END SEM EXAM
NANO MATERIALS(PH401)

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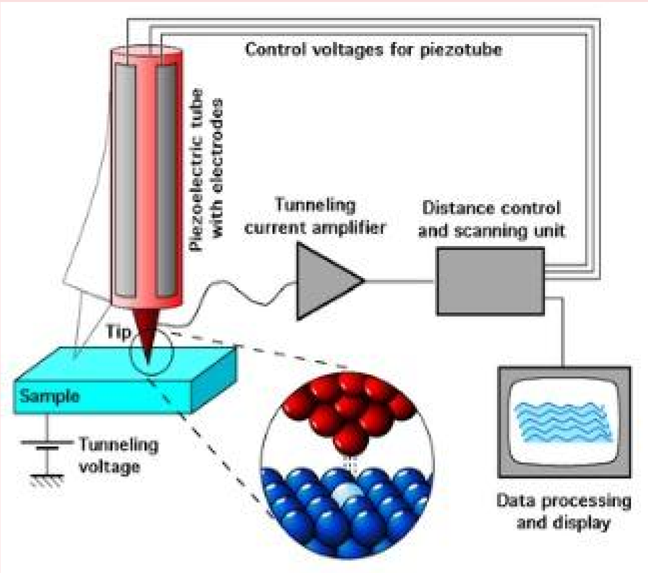
1801CS32

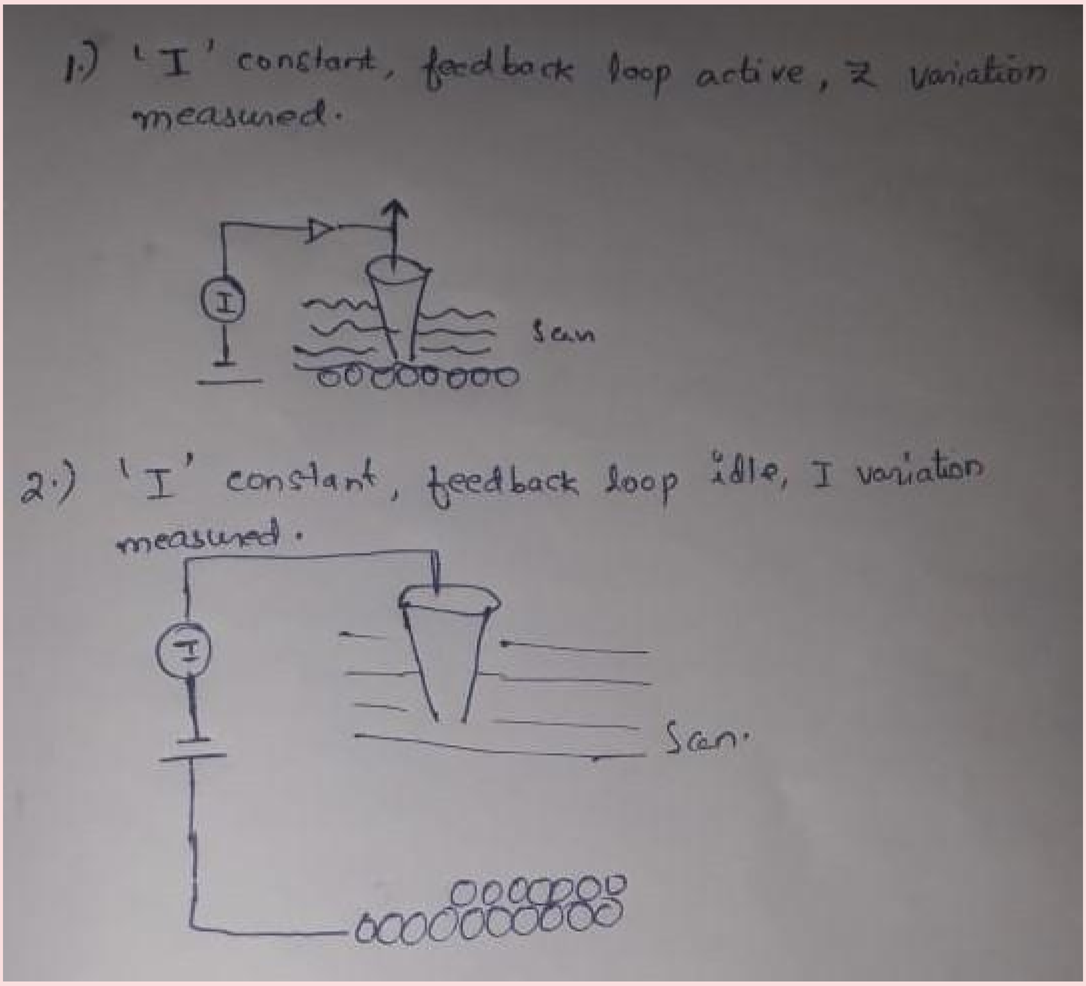
Q1.)

The scanning tunneling microscope (STM) works by scanning a very sharp metal wire tip over a surface. By bringing the tip very close to the surface, and by applying an electrical voltage to the tip or sample, we can image the surface at an extremely small scale – down to resolving individual atoms.

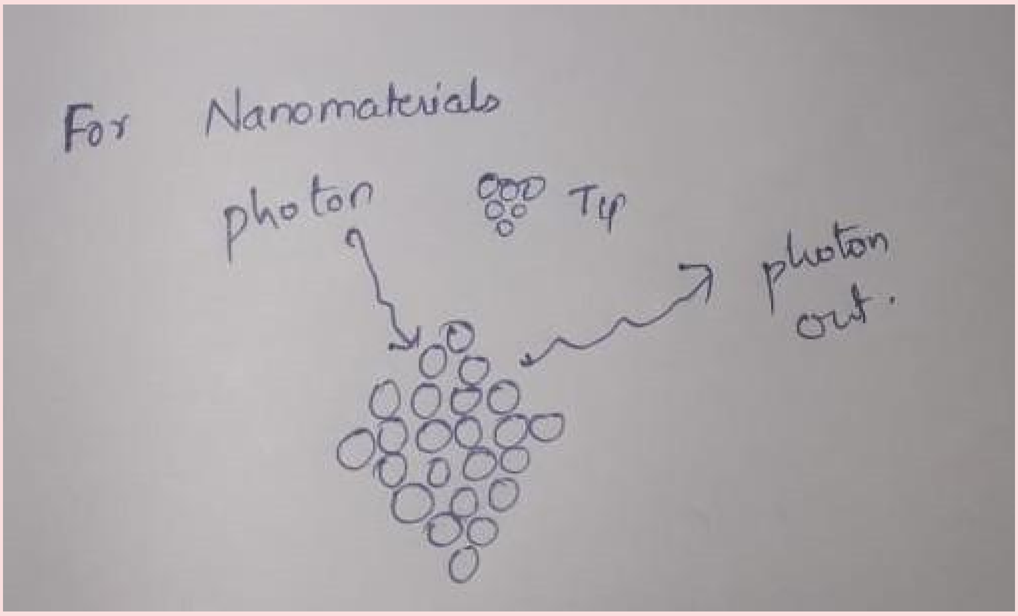
- Basic principle is tunneling ->Tunneling is a quantum mechanical effect. A tunneling current occurs when electrons move through a barrier that they classically shouldn't be able to move through. In classical terms, if you don't have enough energy to move "over" a barrier, you won't.
- Tunneling current flows between tip and sample when separated by less than 100 nm
- The tunneling current gives us atomic information about the surface as the tip scans



There are two ways of forming STM Images. But 1st is preferred in most of the cases



However, STM alone cannot address questions regarding the optoelectronic processes that can occur at the interface. To overcome the limitation, innovative STM strategies, which allow optical imaging and manipulation of light below the diffraction limit



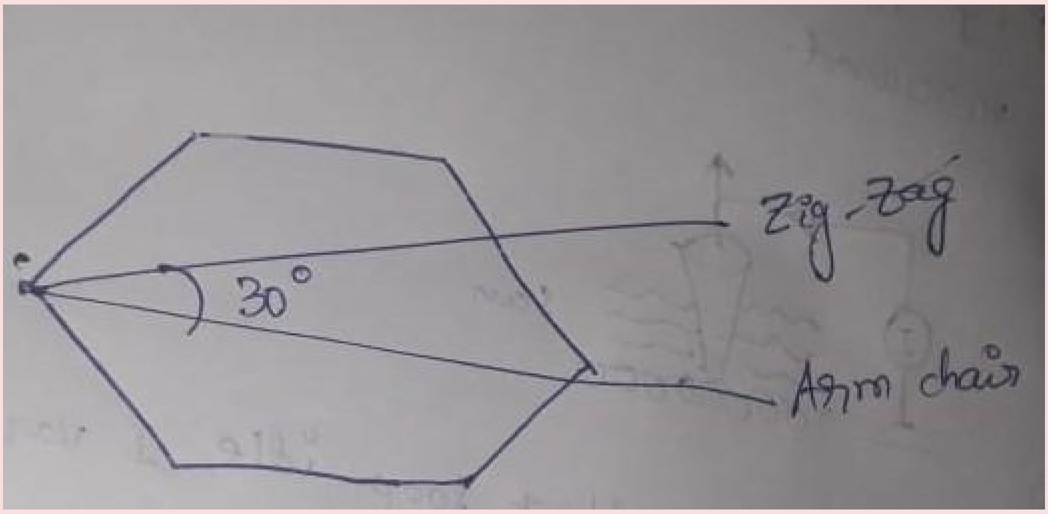
No,We cannot get magnetic domains with STM. The methods for observation are

- MFM -> Magnetic Force Microscopy

- Magento Optical

Q2.)

There are different ways of rolling graphene sheets. Different configurations of rolling the sheet will give rise to different translational vectors pointing in separate directions. In the zigzag tube, the graphene hexagons point along the long axis of the tube. In the armchair tube, the flat side of the hexagon lies along the long axis of the tube. In the chiral nanotube, the configuration lies between the above two mentioned extremes. This can be depicted in the diagram shown below.



We see that, in this diagram, the maximum angle between the translational vectors of the zigzag and the armchair nanotubes is always 30 degrees.

We are given four (n, m) configurations of nano-tubes, we find the angle of helicity and the diameter using the following formulae: -

Angle of helicity:

$$\theta = \sin^{-1} \frac{\sqrt{3}m}{2\sqrt{n^2 + nm + m^2}}$$

Diameter: -

$$D = \frac{|C_h|}{\pi} = \frac{a_{CC}\sqrt{3(n^2 + m^2 + nm)}}{\pi},$$

where

$$\underset{\text{(graphite)}}{1.41\text{ Å}} \le a_{C=C} \le \underset{(C_{60})}{1.44\text{ Å}}.$$

Also, it can be said a carbon nanotube is conducting in nature if the value of *“n-m” is a multiple of 3* ***[n-m =3q]***

So from the question, we can find out the following:-

Sl.no	**(n, m)**	**Diameter (in nm)** **$A_{C=C}$ = 1.41A**	**Angle of helicity** **(degrees)**	**|n-m|**	**Electrical Conductivity**
1	**(4, 12)**	**1.121**	**46.10**	**8**	**Semi-Conducting**
2	**(3, 13)**	**1.145**	**49.83**	**10**	**Semi-Conducting**
3	**(18, 18)**	**2.42**	**30**	**0**	**Yes**
4	**(14, 0)**	**1.088**	**0**	**14**	**Semi-Conducting**

Q3.)

Given, XRD Pattern for steel with 4% carbon added to the iron matrix. Thus, it is a Medium Carbon Steel with FCC crystal structure.

Now, for the given table, using Scherrer’s formula,

$$D = \frac{k\lambda}{B\cos\theta}$$

where,

D = Average Crystallite size

 = Wavelength (1.54 Å)

B = FWHM (deg)

k = 0.94

Putting values in the above equation we get the crystallite sizes for the given data as:

2theta(deg)	Intensity (CPS)	FWHM (deg)	D (nm)

26.53	100	0.237	35.94
44.58	900	0.345	25.97
55.00	40	0.421	22.20
64.98	152	0.332	29.61
82.29	332	0.384	28.68

Thus, from the above data we can interpret that the peaks corresponding to:

Carbon – 40 (Intensity)

Iron – 100 (Intensity)

And, the crystallite sizes in the composite of:

Carbon – 20.2 nm

Iron – 35.94nm

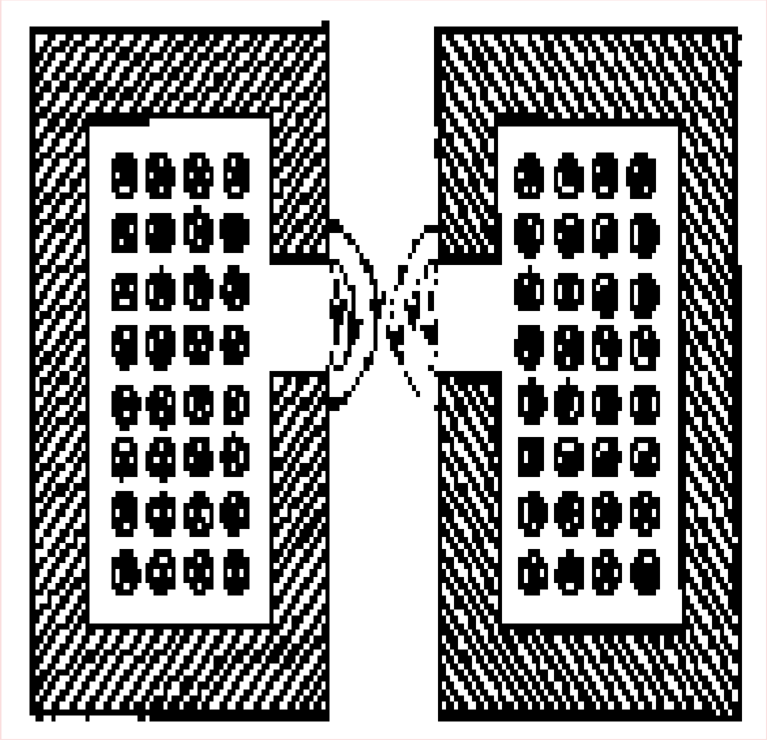
Q4.)

A magnetic lens is a device for the focusing or deflection of moving charged particles, such as electrons or ions, by use of the magnetic Lorentz force. Its strength can often be varied by the usage of electromagnets. They are prominently used in cathode ray tubes, electron microscopy, particle accelerators etc.

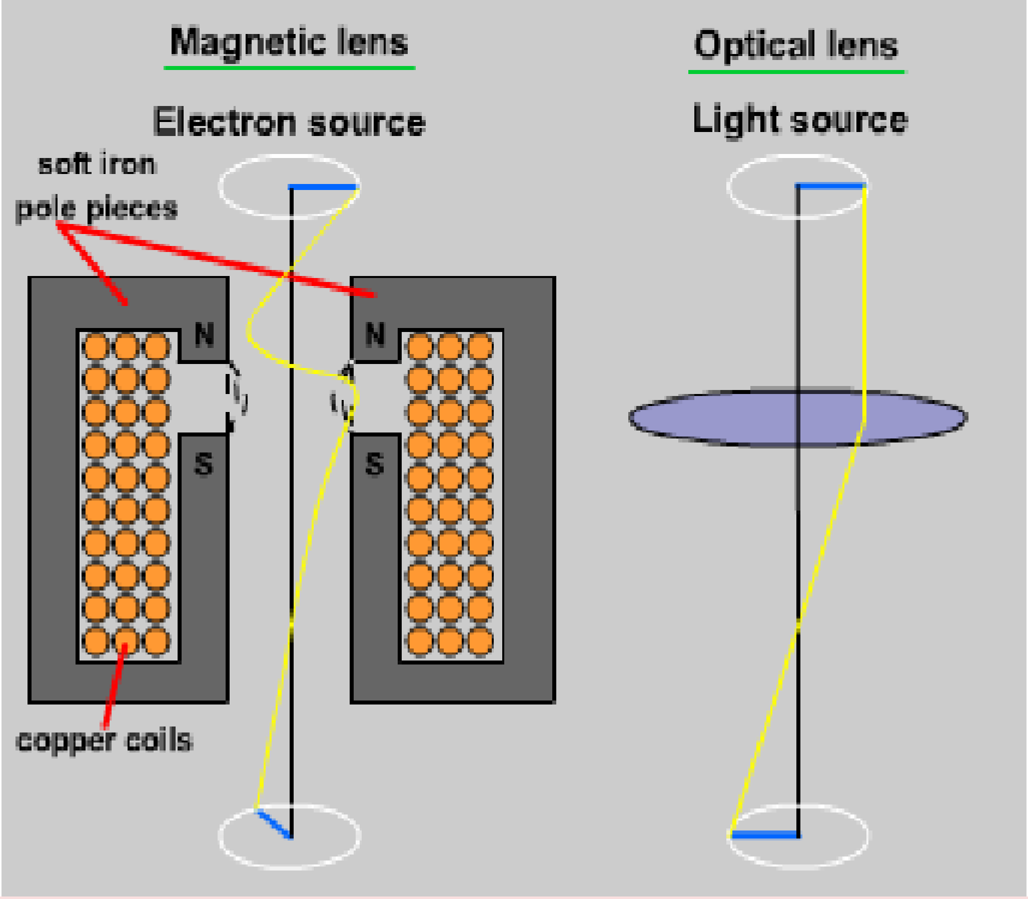
In classical microscopes, whatever is observed by the naked eye is treated as observation. Due to this, the errors in observation are comparatively less significant. But in nanomaterials or nanoscience, there is a need for high accuracy. Even an error of the order of nanometers is considered a significant error. This is the reason why magnetic lenses are used in Transmission Electron Microscopes (TEMs). Magnetic Lenses can precisely control the flow of the electrons emitted by the electron gun in a TEM, which is important for getting a precise output. Hence, the design of a magnetic lens for a TEM is of high importance.

Design of Magnetic Lens:

1. The magnetic lens consists of a tightly wound coil and a soft iron shroud surrounding the coil except for a small gap. The field is concentrated in that gap.



2. The given magnetic field generated through the coil will act as a lens and would converge the electron on the sample.



3. The Magnetic lenses used in TEMs are always constructed with an iron circuit to produce a high field strength across a short gap.
4. The magnetic fields for TEM lenses are in the range of 10,000 - 20,000 gauss.
5. The focal length for the magnetic lens could be calculated using the formula below:

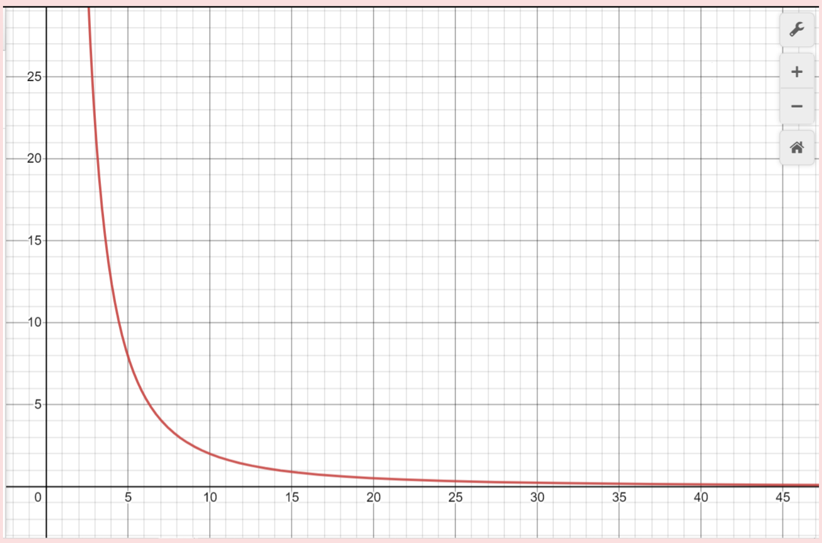
$$f = KV_r/(N \cdot I)^2$$

Where f is the focal length of the magnetic lens,
K is a constant that is dependent on the dimensions and environment of the setup
Vr is the accelerating voltage and is given to be 200KV
N is the number of turns in the coil, and
I represent the current.

6. As evident from the formula, the focal length of the magnetic lens can be altered by changing the strength of the current.

Plotting focal length vs. current
In the above formula for focal length, only Vr is known to be 200kV. Other parameters like K and N depend on the TEM setup. Hence, I have plotted the focal length in terms of K and V in the following manner.

f = 2*(10^5)*K/N^2 * (1/I^2)



On the Y-axis, we have focal length, in terms of K, N and on the X-axis we have current I in amperes.

How will it help the operator with imaging?

If the operator under focuses the specimen, a bright ring may form around the image. If the operator overfocused the specimen, a dark ring may form around the image. So, the operator needs this graph to figure out the right focal length of the magnetic lens to properly focus on the specimen and avoid any rings in the magnified image.

Since changes in current affect the focal length, the operator will be able to determine the correct strength of the current to focus the specimen properly.

Q5.)

There is no electromagnetic radiation used for AFM (Atomic Force Microscopy) since no electromagnetic radiation is used while measuring the micrograph or atomic surface of the sample since the atomic forces are only considered. The tip of the probe (part of the atomic force microscope) is brought very near to the sample so that it is similar to the atomic range, then atomic forces occur between the sample and the tip and using those forces the depths at various parts could be found out and electromagnetic radiations are not at all used. If the tip is nearer to the surface more force is experienced and if away from the surface less force is experienced and the profile is thus generated.

Many kinds of forces can be measured between the atoms such as:

1) Van Der Waals forces

2) Electric forces

3) Magnetic forces

4) Torsional resistance

5) Capacitance

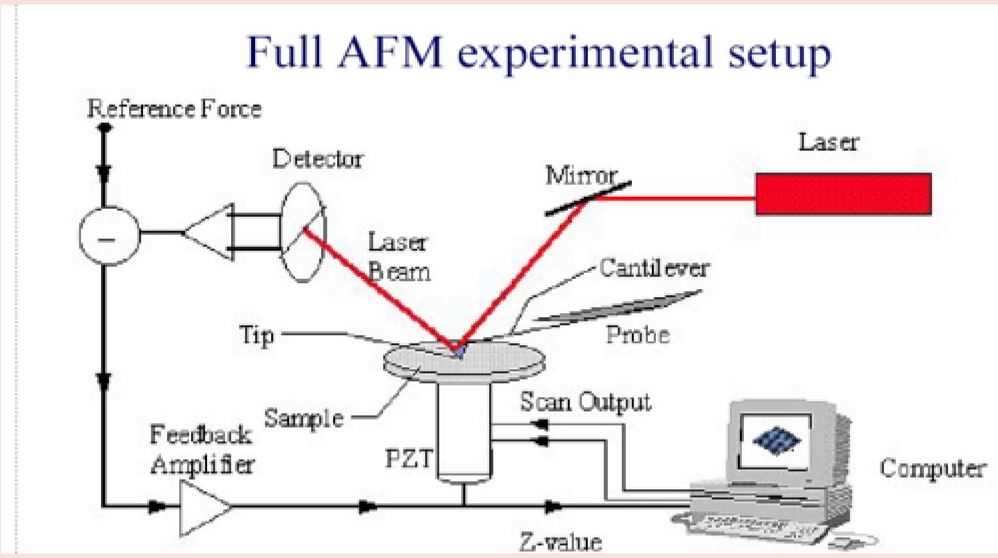
6) Conductive atomic forces.

2 detectors are used in the AFM imaging minimum: -

1) Photo-diode

2) Feedback Voltage

The surface profile can be measured in 2 ways inside the AFM, either by keeping the current constant inside the photo-diode or by keeping the distance between the probe and the surface constant.



In the above diagram, there is a laser that strikes the mirror and then is reflected from the tip which moves over the surface. Then the reflected beam is incident on a photodiode which measures the current. Now here the feedback amplifier gives the voltage between the sample and the tip.

Case 1:

So, if the distance between the tip and surface needs to be constant, the voltage is kept constant since the distance depends on the voltage. Now, if the distance is constant, the tip goes up and down depending on the surface profile, since the surface is not smooth at the nanoscale, and hence it deflects so the laser beam which reflects from the tip also changes and the current changes on the photo-diode is recorded.

Case 2:

But if the tip should be moving at the same line and should not deflect voltage needs to be changed such that it does not deflect and moves in a particular straight motion. So It does not deflect and the reflected light beam is totally constant and there is constant current detection. But here the surface is detected by voltage.

So, the surface can be detected either by changing the voltage or detecting the changing current of either one of them.

Q6.)

Q6.) Given nan-composite of form $Fe_{1-x}Co_x$

Let us assume there are $(a+b)$ moles of the nano composite [a moles of Fe & b moles of Co]

$$\Rightarrow \frac{a}{a+b} = 1-x \quad \& \quad \frac{b}{a+b} = x$$

now taking Fe

$$a = \frac{W_{Fe}}{M_{Fe}}$$

[W → Total weight
M → Molecular mass]

[$\frac{Mass}{Volume} = Density$]

$$\Rightarrow a = \frac{\rho_{Fe} V_{Fe}}{M_{Fe}}$$

$$\Rightarrow V_{Fe} = \frac{a M_{Fe}}{\rho_{Fe}}$$

Similarly for Co

$$V_{Co} = \frac{b M_{Co}}{\rho_{Co}}$$

Determining the Volume fractions (VF)

$$VF_{Fe} = \frac{V_{Fe}}{V_{Fe} + V_{Co}} = \frac{a M_{Fe} \rho_{Co}}{a M_{Fe} \rho_{Co} + b M_{Co} \rho_{Fe}}$$

↳ Dividing Numerator and denominator by a+b

$$\Rightarrow V_{F_{Fe}} = \frac{(1-x) M_{Fe} \rho_{Co}}{(1-x) M_{Fe} \rho_{Co} + x M_{Co} \rho_{Fe}}$$

As

$$V_{F_{Fe}} + V_{F_{Co}} = 1$$

$$\Rightarrow V_{F_{Co}} = \frac{x M_{Co} \rho_{Fe}}{(1-x) M_{Fe} \rho_{Co} + x M_{Co} \rho_{Fe}}$$

For nano composites we know that

a) Tensile strength (σ_{eff})

$$\Rightarrow \sigma_{eff} = \frac{\sigma_{Fe} \sigma_{Co}}{\sigma_{Fe} \times V_{F_{Co}} + \sigma_{Co} \times V_{F_{Fe}}}$$

b) Young's modulus (Y_{eff})

$$\Rightarrow Y_{eff} = \frac{Y_{Fe} Y_{Co}}{Y_{Fe} \times V_{F_{Co}} + Y_{Co} V_{F_{Fe}}}$$

c) Magnetic moment (μ_{eff})

$$\mu_{eff} = \frac{\mu_{Fe} \times \mu_{Co}}{\mu_{Fe} \times V_{F_{Co}} + \mu_{Co} V_{F_{Fe}}}$$

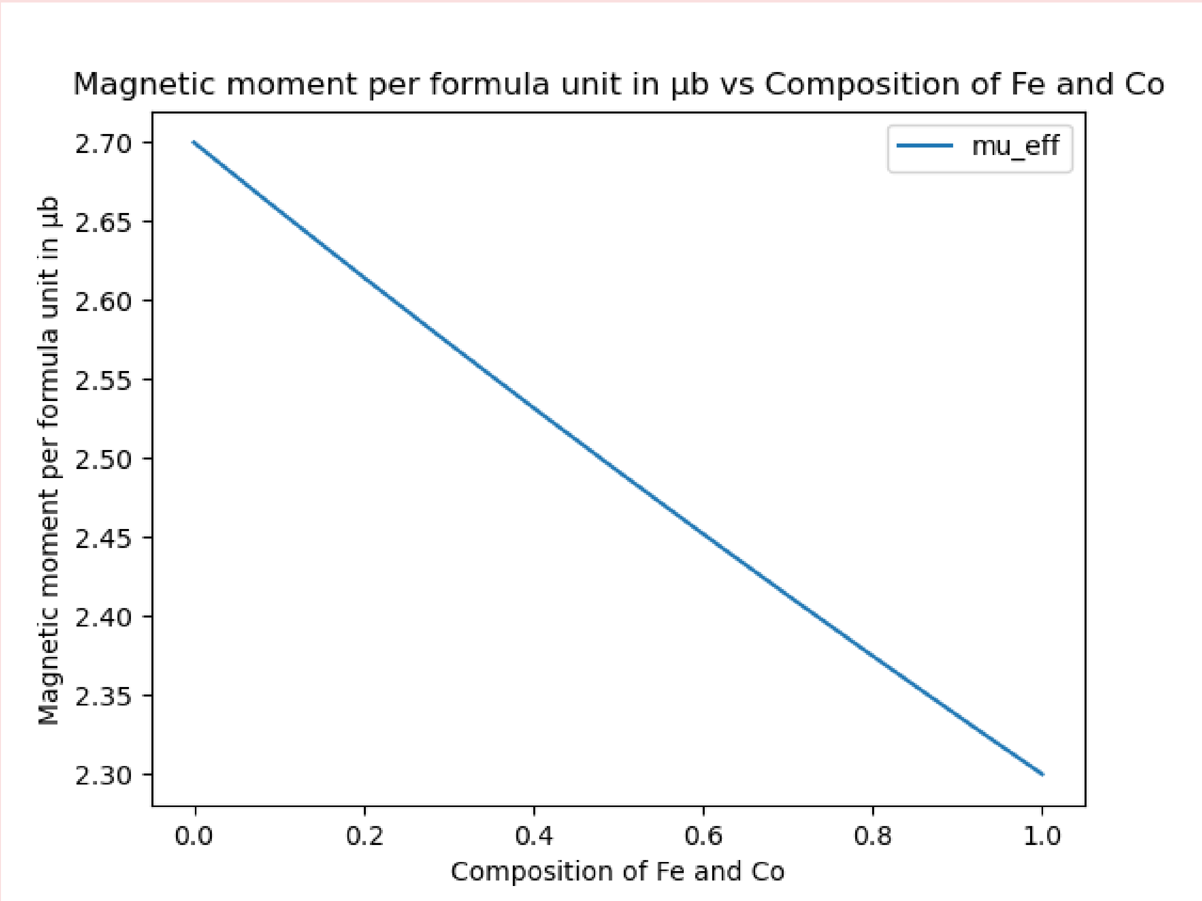
Substituting the following values.

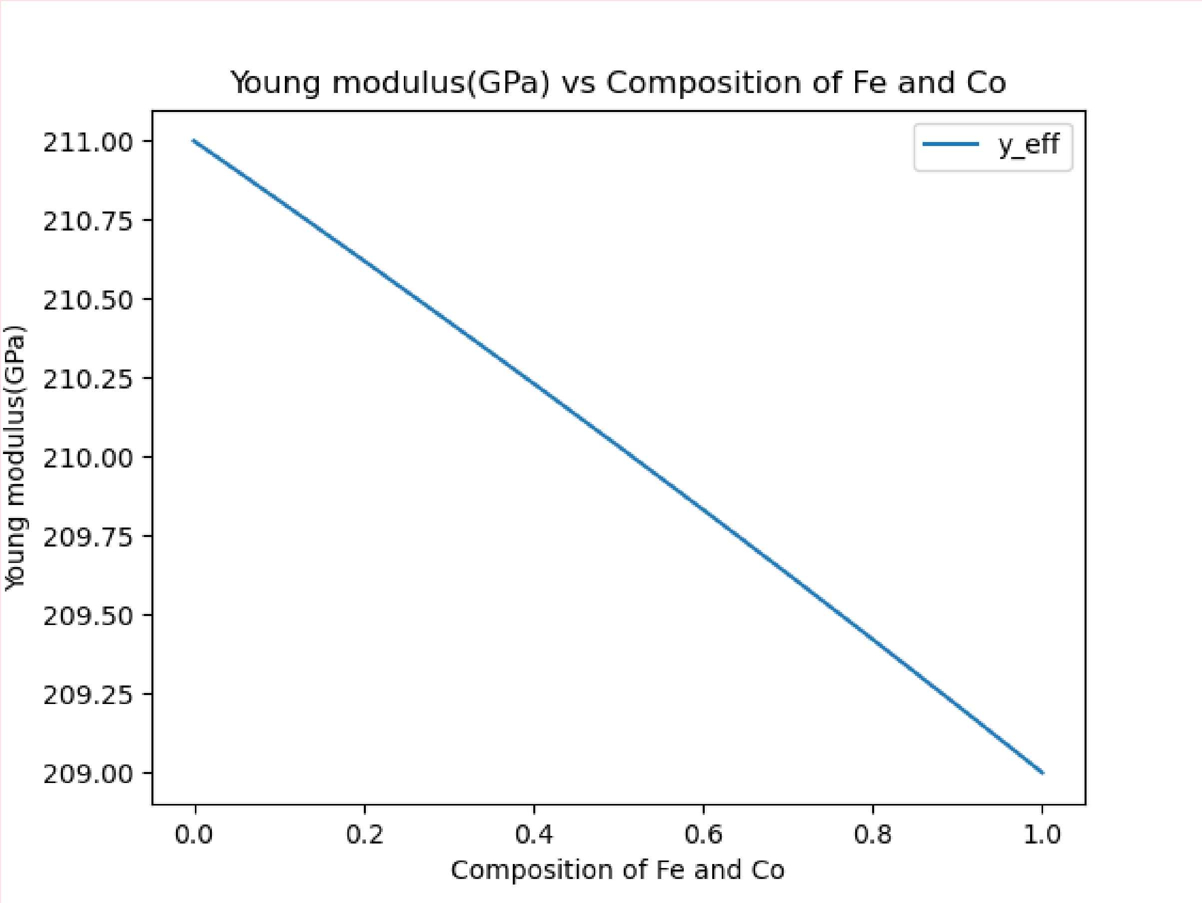
$\sigma_{Fe} = 540\ MPa$, $\sigma_{Co} = 800\ MPa$, $Y_{Fe} = 211\ GPa$

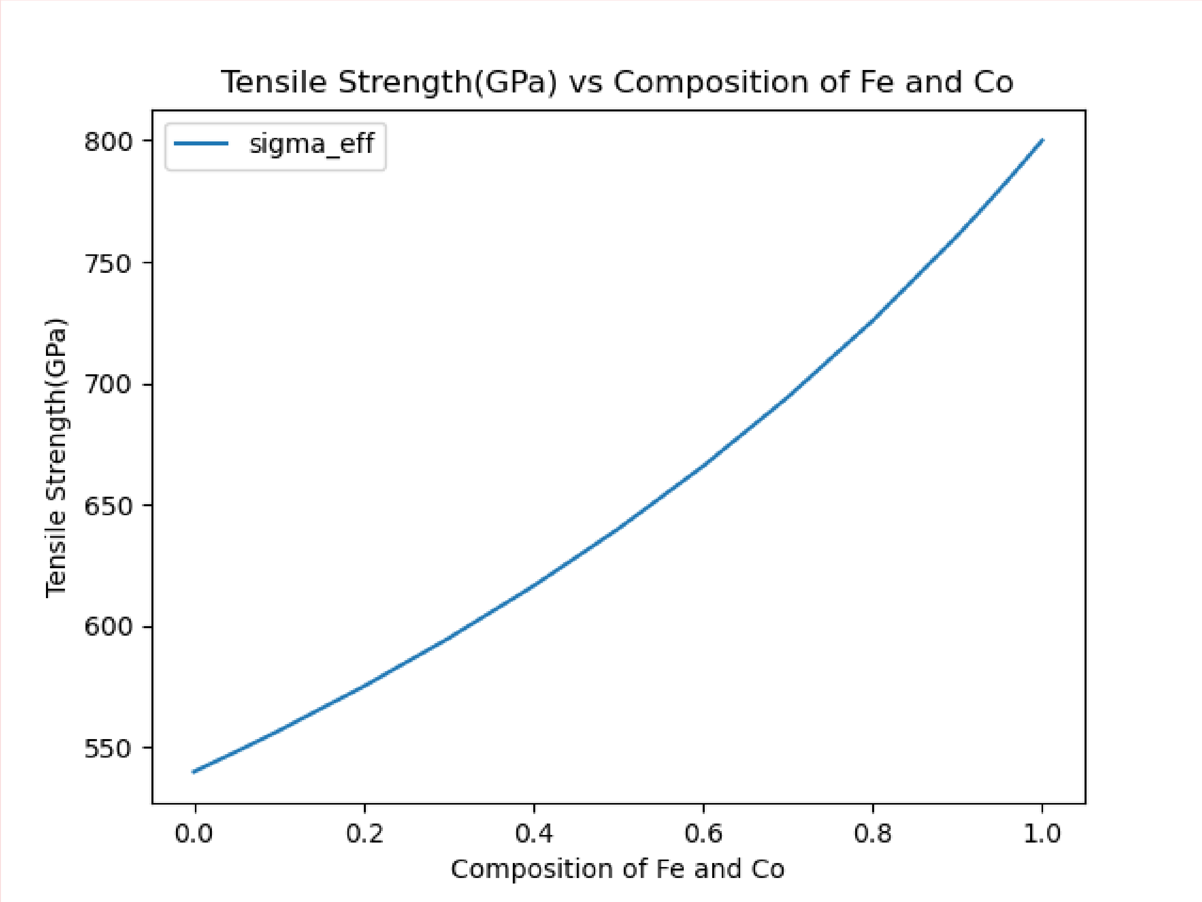
$Y_{Co} = 209\ GPa$, $\mu_{Fe} = 2.7\ \mu_B$, $\mu_{Co} = 2.3\ \mu_B$

$M_{Co} = 58.93\ u$, $M_{Fe} = 55.85\ u$, $\rho_{Fe} = 7.8 \times 10^3\ kg/m^3$

$\rho_{Co} = 8.9 \times 10^3\ kg/m^3$,




Young modulus(GPa) vs Composition of Fe and Co
y_eff
Young modulus(GPa)
211.00
210.75
210.50
210.25
210.00
209.75
209.50
209.25
209.00
0.0
0.2
0.4
0.6
0.8
1.0
Composition of Fe and Co


Tensile Strength(GPa) vs Composition of Fe and Co
sigma_eff
Tensile Strength(GPa)
800
750
700
650
600
550
0.0
0.2
0.4
0.6
0.8
1.0
Composition of Fe and Co

Q7.)

Advantages:

Magnetic Memory Device:

1) Capable of storing large amounts of data - up to 1 Terabyte per tape cartridge.
2) Data is not lost when the computer is switched off.
3) A cheap form of data storage.
4) Less cumbersome than multiple optical disks.

Magnetoresistive memory device:

1) Non-volatility
2) Infinite endurance.
3) High-speed performance.
4) Low cost
5) More compactness due to the use of nanomaterials
6) Greater reliability due to the use of nanomaterials

Disadvantages:

Magnetic Memory Device:

1) Serial access can be quite slow to access data.
2) Requires a large amount of power.
3) Data may be corrupted if the tape is placed near a magnetic field like a large speaker.
4) Need a special piece of equipment to record and read the data on the tape.

Magnetoresistive memory device:

1) Has first-generation selectivity and scalability problems.
2) Memory technology is not scalable at the 32 nm node.
3) The magnetization of nanomaterials is flipped back and forth because these devices utilize heavily spin-polarized current and there is no applied magnetic field.

Q8.)

I took the course of PH 401 this semester and have learnt many basic concepts like Quantum effect,Nanotechnology in nature and its overview .

In this course i have learnt many new concepts :

- Theory of Nanomaterials
- Synthesis of Nanomaterials
- Realizing Nanomaterials
- Applications of Nanomaterials
- Magnetic Properties of Nanomaterials are used in making storage devices like

I have also learnt regarding the diversity in nano field and concepts of Carbon nanotube in detail from lectures

I have learnt most of the concepts of Quantum effect like To-down method of preparation, lithographic method,bottom-up method and few other concepts like Non reflective surfaces,self cleaning,super-hydro phobicity,surface plasmon resonance by taking this course.
The most interesting thing I learnt in the course about the medical application of Nanomaterials. I found that Nanomagnets can be used to enhance signals from magnetic resonance imaging (MRI). Also, nanotech is used in Diagnostics, Separation of red cells from blood, Cancer cells from bone marrow.

Finally ,I got a brief insight about nanomaterials and their applications in the real world and their importance.