Sol.1 (a) For FCC $=\dfrac{4\times\frac{4\pi}{3}\left(\frac{a}{2\sqrt{2}}\right)^3}{a^3}=\dfrac{\pi}{3\sqrt{2}}=.74$

For HCP $=\dfrac{6\times 3\sqrt{3}\,a^2c/2}{a^3}$ where $c/a=\sqrt{8/3}$

$$=\frac{6\times 3\sqrt{3}\,a^3\sqrt{8/3}}{2a^3}=0.74$$

HCP has 12 atoms at corner and 3 atom at centre of body and 2 at faces.

No. of atoms $=\dfrac{2}{2}+3+12/6=6$

Sol.1 (b) $d=\dfrac{a}{\sqrt{h^2+k^2+\ell^2}}$ $\qquad r=\dfrac{a\sqrt{3}}{4}$

$$a=\frac{4}{\sqrt{3}}r$$

$$d=\frac{1.06\times 4/\sqrt{3}}{\sqrt{2}}=1.73\text{Å}$$

Sol.1 (d) Active:
- Piezo electric
- Thermo Couple
- Photo voltaic cell/Photo conductive material
- Tacho generator

Sol.2(a) In case of elemental solid dielectric $E_i=E+\dfrac{P}{3\varepsilon_0}$

where $P\rightarrow$ Polarization Vector $\qquad P=\dfrac{p_{ind}}{b^3}$

In case of elemental solid dielectric value of internal field is (↑) due to presence of adjacent atoms. Claussius Mosotti is valid for elemental solid dielectric eg. Si, Ge, diamond.

$$E_i=E+\frac{P}{3\varepsilon_0}$$

Here $\quad P=Np=N\alpha_e E_i$ so $\quad P=N\alpha_e\left(E+\dfrac{P}{3\varepsilon_0}\right)$

Put $\quad P=\varepsilon_0(\varepsilon_r-1)E$

$$\varepsilon_0(\varepsilon_r-1)\cancel{E}=N\alpha_e\cancel{E}+\frac{N\alpha_e}{3\cancel{\varepsilon_0}}\cdot\cancel{\varepsilon_0}(\varepsilon_r-1)\cancel{E}$$

$$\rightarrow\qquad \varepsilon_0(\varepsilon_r-1)=N d_e\left(1+\frac{\varepsilon_r-1}{3}\right)$$

$\therefore \qquad \boxed{\dfrac{\varepsilon_r - 1}{\varepsilon_r + 2} = \dfrac{N d_e}{3\varepsilon_0}}$

Assumption:

1. This equation is valid only for elemental solid dielectric only.
2. It can be assumed that molecule is isotropic.
3. It is also assumed that polarizability is also isotropic.

Sol.2 (b) Essential condition $\rightarrow$ lack of centre of symmetry

when a mechanical stress is applied on a piezeo electric material then it becomes electrically
polarized it has inverse effect also i.e. when a voltage is applied across a piezeo electric then this material becomes strained, where this strain is proportional to applied field.

Piezeo electric materials must not have centre of symmetry. So essential condition for Piezeo electric is Lack of centre of symmetry.

$$\begin{array}{ccccc} \oplus & \ominus & \oplus & \ominus & \oplus \\ \ominus & \oplus & \ominus & \oplus & \ominus \\ \oplus & \ominus & \oplus & \ominus & \oplus \end{array}$$

If there is centre of symmetry then net dipole moment will zero.

Examples of piezo electric materials are**:** Quartz, Rochelle salt, KDP, $BaTiO_3$ etc.

Sol.2 (c) (i) $\vec{P} = \dfrac{1}{10\pi}\left(3\vec{a}_x - \vec{a}_y + 4\vec{a}_z\right)\times 10^{-9}\,\text{c/m}^2$

Here $\vec{E} = 5\vec{a}_x$ V/m so $\vec{P} = \varepsilon_0\left(\varepsilon_r - 1\right)\vec{E}$

$$\frac{3}{10\pi}\times 10^{-9} = \varepsilon_0 \cdot X_e \cdot 5$$

$$X_e = \frac{3\times 10^{-9}}{50\pi\varepsilon_0} = \frac{3\times 4}{50}\times 9\times 10^{9}\times 10^{-9} = \frac{108}{50} = \left(2.16\right)$$

(ii) $$E_i = E + \frac{P}{3\varepsilon_0} = 5 + \frac{1}{3}\times\frac{\cancel{\varepsilon_0}\,X_e E}{\cancel{\varepsilon_0}} = 5 + \frac{1}{3}\times 2.158\times 5 = 8.5967\left(\text{V/m}\right)$$

(iii) $$D = \varepsilon_0\,\varepsilon_r\,E_i = \varepsilon_0\left(1\times X_e\right)E_i = 8.86\times 10^{-12}\times\left(3.158\right)\times 8.5967$$

$$D = 0.24\left(\text{c/m}^2\right)$$

Sol.3 (a) Materials are classified as:

	X_m
1. Diamagnetic	-10^{-5}
2. Paramagnetic	$+10^{-3}$
3. Ferromagnetic	$+10^{3} - 10^{5}$
4. Ferri Magnetic	$10 - 10^{2}$
5. Anti Ferro	$10^{-1} - 10$

Ni $\rightarrow$ Ferromagnetic

Ag, NaCl $\rightarrow$ Diamagnetic

Tungston $\rightarrow$ Paramagnetic

Ni is a Ferromagnetic so it requires least value of magnetic strength to magnetize it

Sol.3 (b) $B = \mu_0 (M + H)$

But $B = \mu_0 \mu_r H$

$\therefore \quad \cancel{\mu_0} \mu_r H = \cancel{\mu_0} (M + H)$

$M(\mu_r - 1)H$

If $B_1 = 2 \text{wb/m}^2$ & $H_1 = 1200$ $\qquad \mu_1 = \dfrac{2}{1200} = \mu_0 \mu r_1$

Similarly $1.4 = \mu_2 \times 400$ $\qquad \mu_2 = \dfrac{1.4}{400} = \mu_0 \mu r_2$

$$M_1 = \left(\frac{2}{1200\mu_0} - 1\right) H_1 \;\&\; M_2 = \left(\frac{1.4}{400\mu_0} - 1\right) H_2$$

$M_1 = 1590348 \;\&\; M_2 = 1113684$

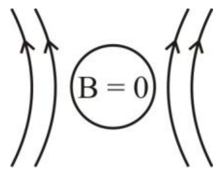
$$\%\text{ change} = \frac{M_1 - M_2}{M_1} = 30\%$$

Sol.3 (c).
1. Hard magnetic material has high coercive force but soft magnetic material has low coercive force
2. Hard magnetic requires high remnant flux density but soft
3. It is difficult to demagnetize hard magnetic but easy in case of soft.
4. Hard magnetic materials are used for hard magnet but soft for electromagnets

Sol.4(a) There are certain materials whose resistivity drops to zero when they are cooled beyond a certain temperature known as transition temp.

eg. In case of Hg this value is 4.12 K

Meissner Effect



When ever a super conductor is placed in a magnetic material then magnetic field will be repelled.

For a super conductor $(\rho = 0)$

But $J = E = 0$

So $E = \dfrac{J}{\sigma} = J = 0$

By Maxwell equation

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$$\nabla \times E = -\frac{dB}{dt} \qquad \text{But} \qquad E = 0 \quad \therefore \quad \frac{dB}{dt} = 0$$

$\therefore \qquad B = \text{constant}$

But Acc. to Meissner effect B = 0

So Both contradict each other.

Sol.4 (b) $H_C(T) = H_C(0)\left(1-(T/T_C)^2\right) = 64\times10^3\left(1-\left(\frac{5}{10.8}\right)^2\right)$

Sol.4 (c) 1. Generation of strong magnet

2. Used in Memory
3. As switch
4. High speed train

Sol.5 (a) $k\theta = \frac{I^2}{2}\cdot\left(\frac{dL}{d\theta}\right)$

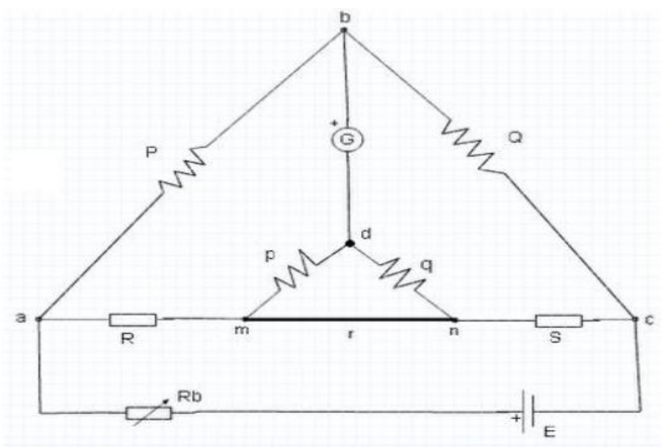
Here $\frac{dL}{d\theta} = \left(3-\frac{2\theta}{4}\right)\times10^{-6}$

So $25\times10^{-6}\theta = \left(3-\frac{2\theta}{4}\right)\times\frac{25}{2}\times10^{-6}$

$\therefore \qquad 2\theta = 3-\frac{\theta}{2} \qquad 2.5\theta = 3 \qquad \therefore \quad \theta = 1.2$ Radian

Sol.5 (b)

We aim to measure the resistance of a given resistor using Kelvin Double Bridge and determine its tolerance. Kelvin Double Bridge is nothing but a modification of Wheatstone bridge. It is used for measuring of low resistance to a good precision. It compares two ratio arms P,Q and p,q and hence is called 'double bridge'.



P, Q, p, q are the resistances in the ratio arms. G is a galvanometer of D'Arsonal type, used as a null detector. S is a small standard resistor, R is a resistance under measurement. Usually low resistance consists of four leads. Two of them are called as voltage leads and remaining as current leads. "r" is the resistance of connecting lead between R and S.

Under balanced conditions,

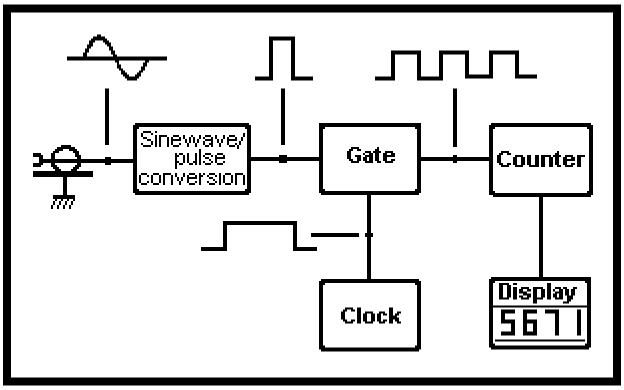
$$E_{ab} = E_{amd}$$

$$E_{ac} = I\left[R + S + \frac{(p+q)r}{p+q+r}\right]$$

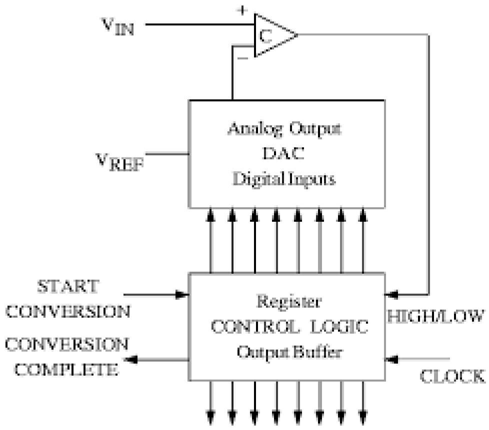
$$By\,equating\; E_{ab} = E_{amd}\; we\; get\;, R = \frac{P}{Q}S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]$$

From the above equation, it is clear that the resistance of connecting leads "r" has no effect on the measurement if the two sets of ratio arms have equal ratios ie, P/Q = p/q.

Sol.6 (a) Block Diagram of Digital Frequency Meter:



Sol.6 (b) Block Diagram of Successive Approximation ADC:



Sol.6(c) Absolute error $= 4.65 - 4.7 \quad = -0.05\,\text{k}\Omega = -(50\Omega)$

2. % error $= \dfrac{50}{4.7\times10^3}\times100 = 1.06\%$

3. % accuracy $= 1 - 1.06 = 98.94\%$

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Sol.7 (a) Multiply factor $= \frac{10}{1} = 10$

$$R_{sh} = \frac{R_m}{m-1} = \frac{5}{10-1} = \left(\frac{5}{9}\right)\Omega$$

$$= 0.55\Omega$$

Sol.7(b) $\Delta R = 0.2\Omega$

$R = 120$

$$k = \frac{(\Delta R/R)}{(\Delta \ell/\ell)}$$

$$\Rightarrow \quad \frac{\Delta \ell}{\ell} = \frac{(0.2/120)}{3} = \left(\frac{0.2}{260}\right)$$

$$F = Y.A.\left(\frac{\Delta \ell}{\ell}\right)$$

$$\frac{F}{A} = \frac{2.1\times10^6\,\text{kg}}{\text{cm}^3} \times \frac{0.2}{260}$$

$$= 11.655\times10^2\ \text{kg/cm}^2$$

Sol.7(c) $R_T = R_A \exp(B/T)$

$$4567 = R_A \exp(B/300) \qquad \text{— (1)}$$

$$4134 = R_A \exp(B/303) \qquad \text{— (2)}$$

$$B = (3018.2)$$

$$R = 4134\, e^{3018.2(1/318 - 1/303)} = 2584.1$$

Sol.7 (d)