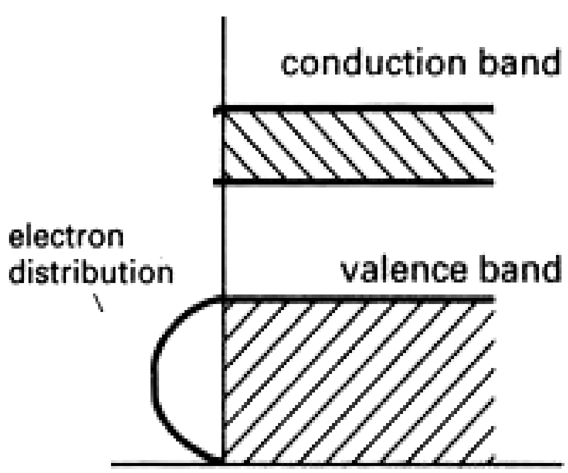
In case of metals, electrons fill the conduction band partially. The overlapping of both the bands (i.e. valence and conduction band) also takes place. For example, iron, copper and all other metals show that no forbidden energy gap is present. Consequently, there is no energy gap to cross in order to reach the conduction band, and any energy that is added to the electron is sufficient to propel it into the conduction band. There are many electrons that are free to move about a conductor, so it is very easy for current to flow if an external electric field is applied.



Conductor

Semiconductors

In case of semiconductors the conduction band is empty and the valence band is fully filled with electrons. The energy gap is very small. This energy gap is nearly of 1eV. For example, in silicon and germanium the energy gap is nearly 1.1 eV and 0.72 eV respectively. At normal temperatures, the thermal (or optical) energy is sufficient to propel some electrons from the valence band into the conduction band, allowing some electrons to be free to conduct current. The number of free charge carriers increases with supplied energy, so the conductivity of a semi-conductor can be manipulated by outside potentials.



Semiconductor

4-b) In Young's experiment, the two slits are placed 0.8 mm apart and the fringes are observed on a screen 90 cm away. It is found that with a certain Laser source of light, the third bright fringe is situated 8.2 mm from the central fringe. (i) Find the wavelength of the light?
(ii) Find the distance of the second dark fringe from the central maximum one?

Answer: 2d = 0.8 mm = 0.8×10^{-1} cm

D = 90 cm

X = 8.2 mm = 8.2×10^{-1} cm

n = 3

(i) $X = n \dfrac{D\ \lambda}{2d}$

$$\lambda = \frac{2d\ X}{n\ D} = \frac{0.8x10^{-1} x\ \ 8.2x10^{-1}}{3\ \ x\ 90} = 2.4x10^{-4}\ \ cm$$

(ii) For dark fringes $X = (n\ -\ 1/2)\dfrac{D\ \lambda}{2d}$

n = 2

$$X = (2\ \ -\ \ 1/2)\frac{90\ x\ 2.4x10^{-4}}{0.8x10^{-1}} = 0.41\ \ cm$$

4-c) What is the importance of nano materials? Discuss “Laser ablation” as an effective method for production of nano particles?

Answer: it is an open question with a free answer depends on students research along with lecture work

GOOD LUCK,

BOARD OF EXAMINERS