APPLIED PHYSICS HANDBOOK

PHYSICAL CONSTANTS AND FORMULAE

Basic Sciences and Humanities (Physics) Composite Board
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Contents

Part I

PHYSICAL CONSTANTS and STANDARD VALUES

Chapter 1

Physical constants and Standard Values for all Streams

1.1 Physical Constants

Acceleration due to Gravity $g = 9.8\ ms^{-2}$

Avogadro Number $6.023 \times 10^{26}\ Jkmole^{-1}K^{-1}$

Boltzmann Constant $k = 1.38 \times 10^{-23}\ JK^{-1}$

Charge on the electron $e = -1.6 \times 10^{-19}\ C$

Charge on the Proton $e = 1.6 \times 10^{-19}\ C$

Magnetic Peameability of Free Space $\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$

Permittivity of Free Space $\epsilon_0 = 8.854 \times 10^{-23}\ Fm^{-1}$

Planck's Constant $h = 6.625 \times 10^{-34}\ Js$

Rest Mass of the Electron $m_e = 9.1 \times 10^{-31}\ Kg$

Rest Mass of the Proton $m_p = 1.6726 \times 10^{-27}\ Kg$

Rest Mass of the Neutron $m_n = 1.6749 \times 10^{-27}\ Kg$

Speed of Light $c = 3 \times 10^{8}\ ms^{-1}$

Universal Gas constant $R = 8.314 Jmole^{-1}K^{-1}$

1.2 Stadard Values

Youngs Modulus of Steel $E = 200GPa$

Rigidity Modulus of Steel $K = 80GPa$

Bulk Modulus of Steel $K = 160GPa$

Fermi Energy of Copper $E_F = 7eV$

Horizontal Component of Earth's Magnetic Field $B_H = 0.3 \times 10^{-4}T$

Part II

FORMULAE

Chapter 2

Applied Physics for CSE Stream

2.1 Module-1 : LASER and Optical Fibers

2.1.1 LASER

1. Expression for the number of photons emitted per t seconds $N = \frac{Pt\lambda}{hc}$ Photons.
   P is LASER Power Output in watt, t is the time in second,
   λ is the wavelength of LASER in m,
   h is Planck's Constant and
   c is the speed of light.

2. The Boltzmann relation $N_2 = N_1 e^{-\frac{hc}{\lambda kT}}$
   N_2 is the Number of Atoms in the higher energy state.
   N_1 is the Number of Atoms in the Lower Energy State,
   λ is the wavelength of LASER,
   $k$is Boltzmann Constant,
   T is Absolute Temperature.

2.1.2 Optical Fibers

1. Expression for Numerical Aperture of an Optical Fiber $NA = \sqrt{\frac{n_1^2 - n_2^2}{n_0^2}}$
   n_0 is the RI of the surrounding medium,
   n_1 is the RI of the Core,
   n_2 is the RI of Cladding.

2. The Acceptance Angle $\theta = Sin^{-1}(NA)$

3. Attenuation Co-efficient $\alpha = \frac{-10}{L} log_{10}\left(\frac{P_o}{P_i}\right) dB/km$
   L is the length of the fiber in km.
   P_o is the Power Output of the fiber in W.

P_i is the Power input of the fiber in W.
dB is the unit in decibel.

2.2 Module -2 : Quantum Mechanics

1. The relation between Kinetic Energy and Momentum $E = \frac{p^2}{2m}$,
   m is the mass of the particle in kg,
   p is the momentum of the particle in Ns.
2. Energy of the photon $E = h\nu = \frac{hc}{\lambda}$,
   h is Planck's Constant,
   ν is the frequency of the radiation in Hz,
   λ is the wavelength of the radiation in m, c is the speed of light.
3. de Broglie Wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$ in $meter$
   h is Planck's Constant,
   m is mass of the particle in kg,
   v is the velocity of the particle ms^{-1}.
4. de Broglie Wavelength $\lambda = \frac{h}{\sqrt{2mE}}$
   h is Planck's Constant,
   m is mass of the particle in kg,
   E is the Kinetic Energy of the particle in J.
5. de Broglie Wavelength $\lambda = \frac{h}{\sqrt{2mqV}}$
   h is Planck's Constant,
   m is the mass of the particle in kg,
   q is the charge on the particle in C ,
   V is the accelerating potential in V.
6. de Broglie Wavelength $\lambda = \frac{h}{\sqrt{2m_e eV}} = \frac{12.27 \times 10^{-10}}{\sqrt{V}}$ m
   h is Planck's Constant,
   m_e is the mass of the electron in kg,
   e is the charge on the electron in C ,
   V is the electron accelerating potential in V.
7. Heisenberg's Uncertainty Principle
   $\Delta x \Delta p_x \geq \frac{h}{4\pi}$
   $\Delta E \Delta T \geq \frac{h}{4\pi}$
   Δx is the uncertainty in the measurement of Position,
   ΔP is the uncertainty in the measurement of Momentum,
   ΔE is the uncertainty in the measurement of Energy,
   ΔT is the uncertainty inn the measurement of transistion time.

8. The uncertainty in the measurment of momentum $\Delta P = m\Delta v$.
   Δv is the uncertainty in the measurment of velocity.

9. Eigen Energy Values for a Particle in a one dimensional potential well of infinite depth
   $E_n = \frac{n^2h^2}{8ma^2}$,
   $n = 1, 2, 3...$ for the Ground, First and Second energy states etc.,
   h is Planck's Constant,
   m is the mass of the particle in kg,
   a is the width of the potential well in m.

2.3 Module -3 : Quantum Computing

1. The wave function in Ket notation $|\psi\rangle$ (Ket Vector), ψ is the wave function.
   $|\psi\rangle = \begin{pmatrix}\alpha_1\\ \alpha_2\end{pmatrix}$

2. The matrix for of the states $|0\rangle$ and $|1\rangle$.
   $|0\rangle = \begin{pmatrix}1\\0\end{pmatrix}$ and $|1\rangle = \begin{pmatrix}0\\1\end{pmatrix}$

3. Identity Operator $I = \begin{pmatrix}1 & 0\\0 & 1\end{pmatrix}$

4. Pauli Matrices
   - $\sigma_0 = I = \begin{pmatrix}1 & 0\\0 & 1\end{pmatrix}$.
   - $\sigma_1 = \sigma_x = X = \begin{pmatrix}0 & 1\\1 & 0\end{pmatrix}$.
   - $\sigma_2 = \sigma_y = Y = \begin{pmatrix}0 & -i\\i & 0\end{pmatrix}$.
   - $\sigma_3 = \sigma_z = Z = \begin{pmatrix}1 & 0\\0 & -1\end{pmatrix}$.

5. A Matrix is said to be Unitary Matrix is $U^\dagger U = I$,
   Here $U^\dagger$ is the conjugate-transpose of a matrix U.

6. A matrix A is Hermitian if $A^\dagger = A$

7. The wave function in Bra notation $\langle\psi|$ (bra Vector), ψ is the wave function.
   $\langle\psi| = \begin{pmatrix}\alpha_1^* & \alpha_2^*\end{pmatrix}$

8. Inner Product $\langle\psi|\phi\rangle = \langle\psi| * |\phi\rangle$. Here $\langle\psi|$ is a Row Vector and $|\phi\rangle$ is a Column Vector. The result is always a scalar product.

9. The product $\langle\psi|\psi\rangle = |\psi|^2$, the probability density.

10. Orthogonality $\langle\psi|\phi\rangle = 0$

2.4 Module -4 : Electrical Properties of Materials and Applications

2.4.1 Electrical conductivity in Solids

1. The Fermi Factor $f(E) = \frac{1}{e^{\left(\frac{E-E_F}{kT}\right)}+1}$
E is the energy of the level above or below fermi level in, E_F is the Fermi Energy, k is Boltzmann Constant, T is Absolute Temperature.

2.4.2 Superconductivity

1. The variation of Critical Field with Temperature $H_c = H_0\left[1 - \frac{T^2}{T_c^2}\right]$ tesla,
H_c is the critical field at a temperature T less than the critical temperature T_c,
H_0 is the critical field at $0K$.

2.5 Module -5 : Application of Physics in Computing

2.5.1 Physics of Animation

1. **The Odd Rule :**When acceleration is constant, one can use the Odd Rule to time the frames. With this method, one calculate the distance the object moves between frames using a simple pattern of odd numbers. Between consecutive frames, the distance the object moves is a multiple of an odd number. For acceleration, the distance between frames increases by multiples of 1, 3, 5, 7,...

2. The Odd number multiplier for consecutive frames= $((frame\# - 1) * 2) - 1$

3. Multiplier for distance from first frame to current frame = $(current frame\# - 1)2$

4. $Base\ distance = \frac{Total\ distance}{(Last\ frame\ number - 1)2}$

5. Jump Magnification $JM = \frac{Jump\ time}{Push\ time} = \frac{Jump\ Height}{Push\ Height} = \frac{Push\ Acceleration}{Jump\ Acceleration}$

6. $JH = \frac{Push\ Acceleration}{Gravitational\ Acceleration}$

2.5.2 Statistical Physics for Computing

1. Poisson Distribution Probability Mass Function = $f(k;\lambda) = P(X = k) = \frac{\lambda^k e^{-\lambda}}{k!}$
2. The Decay Equation $N = N_0 e^{-\lambda t}$
   λ is decay constant,
   t is the time, N_0 is Initial Number of Events,
   N is number of events after time t.

Chapter 3

Applied Physics for EEE Stream

3.1 Module -1 : Quantum Mechanics

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   m is the mass of the particle in kg,
   p is the momentum of the particle in Ns.

2. Energy of the photon $E = h\nu = \frac{hc}{\lambda}$,
   h is Planck's Constant,
   ν is the frequency of the radiation in Hz,
   λ is the wavelength of the radiation in m, c is the speed of light.

3. de Broglie Wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$ in $meter$
   h is Planck's Constant,
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   h is Planck's Constant,
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   h is Planck's Constant,
   m is the mass of the particle in kg,
   q is the charge on the particle in C ,
   V is the accelerating potential in V.

6. de Broglie Wavelength $\lambda = \frac{h}{\sqrt{2m_e eV}} = \frac{12.27\times10^{-10}}{\sqrt{V}}$ m
   h is Planck's Constant,
   m_e is the mass of the electron in kg,

e is the charge on the electron in C ,
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7. Heisenberg's Uncertainty Principle
   $\Delta x \Delta p_x \geq \frac{h}{4\pi}$
   $\Delta E \Delta T \geq \frac{h}{4\pi}$
   Δx is the uncertainty in the measurement of Position,
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8. The uncertainty in the measurment of momentum $\Delta P = m\Delta v$.
   Δv is the uncertainty in the measurment of velocity.

9. Eigen Energy Values for a Particle in a one dimensional potential well of infinite depth
   $E_n = \frac{n^2h^2}{8ma^2}$,
   $n = 1, 2, 3...$ for the Ground, First and Second energy states etc.,
   h is Planck's Constant,
   m is the mass of the particle in kg,
   a is the width of the potential well in m.

3.2 Module-2 : Electrical Properties of Materials

3.2.1 Electrical conductivity in Solids

1. The free electron mobility $\mu = \frac{v_d}{E} = \frac{\sigma}{ne}\ m^2V^{-1}s^{-1}$,
   v_d is the drift velocity of the free elctrons,
   E the applied electric field strength.

2. The Fermi Factor $f(E) = \frac{1}{e^{\left(\frac{E-E_F}{kT}\right)}+1}$
   E is the energy of the level above or below fermi level,
   E_F is the Fermi Energy,
   k is Boltzmann Constant,
   T is Absolute Temperature.

3. The electrical conductivity of metals as per Quantum Free Electron Theory $\sigma = \frac{1}{\rho} = \frac{ne^2\lambda_F}{mv_F}$
   n is number density of free electron (free electron concentration) in m^{-3}
   e is electronic charge in C,
   λ_F is fermi level mean free path in m,
   m is the rest mass of the electron in kg,
   v_F is the fermi velocity in ms^{-1}

4. Free electron concentration is given by $n = \frac{NN_A D}{A} m^{-3}$
   N is the number of free electrons per atom.
   N_A Avogadro number per kilo mole,
   D is the density of material in kg,
   A is the atomic mass.

3.2.2 Dielectrics

1. The Dipole Moment $\mu = qdx$,
   q is either of the charge,
   dx is the separation between the charges.

2. The Electronic Polarizability $\alpha_e = \frac{\mu_e}{E}$.
   E is the applied electric field strength.

3. The polarization $P = N\mu = \frac{q^{|}}{A}$,
   N is number of dipoles per unit volume,
   $q^{|}$ is surface image charge,
   A is the surface area.

4. The polarization $\vec{P} = \epsilon_0(\epsilon_r - 1)\vec{E}$,
   ϵ_0 is Permittivity of Free Space,
   ϵ_r is Dielectric Constant,
   E is the magnitude of Applied Field strength.

5. The internal field $E_i = E + \frac{1.2\mu}{\pi\epsilon_0 a^3}$ in one dimension.
   a is the interdipole distance in m.

6. The internal field in Three Dimension is $E_i = E + \frac{\gamma N\alpha_e E}{3\epsilon_0}$ in one dimension.
   γ is internal field constant.

7. The internal field for elemental solid dielectric is called Lorentz Field $E_L = E + \frac{P}{3\epsilon_0}$

8. Clausius-Mossotti relation $\frac{N\alpha_e}{3\epsilon_0} = \frac{\epsilon_r - 1}{\epsilon_r + 2}$, Applicable only for Elemental Solid Dielectrics.

3.2.3 Superconductivity

1. The variation of Critical Field with Temperature $H_c = H_0\left[1 - \frac{T^2}{T_c^2}\right]$ tesla,
   H_c is the critical field at a temperature T less than the critical temperature T_c,
   H_0 is the critical field at $0K$.

3.3 Module - 3 : LASER and Optical Fibers

3.3.1 LASER

1. Expression for the number of photons emitted per t seconds $N = \frac{Pt\lambda}{hc}$ Photons.
   P is LASER Power Output in watt, t is the time in second,
   λ is the wavelength of LASER in m,
   h is Planck's Constant and
   c is the speed of light.

2. The Boltzmann relation $N_2 = N_1 e^{-\frac{hc}{\lambda kT}}$
   N_2 is the Number of Atoms in the higher energy state.
   N_1 is the Number of Atoms in the Lower Energy State,
   λ is the wavelength of LASER,
   'k'is Boltzmann Constant,
   T' is Absolute Temperature.

3.3.2 Optical Fibers

1. Expression for Numerical Aperture of an Optical Fiber $NA = \sqrt{\frac{n_1^2 - n_2^2}{n_0^2}}$
   n_0 is the RI of the surrounding medium,
   n_1 is the RI of the Core,
   n_2 is the RI of Cladding.

2. The Acceptance Angle $\theta = Sin^{-1}(NA)$

3. The fractional RI change $\Delta = \frac{n_1 - n_2}{n_1}$

4. V-Number $V = \frac{2\pi d}{\lambda}\sqrt{(n_1^2 - n_2^2)}$
   d is the diameter of the fiber in m,
   λ is the wavelength of light in m

5. The number of modes $N = \frac{V^2}{2}$

6. Attenuation Co-efficient $\alpha = \frac{-10}{L} log_{10}\left(\frac{P_o}{P_i}\right)\ dB/km$
   L is the length of the fiber in km.
   P_o is the Power Output of the fiber in W
   P_i is the Power input of the fiber in W.
   dB is the unit in decibel.

3.4 Module - 4 : Maxwell's Equations and EM Waves

3.4.1 Vector Calculus

1. The ∇ operator is given by $\left(\frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial}\hat{z}\right)$ and a vector field $\vec{E}$ is given by $(E_x\hat{x} + E_y\hat{y} + E_z\hat{z})$
   Then the Divergence of a vector field $\vec{E}$ is given by
   $\nabla.\vec{E} = \left(\frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial}\hat{y} + \frac{\partial}{\partial}\hat{z}\right).(E_x\hat{x} + E_y\hat{y} + E_z\hat{z}) = \frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z}$
   Divergence of a vector field signifies whether the point in a vector field is a source or a sink. If the divergence is zero then the vector field is **Solenoidal**.

2. ∇ operator is given by $\left(\frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial}\hat{z}\right)$ and a vector field $\vec{E}$ is given by $(E_x\hat{x} + E_y\hat{y} + E_z\hat{z})$
   Then the curl of a vector field $\vec{E}$ is given by
   $\nabla \times \vec{E} = \left(\frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial}\hat{y} + \frac{\partial}{\partial}\hat{z}\right) \times (E_x\hat{x} + E_y\hat{y} + E_z\hat{z}) = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x & E_y & E_z \end{vmatrix}$
   The Curl of a vector field signifies how much the vector field rotates at a given point. If the Curl of a vector field is zero then the vector field is called **Irrotational**.

3.5 Module - 5 : Semiconductors and Devices

3.5.1 Electrical Conductivity in Semiconductors

1. The electrical conductivity of a semiconductor is $\sigma_i = \frac{1}{\rho_i} = n_i e(\mu_e + \mu_h)$
   ni is the intrinsic carrier concentration in m^{-3},
   e is electronic charge in C,
   μ_e and μ_h are electron and hole mobilities in $m^2V^{-1}s^{-1}$.

2. Relation between fermi energy E_F and energy gap E_g is given by
   $E_f = \frac{E_g}{2}$

3. Law of mass action $n_i^2 = N_e N_h$
   N_e and N_h are electron and hole concentrations respectively.

3.5.2 Hall Effect

1. The Hall Coefficient $R_H = \frac{1}{\rho n_e}$
   n_e is the free electron concentration.
   R_H is positive for holes and negative for electrons.

2. Hall field $E_H = R_H BJ$
   B is the applied magnetic flux density,
   J is the current density.

3. Hall Voltage $V_H = R_H BJd$
   B is the applied magnetic flux density,
   J is the current density,
   d is the thickness of the material.

Chapter 4

Applied Physics for CV Stream

4.1 Module-1 : Oscillations and Shock waves

4.1.1 Oscillations

1. The angular velocity or angular frequency $\omega = 2\pi\nu = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$
   ν is the frequency of Oscillations in Hz,
   T is the Time Period of oscillations in s,
   k is the force constant/stiffness factor in Ns^{-1},
   m is the mass of the body in kg.

2. Effective spring constant k_s for n springs in series $\frac{1}{k_S} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \ldots \frac{1}{k_3}$
   k_1, k_2, k_3... are the spring constants of individual springs in Nm^{-1}.
   for n identical springs $k_s = \frac{k}{n}$
   k is the stiffness factor of each spring in Nm^{-1}..

3. Effective spring constant k_p for n springs in parallel $k_p = k_1 + k_2 + k_3 + \ldots k_n$
   k_1, k_2, k_3... are the spring constants of individual springs in Nm^{-1}.
   for n identical springs $k_p = nk$
   k is the stiffness factor of each spring in Nm^{-1}..

4. The amplitude of damped oscillations $A_d = Ae^{\frac{-b}{2m}t}$ in m.
   b is damping constant,
   t is the time.

5. Amplitude in forced oscillations (As per the book Vibrations and Waves by A P French)
   $A = \frac{\frac{f_0}{m}}{\sqrt{(\omega_0^2 - \omega^2)^2 + (\gamma\omega)^2}}$
   $\frac{f_0}{m}$ is the amplitude of the applied periodic force per unit mass.
   γ is damping ration.
   ω_0 is the natural angular frequency of the system.
   ω is the angular frequency of the applied periodic force.

or $A = \frac{\frac{f_0}{m}}{\sqrt{(\omega^2-p^2)^2+4b^2p^2}}$
$b = \frac{r}{2m}$, p is the frequency of the applied periodic force.

4.1.2 Shock Waves

1. Mach Number $M = \frac{v_0}{v_s}$
   v_0 is the velocity of the object or flow in a medium.
   v_s is the velocity of sound in the same medium.

2. Mach Angle $\theta_M = Sin^{-1}\left(\frac{1}{M}\right)$

4.2 Module-2 : Elasticity

1. The Young's Modulus of the material of a wire of circular cross section loaded at one and fixed at the other $Y = \frac{FL}{\pi r^2 l} \quad Nm^{-2} or Pa$
   F is the applied force in N,
   L is the original length of the wire in m,
   r is the radius of the wire in m,
   l is the extension in the wire in m.

2. The bulk modulus of the material is given by $K = \frac{PV}{\Delta V} Nm^{-2} or Pa$

   P is the univorm pressure in Pa,
   V is the original volum in m^{-3},
   ΔV is he change in volume in m^{-3}

3. The Rigidity Modulus of the material of a wire of circular cross section loaded at one and fixed at the other $\eta = \frac{FL}{Ax} \quad Nm^{-2} or Pa$
   F is the applied force tagnentially to the top surface N,
   L length of the edege of the cube m,
   A is the surface area of te top surface m^2,
   x is the shearing distance m.

4. The Bending moment of a beam is given by $M = \frac{Y}{R} I_g \quad Nm$
   Y is the Young's Modulus of the material of the beam in Pa,
   R is the radius of curvature of the beam in m^2,
   I_g is the geometrical moment inertia of the beam in kgm^2.

4.3 Module-3 : Acoustics, Radiometry & Photometry

4.3.1 Acoustics

1. The absorption coefficient of a material surface $\alpha = \frac{Sound\ \ Energy\ \ Absorbed}{Total\ \ Sound\ \ Energy\ \ Incident}$
2. The total absorption co-efficient of all the materials in a hall is $A = \sum_1^n \alpha_n S_n$.
   $\alpha_1, \alpha_2 ...$ are the absorption coefficients of the surfaces with areas $S_1, S_2 ....$
3. Sabine's Formula for Reverberation time is $T = \frac{0.161V}{A}$
   V is the volume of the Hall.

4.4 Module -2 : LASER and Optical Fibers

4.4.1 LASER

1. Expression for the number of photons emitted per t seconds $N = \frac{Pt\lambda}{hc}$ Photons.
   P is LASER Power Output in watt, t is the time in second,
   λ is the wavelength of LASER in m,
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   c is the speed of light.
2. The Boltzmann relation $N_2 = N_1 e^{-\frac{hc}{\lambda kT}}$
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4.4.2 Optical Fibers

1. Expression for Numerical Aperture of an Optical Fiber $NA = \sqrt{\frac{n_1^2 - n_2^2}{n_0^2}}$
   n_0 is the RI of the surrounding medium,
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2. The Acceptance Angle $\theta = Sin^{-1}(NA)$
3. Attenuation Co-efficient $\alpha = \frac{-10}{L} log_{10}\left(\frac{P_o}{P_i}\right) dB$
   L is the length of the fiber in km.
   P_o is the Power Output of the fiber.
   P_i is the Power input of the fiber.
   dB is the unit in decibel.

4.5 Module-5 : Natural Hazards and Safety

1. Energy released during earthquake $logE = 5.24 + 1.44M_w$,
   M_w is the magnitude of the earthquake.
2. Magnitude of the earthquake $M_w = \frac{2}{3} logM_0 - 10.7$
   M_0 is the Seismic moment of the earthquake.
3. Magnitude of the earthquake interms of intensities$M = log\left(\frac{I}{I_0}\right)$, I is the intensity of earthquake and I_0 is the base intesity.
4. Ratio of intensities of two earthquakes $log\left(\frac{I_1}{I_2}\right) = 10^{M_1 - M_2}$
   I_1 and I_2 are the intensities of two different earthquakes,
   M_1 and M_2 are the respective magnitudes.

In all the above equations log is log_{10}

Chapter 5

Applied Physics for ME Stream

5.1 Module-1 : Oscillations and Shock waves

5.1.1 Oscillations

1. The angular velocity or angular frequency $\omega = 2\pi\nu = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$
   ν is the frequency of Oscillations in Hz,
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2. Effective spring constant k_s for n springs in series $\frac{1}{k_S} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \ldots \frac{1}{k_3}$
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   v_0 is the velocity of the object or flow in a medium.
   v_s is the velocity of sound in the same medium.

2. Mach Angle $\theta_M = Sin^{-1}\left(\frac{1}{M}\right)$

5.2 Module-2 : Elasticity

1. The Young's Modulus of the material of a wire of circular cross section loaded at one and fixed at the other $Y = \frac{FL}{\pi r^2 l} \quad Nm^{-2} or Pa$
   F is the applied force in N,
   L is the original length of the wire in m,
   r is the radius of the wire in m,
   l is the extension in the wire in m.

2. The bulk modulus of the material is given by $K = \frac{PV}{\Delta V} Nm^{-2} or Pa$

   P is the univorm pressure in Pa,
   V is the original volum in m^{-3},
   ΔV is he change in volume in m^{-3}

3. The Rigidity Modulus of the material of a wire of circular cross section loaded at one and fixed at the other $\eta = \frac{FL}{Ax} \quad Nm^{-2} or Pa$
   F is the applied force tagnentially to the top surface N,
   L length of the edege of the cube m,
   A is the surface area of te top surface m^2,
   x is the shearing distance m.

4. The Bending moment of a beam is given by $M = \frac{Y}{R} I_g \quad Nm$
   Y is the Young's Modulus of the material of the beam in Pa,
   R is the radius of curvature of the beam in m^2,
   I_g is the geometrical moment inertia of the beam in kgm^2.

5.3 Module-3 : Thermoelectric Materials

5.3.1 Thermoelectricity

1. Seebeck effect, The voltage generated at the junction is $V = \alpha(T_2 - T_1)$
   $\alpha = \alpha_A + \alpha_B$ are the seebeck coefficients of metals A annd B.
   T_1 and T_2 are the temperatures at the two junctions.

2. The $\alpha = \frac{\Delta V}{\Delta T} = \frac{E}{\Delta T}$
   E is the electric field in Vm^{-1}
   ΔT is the temperature gradient.

3. the peltiere coefficient $\pi_{ab} = \frac{H}{It}$,
   I is the junction current,
   H is the heat absorbed in t seconds.

4. The variation of thermo emf with temperature is $e = at + \frac{1}{2}bt^2$.
   a and b are Seebeck constants and $t = T_2 - T_1$,
   T_2 is the hot end emperature in K and T_1 is the cold end temperature in K.

5. Figure of Merit $Z = \frac{\alpha^2\sigma}{K}$.
   α is the seebeck coefficient of the material in $microvolt/K$,
   σ is electricla conductivity,
   K is Total thermal conductivity.

6. The Theromo EMF e in terms of temperatures T_1 and T_2 is given by $e = \frac{\pi_1}{T_1}(T_2 - T_1)$.
   π_1 is peltier coefficient.

5.4 Module-4 : Cryogenics

1. Joule Thomson Effect $\left(\frac{\delta T}{\delta P}\right)_H = \frac{1}{C_p}\left(\frac{2a}{RT} - b\right)$
   a and b are Van der wall's constant,
   R is universal gas constant = 8.314 Joule/mole/K.

2. Inversion Temperature $T_i = \frac{2a}{bR}$
   a and b are Van der wall's constant,
   R is universl gas constant = 8.314 Joule/mole/K

5.5 Module-5 : Materials and Characterization Techniques

1. Braggs' Law$n\lambda = 2dsin(\theta)$
   n is the order of diffraction and can take values 1,2,3...,
   λ is the wavelength of X-rays,

d is the interplanar spacing, and
θ is the glancing angle corrsponding to the order of diffraction n.

2. Schrrer's Equation $B(2\theta) = \frac{k\lambda}{Lcos\theta}$
   $B(2\theta)$ is the full width at half maximum,
   λ is the wavelength of X-rays, L is the crystallite size,
   k is scherrer constant with the most common value 0.94,
   θ is the glancing angle.