Physics Point

Class 11 Physics Formula Sheet

Units & Measurements

1. Measurement of Length

- 1 Å (angstrom) = 10^{-10} m
- 1 fermi = 10^{-15} m

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2. Errors in Measurement

- **Absolute error**
  $\Delta A = |A_i - \bar{A}|$
- **Mean absolute error**
  $\Delta \bar{A} = (\Delta A_1 + \Delta A_2 + \ldots + \Delta A_n) / n$
- **Relative error**
  Relative error = $\Delta \bar{A} / \bar{A}$
- **Percentage error**
  Percentage error = $(\Delta \bar{A} / \bar{A}) \times 100$

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3. Error Propagation

- **Addition / Subtraction**
  $\Delta Z = \Delta A + \Delta B$
  (for $Z = A \pm B$)

- **Multiplication / Division**
  $\Delta Z / Z = (\Delta A / A) + (\Delta B / B)$
  (for $Z = AB$ or A/B)

- **Power of quantity**
  If $Z = A^n$
  $\Delta Z / Z = n (\Delta A / A)$

🔹 4. Significant Figures

- Non-zero digits → **significant**
- Zeros between non-zero digits → **significant**
- Leading zeros → **not significant**
- Trailing zeros (without decimal) → **not significant**

🔹 5. Dimensions of Physical Quantities

- **Velocity** = $[L T^{-1}]$
- **Acceleration** = $[L T^{-2}]$
- **Force** = $[M L T^{-2}]$

- **Work / Energy** = $[M L^2 T^{-2}]$
- **Power** = $[M L^2 T^{-3}]$
- **Pressure** = $[M L^{-1} T^{-2}]$
- **Density** = $[M L^{-3}]$

🔹 **6. Dimensional Formula**

- Physical quantity = $M^a L^b T^c$

Used to:

- Check correctness of equations
- Convert units
- Derive relations

Least Count

- **Least Count = Smallest measurable value of the instrument**

Example:

- Vernier Caliper
  LC = 1 MSD − 1 VSD

Kinematics

Formula	Description	Variables
$v = u + at$	Final velocity	v=final velocity, u=initial velocity, a=acceleration, t=time
$s = ut + \frac{1}{2}at^2$	Displacement	s=displacement
$v^2 = u^2 + 2as$	Velocity-displacement relation	-
$s = \frac{1}{2}(u+v)t$	Average velocity method	-
$s_{nth} = u + a(n - \frac{1}{2})$	Displacement in nth second	n=nth second

Relative Velocity

- $v_{a\beta} = v_a - v_\beta$ (velocity of A w.r.t. B)
- For perpendicular motion: $v_{a\beta} = \sqrt{(v_a^2 + v_\beta^2)}$

Projectile Motion

Component	Formula
Horizontal velocity	$v_x = u \cos \theta$ (constant)
Vertical velocity	$v_y = u \sin \theta - gt$
Time of flight	$T = (2u \sin \theta)/g$
Maximum height	$H = (u^2 \sin^2 \theta)/2g$
Range	$R = (u^2 \sin 2\theta)/g$
Maximum range	$R_{max} = u^2/g$ (at $\theta = 45°$)
Trajectory equation	$y = x \tan \theta - (gx^2)/(2u^2 \cos^2 \theta)$

Circular Motion

Quantity	Formula
Angular displacement	$\theta = s/r$ (radians)
Angular velocity	$\omega = \theta/t = 2\pi/T = 2\pi f$
Linear velocity	$v = r\omega$
Centripetal acceleration	$a_c = v^2/r = r\omega^2$
Centripetal force	$F_c = mv^2/r = mr\omega^2$
Relation	$v = u + \alpha t$, $\theta = \omega t + \frac{1}{2}\alpha t^2$

Laws of Motion

Newton's Laws

Law	Formula
First Law	$F = 0 \Longrightarrow v = \text{constant}$
Second Law	$F = ma$ or $F = dp/dt$
Third Law	$F_{a\beta} = -F_{\beta a}$

Linear Momentum

- $p = mv$
- Impulse: $J = F \cdot t = \Delta p = m(v - u)$

Friction

Type	Formula
Static friction	$0 \le f_{\square} \le \mu_{\square} N$
Kinetic friction	$f_{\square} = \mu_{\square} N$

Angle of friction	$\tan \lambda = \mu$
Angle of repose	$\tan \theta = \mu$□

Motion on an Inclined Plane

- Acceleration (downward): $a = g(\sin \theta - \mu \cos \theta)$
- Acceleration (upward): $a = -g(\sin \theta + \mu \cos \theta)$

Connected Bodies

- Two masses, one pulley:
    - $a = (m_1 - m_2)g/(m_1 + m_2)$
    - $T = 2m_1m_2g/(m_1 + m_2)$

Work, Energy & Power

Work

Type	**Formula**
General	$W = F\cdot s = Fs \cos \theta$
Variable force	$W = \int F\cdot ds$

By gravity	$W = mgh$ (downward)
By spring	$W = -\frac{1}{2}kx^2$

Energy

Type	Formula
Kinetic Energy	$KE = \frac{1}{2}mv^2$
Potential Energy (gravity)	$PE = mgh$
Elastic PE (spring)	$PE = \frac{1}{2}kx^2$
Total Mechanical Energy	$E = KE + PE$

Work-Energy Theorem

- $W_{net} = \Delta KE = \frac{1}{2}m(v^2 - u^2)$

Conservation of Energy

- $KE_i + PE_i = KEf + PEf$ (if no friction)

Power

Formula	Description
$P = W/t$	Average power
$P = F \cdot v$	Instantaneous power
$P = Fv \cos \theta$	Power at angle

Collisions

Type	Characteristics
Elastic	KE conserved, $e = 1$

Inelastic	KE not conserved, $0 < e < 1$
Perfectly inelastic	Bodies stick together, $e = 0$
Coefficient of restitution	$e = (v_2 - v_1)/(u_1 - u_2)$

Centre of Mass & Rotational Motion

Centre of Mass

System	Formula
Two particles	$x_{CM} = (m_1x_1 + m_2x_2)/(m_1 + m_2)$
N particles	$r_{CM} = (\Sigma m_ir_i)/M$
Velocity of CM	$v_{CM} = (\Sigma m_iv_i)/M$

Acceleration of CM	$a_{CM} = F_{ext}/M$

Moment of Inertia

Body	Axis	I
Thin rod	Perpendicular, through the center	$ML^2/12$
Thin rod	Perpendicular, through the end	$ML^2/3$
Ring	Through the center, perpendicular	MR^2
Disc	Through the center, perpendicular	$MR^2/2$
Solid sphere	Through the centre	$2MR^2/5$
Hollow sphere	Through the centre	$2MR^2/3$

Solid cylinder	About axis	$MR^2/2$

Theorems

Theorem	Formula
Parallel axis	$I = I_{CM} + Md^2$
Perpendicular axis	$I_z = I_x + I_y$

Rotational Dynamics

Quantity	Formula
Torque	$\tau = r \times F = rF \sin \theta$
Angular momentum	$L = I\omega = r \times p$

Rotational KE	KE = $\frac{1}{2}I\omega^2$
Newton's 2nd law	$\tau = I\alpha$
Work done	$W = \tau\theta$
Power	$P = \tau\omega$

Rolling Motion

- $v = r\omega$ (pure rolling)
- Total KE = $\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2(1 + K^2/R^2)$
- Acceleration (incline): $a = g \sin\theta/(1 + I/MR^2)$

Gravitation

Newton's Law of Gravitation

- $F = Gm_1m_2/r^2$
- $G = 6.67 \times 10^{-11}$ Nm^2/kg^2

Gravitational Field & Potential

Quantity	Formula

Field intensity	$E = F/m = GM/r^2$
Potential	$V = -GM/r$
Potential energy	$U = -Gm_1m_2/r$
Escape velocity	$v_e = \sqrt{(2GM/R)} = \sqrt{(2gR)}$
Orbital velocity	$v_0 = \sqrt{(GM/r)} = \sqrt{(gR^2/r)}$

Satellite Motion

Parameter	Formula
Orbital velocity	$v = \sqrt{(GM/r)}$
Time period	$T = 2\pi\sqrt{(r^3/GM)}$

Total energy	$E = -GMm/2r$
Binding energy	$BE = GMm/2r$
Relation	$v_e = \sqrt{2} \times v_0$

Kepler's Laws

- Third law: $T^2 \propto r^3$ or $T^2/r^3 = 4\pi^2/GM$

Acceleration due to Gravity

Location	**Formula**
At surface	$g = GM/R^2$
At height h	$g' = g(R/(R+h))^2 \approx g(1 - 2h/R)$
At depth d	$g' = g(1 - d/R)$

Properties of Matter

Elasticity

Quantity	Formula
Stress	Stress = Force/Area
Strain	Strain = Change/Original
Young's modulus	$Y = (F/A)/(\Delta L/L)$ = Stress/Strain
Bulk modulus	$B = -P/(\Delta V/V)$
Shear modulus	$\eta = (F/A)/(\theta)$
Poisson's ratio	σ = -Lateral strain/Longitudinal strain

Relations

- $Y = 3B(1 - 2\sigma)$
- Elastic PE = ½ × Stress × Strain × Volume

Surface Tension

Formula	Description
$T = F/L$	Surface tension
Excess pressure (bubble)	$\Delta P = 4T/R$
Excess pressure (drop)	$\Delta P = 2T/R$
Capillary rise	$h = 2T \cos \theta/(r\rho g)$
Surface energy	$U = T \times A$

Viscosity

Formula	Description

$\eta = F/(A \cdot dv/dx)$	Coefficient of viscosity
Stokes' law	$F = 6\pi\eta rv$
Terminal velocity	$v_{\square} = 2r^2(\rho-\sigma)g/9\eta$
Poiseuille's formula	$V = \pi Pr^4/8\eta L$

Fluid Mechanics

Principle	Formula
Pressure	$P = F/A = h\rho g$
Pascal's law	$P_1 = P_2$
Archimedes	$F_\beta = \rho Vg$

Continuity equation	$A_1v_1 = A_2v_2$
Bernoulli's equation	$P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$
Torricelli's theorem	$v = \sqrt{(2gh)}$

8. Thermodynamics

Temperature & Heat

Formula	Description
$C = 9F/5 + 32$	Fahrenheit-Celsius
$K = C + 273.15$	Kelvin-Celsius
$Q = mc\Delta T$	Heat transfer

$Q = mL$	Latent heat

Thermal Expansion

Type	Formula
Linear	$\Delta L = \alpha L_0 \Delta T$
Area	$\Delta A = \beta A_0 \Delta T$, $\beta = 2\alpha$
Volume	$\Delta V = \gamma V_0 \Delta T$, $\gamma = 3\alpha$

Calorimetry

- Heat lost = Heat gained
- $m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$

Gas Laws

Law	Formula

Boyle's law	$PV = \text{constant}$ (T constant)
Charles' law	$V/T = \text{constant}$ (P constant)
Gay-Lussac's	$P/T = \text{constant}$ (V constant)
Ideal gas equation	$PV = nRT = NkT$
Dalton's law	$P = P_1 + P_2 + P_3 + \ldots$

Kinetic Theory

Quantity	**Formula**
RMS speed	$v_{r□□} = \sqrt{(3RT/M)} = \sqrt{(3kT/m)} = \sqrt{(3P/\rho)}$
Average speed	$\bar{v} = \sqrt{(8RT/\pi M)} = \sqrt{(8kT/\pi m)}$

Most probable speed	$v_{mp} = \sqrt{2RT/M} = \sqrt{2kT/m}$
Pressure	$P = \frac{1}{3}\rho v^2_{rms}$
Mean KE	$KE = (3/2)kT$

Degrees of Freedom

- Monoatomic: $f = 3$
- Diatomic: $f = 5$
- Polyatomic: $f = 6$

Specific Heat Capacities

Formula	Description
$C_v = (f/2)R$	At constant volume
$C_p = C_v + R$	At constant pressure
$\gamma = C_p/C_v$	Heat capacity ratio

$\gamma = 1 + 2/f$	In terms of f

First Law of Thermodynamics

- $\Delta Q = \Delta U + \Delta W$
- $\Delta U = nC_v\Delta T$ (for ideal gas)
- $\Delta W = P\Delta V$ or $\int PdV$

Thermodynamic Processes

Process	**Conditions**	**Work**	**ΔU**	**ΔQ**
Isothermal	T = const, PV = const	$nRT \ln(V_2/V_1)$	0	W
Adiabatic	Q = 0, PV^γ = const	$(P_1V_1-P_2V_2)/(\gamma-1)$	-W	0
Isochoric	V = const	0	$nC_v\Delta T$	ΔU
Isobaric	P = const	$P\Delta V$	$nC_v\Delta T$	$nC_p\Delta T$

Heat Engine

Formula	Description
Efficiency	$\eta = W/Q_1 = 1 - Q_2/Q_1$
Carnot efficiency	$\eta = 1 - T_2/T_1$
Refrigerator COP	$\beta = Q_2/W = T_2/(T_1-T_2)$

9. Oscillations & Waves

Simple Harmonic Motion (SHM)

Formula	Description
Displacement	$x = A \sin(\omega t + \varphi)$
Velocity	$v = \pm\omega\sqrt{(A^2 - x^2)}$

Acceleration	$a = -\omega^2 x$
Time period	$T = 2\pi/\omega$
Frequency	$f = 1/T = \omega/2\pi$
Max velocity	$v_{max} = A\omega$
Max acceleration	$a_{max} = A\omega^2$

Energy in SHM

Energy	Formula
Kinetic	$KE = \frac{1}{2}m\omega^2(A^2 - x^2)$
Potential	$PE = \frac{1}{2}m\omega^2 x^2$

Total	$E = \frac{1}{2}m\omega^2A^2 = \frac{1}{2}kA^2$

Systems in SHM

System	Time Period
Spring	$T = 2\pi\sqrt{(m/k)}$
Simple pendulum	$T = 2\pi\sqrt{(L/g)}$
Physical pendulum	$T = 2\pi\sqrt{(I/mgd)}$
Torsional pendulum	$T = 2\pi\sqrt{(I/C)}$
LC circuit	$T = 2\pi\sqrt{(LC)}$

Damped Oscillations

- $x = A_0e^{-bt} \cos(\omega t + \varphi)$
- $\omega' = \sqrt{(\omega_0^2 - b^2)}$

Wave Motion

Formula	Description
Wave equation	$y = A \sin(kx - \omega t)$
Wave velocity	$v = f\lambda = \omega/k$
Wave number	$k = 2\pi/\lambda$
Speed on string	$v = \sqrt{(T/\mu)}$
Speed of sound	$v = \sqrt{(\gamma RT/M)} = \sqrt{(B/\rho)}$

Stationary Waves

- $y = 2A \cos(kx) \sin(\omega t)$
-

Organ Pipes

Type	Frequency
Open pipe	$f = nv/2L$ ($n = 1,2,3...$)
Closed pipe	$f = nv/4L$ ($n = 1,3,5...$)

Doppler Effect

Case	Formula
General	$f' = f(v \pm v_o)/(v \mp v_{\square})$
Source moving toward	$f' = fv/(v - v_{\square})$
Source moving away	$f' = fv/(v + v_{\square})$
Observer moving toward	$f' = f(v + v_o)/v$

Observer moving away	$f' = f(v - v_o)/v$

Beats

- Beat frequency = $|f_1 - f_2|$

TIPS FOR USING FORMULAS

1. Understand the derivation – don't just memorise.
2. Check units – Helps catch errors
3. Identify the type of problem first
4. Draw diagrams for clarity
5. List known & unknown quantities
6. Practice dimensional analysis

Physics Point

Class 12 Physics Formula Sheet

1. Electrostatics

Coulomb's Law

Formula	Description
$F = k(q_1 q_2)/r^2$	Force between two charges
$F = (1/4\pi\varepsilon_0)(q_1 q_2)/r^2$	In terms of permittivity
$k = 9 \times 10^9$ Nm^2/C^2	Coulomb's constant
$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2	Permittivity of free space

Electric Field

Formula	Description
$E = F/q$	Electric field intensity
$E = kQ/r^2$	Field due to point charge

$E = (1/4\pi\varepsilon_0)(Q/r^2)$	Alternative form
$E = \sigma/\varepsilon_0$	Field due to infinite sheet
$E = \sigma/2\varepsilon_0$	Field due to conducting plate
$E = \lambda/2\pi\varepsilon_0 r$	Field due to line charge

Electric Potential

Formula	Description
$V = W/q$	Electric potential
$V = kQ/r$	Potential due to point charge
$V = (1/4\pi\varepsilon_0)(Q/r)$	Alternative form

$V = -\int E \cdot dr$	Relation with field
$E = -dV/dr$	Field from potential
$\Delta V = Ed$	Potential difference (uniform field)

Electric Potential Energy

Formula	Description
$U = kq_1q_2/r$	PE of two charges
$U = qV$	PE of charge in potential
$W = q(V_2 - V_1)$	Work done

Electric Dipole

Formula	Description
$p = q \times 2l$	Dipole moment
E (axial) $= 2kp/r^3$	Field on axis ($r >> l$)
E (equatorial) $= -kp/r^3$	Field on equatorial
V (general) $= kp \cos \theta/r^2$	Potential at angle θ
$\tau = p \times E = pE \sin \theta$	Torque on dipole
$U = -p \cdot E = -pE \cos \theta$	PE of dipole
$W = pE(\cos \theta_1 - \cos \theta_2)$	Work done to rotate

Gauss's Law

Formula	Description
$\Phi = \oint E \cdot dA$	Electric flux
$\Phi = q/\varepsilon_0$	Gauss's law
$\Phi = EA \cos \theta$	Flux through surface

Capacitance

Formula	Description
$C = Q/V$	Capacitance
$C = \varepsilon_0 A/d$	Parallel plate capacitor
$C = K\varepsilon_0 A/d$	With dielectric

$C = 4\pi\varepsilon_0 R$	Spherical conductor
$U = \frac{1}{2}CV^2$	Energy stored
$U = \frac{1}{2}Q^2/C$	Alternative form
$U = \frac{1}{2}QV$	Alternative form
$u = \frac{1}{2}\varepsilon_0 E^2$	Energy density

Capacitor Combinations

Type	**Formula**
Series	$1/C = 1/C_1 + 1/C_2 + 1/C_3 + \ldots$
Parallel	$C = C_1 + C_2 + C_3 + \ldots$

Dielectric

Formula	Description
$K = C/C_0$	Dielectric constant
$K = E_0/E$	In terms of field
$C = KC_0$	Capacitance with dielectric
$E = E_0/K$	Reduced field

2. Current Electricity

Current & Drift Velocity

Formula	Description
$I = Q/t$	Electric current

$I = neAv_d$	Microscopic form
$v_d = eE\tau/m$	Drift velocity
$J = I/A$	Current density
$J = neV_d = \sigma E$	Alternative forms

Ohm's Law

Formula	Description
$V = IR$	Ohm's law
$R = \rho L/A$	Resistance
$\rho = m/ne^2\tau$	Resistivity (microscopic)

$\sigma = 1/\rho$	Conductivity
$G = 1/R$	Conductance

Temperature Dependence

Formula	Description
$R_t = R_0(1 + \alpha\Delta T)$	Resistance variation
$\rho_t = \rho_0(1 + \alpha\Delta T)$	Resistivity variation
$\alpha = (R_2-R_1)/R_1(T_2-T_1)$	Temperature coefficient

Resistor Combinations

Type	Resistance	Voltage	Current

Series	$R = R_1+R_2+R_3$...	$V = V_1+V_2+V_3$	I = same
Parallel	$1/R = 1/R_1+1/R_2+$...	V = same	$I = I_1+I_2+I_3$

Electrical Energy & Power

Formula	**Description**
$P = VI$	Power
$P = I^2R$	Power (Joule heating)
$P = V^2/R$	Power (alternative)
$H = I^2Rt$	Heat produced
$W = VIt$	Work/Energy

EMF & Internal Resistance

Formula	Description
$\varepsilon = V + Ir$	EMF equation
$V = \varepsilon - Ir$	Terminal voltage
$\varepsilon = I(R + r)$	Current in circuit
$I = \varepsilon/(R + r)$	Current formula
$V = \varepsilon R/(R + r)$	Voltage across R

Cells in Combination

Type	EMF	Internal Resistance

Series	$\varepsilon = \varepsilon_1 + \varepsilon_2 + \varepsilon_3$	$r = r_1 + r_2 + r_3$
Parallel (identical)	$\varepsilon = \varepsilon_1$	$r = r_1/n$

Kirchhoff's Laws

Law	Statement
KCL (Junction)	$\Sigma I = 0$ (entering = leaving)
KVL (Loop)	$\Sigma V = 0$ (around closed loop)

Wheatstone Bridge

Formula	Description
$P/Q = R/S$	Balance condition

$R = (P \times S)/Q$	Unknown resistance

Meter Bridge

- $R/S = l_1/l_2$
- $R = S(l_1/l_2)$

Potentiometer

Formula	Description
$V = kl$	Potential vs length
$V_1/V_2 = l_1/l_2$	Comparison
$\varepsilon/V = l_1/l_2$	EMF comparison
$r = R(l_1-l_2)/l_2$	Internal resistance

3. Magnetic Effects of Current

Magnetic Field

Formula	Description
$F = qvB \sin \theta$	Force on moving charge
$F = q(v \times B)$	Vector form
$F = BIL \sin \theta$	Force on current element
$F = I(L \times B)$	Vector form

Biot-Savart Law

Formula	Description
$dB = (\mu_0/4\pi)(Idl \sin \theta)/r^2$	Magnetic field element

$dB = (\mu_0/4\pi)(Idl \times \hat{r})/r^2$	Vector form
$\mu_0 = 4\pi \times 10^{-7}$ Tm/A	Permeability of free space

Magnetic Field Due to Various Configurations

Configuration	Formula
Straight wire (infinite)	$B = \mu_0 I/2\pi r$
Straight wire (finite)	$B = (\mu_0 I/4\pi r)(\sin\theta_1 + \sin\theta_2)$
Circular loop (at center)	$B = \mu_0 I/2R$
Circular loop (on axis)	$B = \mu_0 IR^2/2(R^2+x^2)$^(3/2)
Solenoid (inside)	$B = \mu_0 nI$

Toroid	$B = \mu_0 NI/2\pi r$

Ampere's Circuital Law

- $\oint B \cdot dl = \mu_0 I_{enc}$

Force Between Parallel Conductors

Formula	Description
$F/L = \mu_0 I_1 I_2/2\pi d$	Force per unit length
Attractive	Currents in same direction
Repulsive	Currents in opposite direction

Motion of a Charged Particle in a Magnetic Field

Formula	Description

$r = mv/qB$	Radius of circular path
$T = 2\pi m/qB$	Time period
$f = qB/2\pi m$	Frequency (cyclotron)
$\omega = qB/m$	Angular frequency
Pitch = $vT \cos \theta$	Pitch of helix

Magnetic Dipole

Formula	Description
$M = NIA$	Magnetic moment
$\tau = M \times B = MB \sin \theta$	Torque on dipole

$U = -M\cdot B = -MB\cos\theta$	PE of dipole
$W = MB(\cos\theta_1 - \cos\theta_2)$	Work done

Moving Coil Galvanometer

Formula	Description
$\tau = NBIA$	Deflecting torque
$\tau = C\theta$	Restoring torque
$I = (C/NAB)\theta = k\theta$	Current
$S = (I_g\cdot G)/(I-I_g)$	Shunt resistance
$R = G(V/I_g - 1)$	Multiplier resistance

Magnetic Materials

Formula	Description
$B = \mu_0(H + M)$	Magnetic field in material
$\mu_r = B/B_0$	Relative permeability
$\chi_m = M/H$	Magnetic susceptibility
$\mu_r = 1 + \chi_m$	Relation

4. Electromagnetic Induction

Faraday's Law

Formula	Description
$\varepsilon = -d\Phi/dt$	Induced EMF

$\varepsilon = -N(d\Phi/dt)$	For N turns
$\Phi = BA \cos \theta$	Magnetic flux
$\Phi = \int B \cdot dA$	General flux

Motional EMF

Formula	Description
$\varepsilon = BLv$	Rod moving perpendicular
$\varepsilon = Bvl \sin \theta$	At angle θ
$\varepsilon = \frac{1}{2}B\omega l^2$	Rotating rod

Lenz's Law

- Induced current opposes the change in flux

Self-Inductance

Formula	Description
$\varepsilon = -L(dI/dt)$	Self induced EMF
$\Phi = LI$	Flux linkage
$L = \mu_0 n^2 Al$	Solenoid
$L = \mu_0 N^2 A/l$	Alternative form

Mutual Inductance

Formula	Description
$\varepsilon_2 = -M(dI_1/dt)$	Induced EMF

$\Phi_2 = MI_1$	Flux in coil 2
$M = \mu_0 N_1 N_2 A/l$	For two solenoids

Energy Stored in Inductor

Formula	Description
$U = \frac{1}{2}LI^2$	Energy stored
$u = B^2/2\mu_0$	Energy density

AC Generator

- $\varepsilon = \varepsilon_0 \sin \omega t$
- $\varepsilon_0 = NAB\omega$

5. Alternating Current

Basic AC Quantities

Formula	Description
$i = i_0 \sin \omega t$	Instantaneous current
$v = v_0 \sin \omega t$	Instantaneous voltage
$\omega = 2\pi f = 2\pi/T$	Angular frequency

RMS & Average Values

Quantity	Formula
RMS current	$I_{r\square\square} = I_0/\sqrt{2}$
RMS voltage	$V_{r\square\square} = V_0/\sqrt{2}$
Average (half cycle)	$I_{av} = 2I_0/\pi$

Form factor	$I_{r□□}/I_{av} = \pi/2\sqrt{2}$

AC Through Different Elements

Element	Resistance	Phase	V-I Relation
Resistor (R)	R	In phase	V = IR
Inductor (L)	XL = ωL	V leads I by 90°	V = IXL
Capacitor (C)	XC = 1/ωC	I leads V by 90°	V = IXC

LCR Series Circuit

Formul	Description
$Z = \sqrt{[R^2 + (XL - XC)^2]}$	Impedance

$I = V/Z$	Current
$\tan \varphi = (X_L - X_C)/R$	Phase angle
$\cos \varphi = R/Z$	Power factor
$V = \sqrt{V_R^2 + (V_L - V_C)^2}$	Voltage

Resonance

Formula	Description
$X_L = X_C$	Resonance condition
$\omega_0 = 1/\sqrt{LC}$	Resonant frequency
$f_0 = 1/(2\pi\sqrt{LC})$	Alternative form

$Z = R$	Impedance at resonance
$I = V/R$	Maximum current

Power in AC Circuit

Formula	Description
$P_{av} = V_{rms} I_{rms} \cos \varphi$	Average power
$P_{av} = I^2_{rms} R$	Power dissipation
$\cos \varphi = R/Z$	Power factor
Q-factor $= \omega L/R = 1/\omega CR$	Quality factor
$Q = \omega_0 L/R$	At resonance

Transformer

Formula	Description
$V_s/V_p = N_s/N_p$	Voltage ratio
$I_p/I_s = N_s/N_p$	Current ratio
$V_pI_p = V_sI_s$	For ideal transformer
$K = N_s/N_p$	Transformation ratio
Efficiency $\eta = (\text{Output}/\text{Input})\times 100$	Efficiency

6. Optics

REFLECTION

Mirror Formula & Magnification

Formula	Description
1/f = 1/v + 1/u	Mirror formula
f = R/2	Focal length
m = -v/u	Magnification
m = h'/h	Image/object height

Sign Convention:

- Distances measured from pole
- Against incident light: negative
- Along incident light: positive

REFRACTION

Snell's Law

Formula	Description

$n_1 \sin i = n_2 \sin r$	Snell's law
$n = c/v$	Refractive index
$n_{21} = n_2/n_1$	Relative RI
$n_{12} \times n_{21} = 1$	Reciprocal relation

Critical Angle & TIR

Formula	Description
$\sin C = n_2/n_1$	Critical angle
$\sin C = 1/n$	For denser to rarer

Lens Formula

Formula	Description
$1/f = 1/v - 1/u$	Lens formula
$P = 1/f$	Power (in diopters)
$m = v/u$	Magnification
$m = h'/h$	Image/object height

Lens Maker's Formula

Formula	Description
$1/f = (n-1)(1/R_1 - 1/R_2)$	In air
$1/f = (n_2/n_1 - 1)(1/R_1 - 1/R_2)$	In medium

Lenses in Combination

Formula	Description
$1/F = 1/f_1 + 1/f_2$	Two thin lenses in contact
$P = P_1 + P_2$	Power combination

Refraction Through Prism

Formula	Description
$A = r_1 + r_2$	Angle of prism
$\delta = i_1 + i_2 - A$	Deviation
$\delta_{\square} = 2i - A$	At minimum deviation

$n = \sin[(A+\delta_{□})/2]/\sin(A/2)$	RI from prism
$A = r_1 + r_2$ (at $\delta_{□}$)	Condition

Dispersion

Formula	Description
$\delta = (n - 1)A$	Deviation (small angle)
$\omega = n_v - n_r$	Dispersive power
$\omega = (n_v - n_r)/(n - 1)$	Dispersive power

OPTICAL INSTRUMENTS

Simple Microscope

Formula	Description

$m = D/f$	Magnification (image at D)
$m = 1 + D/f$	Image at infinity
$D = 25$ cm	Least distance of distinct vision

Compound Microscope

Formula	Description
$m = m_0 \times m_e$	Total magnification
$m = (v_0/u_0)(D/f_e)$	Image at D
$m = (v_0/u_0)(1 + D/f_e)$	Image at infinity
$m = -(L/f_0)(D/f_e)$	Normal adjustment

Telescope

Formula	Description
$m = -f_0/f_e$	Magnifying power
$L = f_0 + f_e$	Length (normal adjustment)

WAVE OPTICS

Young's Double Slit Experiment

Formula	Description
Path difference	$\Delta x = d \sin \theta \approx dy/D$
Fringe width	$\beta = \lambda D/d$
Bright fringe	$y = n\lambda D/d$

Dark fringe	y = (2n-1)λD/2d
Angular width	θ = λ/d

Interference

Condition	Path Difference	Phase Difference
Constructive	Δx = nλ	Δφ = 2nπ
Destructive	Δx = (2n-1)λ/2	Δφ = (2n-1)π

Diffraction

Formula	Description
a sin θ = nλ	Minima condition

Width of central max	$2\lambda D/a$

Resolving Power

Instrument	Formula
Microscope	$RP = 2n \sin \theta/\lambda$
Telescope	$RP = a/1.22\lambda$

Polarization

Formula	Description
Malus law	$I = I_0 \cos^2 \theta$
Brewster's law	$\tan i_B = n$

At Brewster angle	$i + r = 90°$

7. Dual Nature of Matter & Radiation

Photoelectric Effect

Formula	Description
$E = hf = hc/\lambda$	Energy of photon
$KE_{max} = hf - \varphi$	Einstein's equation
$KE_{max} = eV_0$	Stopping potential
$eV_0 = hf - \varphi$	Complete equation
$f_0 = \varphi/h$	Threshold frequency

$\lambda_0 = hc/\varphi$	Threshold wavelength

Constants:

- $h = 6.63 \times 10^{-34}$ J·s (Planck's constant)
- $c = 3 \times 10^{8}$ m/s (Speed of light)

De Broglie Wavelength

Formula	Description
$\lambda = h/p$	Matter wave wavelength
$\lambda = h/mv$	In terms of velocity
$\lambda = h/\sqrt{2mE}$	In terms of energy
$\lambda = h/\sqrt{2meV}$	For electron (accelerated)
$\lambda = 12.27/\sqrt{V}$ Å	Practical (for electron)

Davisson-Germer Experiment

- $n\lambda = d \sin \theta$ (Bragg's law)

8. Atoms & Nuclei

ATOMIC STRUCTURE

Bohr's Model

Formula	Description
$mvr = nh/2\pi$	Angular momentum quantization
$r_n = n^2h^2\varepsilon_0/\pi me^2$	Radius of orbit
$r_n = 0.529n^2$ Å	For hydrogen
$r_1 = 0.529$ Å	Bohr radius
$v_n = e^2/2\varepsilon_0 nh$	Velocity in orbit

$v_1 = c/137$	Velocity in first orbit

Energy Levels

Formula	Description
$E_n = -13.6/n^2$ eV	Energy of nth orbit (H)
$E_1 = -13.6$ eV	Ground state energy
$E = -13.6Z^2/n^2$ eV	For hydrogen-like atoms
$\Delta E = E_2 - E_1$	Energy difference

Spectral Series (Hydrogen)

Series	Formula	Region

Lyman	$1/\lambda = R(1/1^2 - 1/n^2)$, n=2,3,4...	UV
Balmer	$1/\lambda = R(1/2^2 - 1/n^2)$, n=3,4,5...	Visible
Paschen	$1/\lambda = R(1/3^2 - 1/n^2)$, n=4,5,6...	IR
Brackett	$1/\lambda = R(1/4^2 - 1/n^2)$, n=5,6,7...	IR
Pfund	$1/\lambda = R(1/5^2 - 1/n^2)$, n=6,7,8...	IR

Rydberg constant: $R = 1.097 \times 10^7\ m^{-1}$

X-rays

Formula	Description
$\lambda_{min} = hc/eV$	Cut-off wavelength
$\lambda_{min} = 12400/V$ Å	Practical form

$f = a(Z - b)$	Moseley's law

NUCLEAR PHYSICS

Nuclear Size & Density

Formula	Description
$R = R_0A^{(1/3)}$	Nuclear radius
$R_0 = 1.2 \times 10^{-15}$ m	Constant
$\rho = 3m/4\pi R_0^3$	Nuclear density

Mass-Energy Relation

Formula	Description
$E = mc^2$	Mass-energy equivalence

1 amu = 931.5 MeV/c^2	Energy equivalent
$\Delta m = Zm_p + Nm_n - M$	Mass defect
$BE = \Delta m \times c^2$	Binding energy
BE/A	Binding energy per nucleon

Radioactivity

Formula	Description
$dN/dt = -\lambda N$	Rate of decay
$N = N_0e^{(-\lambda t)}$	Decay law
$A = A_0e^{(-\lambda t)}$	Activity

$T_{1/2} = 0.693/\lambda$	Half-life
$T_{av} = 1/\lambda$	Mean life
$T_{av} = T_{1/2}/0.693 = 1.44T_{1/2}$	Relation
$N = N_0(1/2)^{(t/T_{1/2})}$	After n half-lives
$N = N_0(1/2)^n$	Alternative form

Nuclear Reactions

Reaction	Equation
Alpha decay	$^{A}ZX \rightarrow {}^{A-4}Z\text{-}2Y + {}^{4}_{2}He$
$Beta^{-}$ decay	$^{A}ZX \rightarrow {}^{A}Z+1Y + {}^{0}_{-1}e + \bar{v}$

Beta⁺ decay	$^{A}{}_{Z}X \rightarrow {}^{A}{}_{Z-1}Y + {}^{0}{}_{+1}e + \nu$
Gamma decay	$^{A}{}_{Z}X^{*} \rightarrow {}^{A}{}_{Z}X + \gamma$

Nuclear Energy

Formula	Description
$Q = \Delta m \times c^2$	Energy released
$Q = (\text{reactants} - \text{products})c^2$	Reaction energy

9. Semiconductors

Energy Bands

Material	Band Gap (eV)

Conductor	0
Semiconductor	< 3
Insulator	> 3
Si	1.1
Ge	0.7

Intrinsic Semiconductor

Formula	**Description**
$n_i = n_e = n_h$	Electron = hole concentration
$\sigma = n_i e(\mu_e + \mu_h)$	Conductivity

Extrinsic Semiconductor

Type	Dopant	Majority	Minority
n-type	Pentavalent	Electrons	Holes
p-type	Trivalent	Holes	Electrons

P-N Junction

Formula	Description
$V_0 \approx 0.7$ V	Barrier potential (Si)
$V_0 \approx 0.3$ V	Barrier potential (Ge)

Diode Current Equation

Formula	Description

$I = I_0(e^{(eV/kT)} - 1)$	Diode equation
Forward bias	$V > 0$, I increases
Reverse bias	$V < 0$, $I \approx -I_0$

Zener Diode

- Used in reverse bias for voltage regulation
- $V_{out} = V_z$ (constant)

Transistor

Configuration	**Input**	**Output**
Common Base (CB)	Emitter	Collector
Common Emitter (CE)	Base	Collector
Common Collector (CC)	Base	Emitter

Transistor Relations

Formula	Description
$I_e = I_\beta + Ic$	Current relation
$\alpha = Ic/I_e$	Current gain (CB)
$\beta = Ic/I_\beta$	Current gain (CE)
$\beta = \alpha/(1-\alpha)$	Relation between α and β
$\alpha = \beta/(1+\beta)$	Alternative relation

Logic Gates

Gate	Boolean Expression	Output

AND	Y = A·B	1 if both 1
OR	Y = A+B	1 if any 1
NOT	Y = Ā	Complement
NAND	Y = (A·B)'	NOT AND
NOR	Y = (A+B)'	NOT OR
XOR	Y = A⊕B	1 if different

IMPORTANT CONSTANTS

Constant	**Symbol**	**Value**
Speed of light	c	3×10^8 m/s

Planck's constant	h	6.63×10^{-34} J·s
Electron charge	e	1.6×10^{-19} C
Electron mass	m_e	9.1×10^{-31} kg
Proton mass	m□	1.67×10^{-27} kg
Permittivity of space	ε_0	8.85×10^{-12} C^2/Nm^2
Permeability of space	μ_0	$4\pi \times 10^{-7}$ Tm/A
Coulomb's constant	k	9×10^{9} Nm^2/C^2
Boltzmann constant	k	1.38×10^{-23} J/K
Avogadro number	N_a	6.022×10^{23} /mol

Rydberg constant	R	$1.097 \times 10^{7}\ m^{-1}$
1 eV	-	1.6×10^{-19} J
1 amu	-	931.5 MeV/c^2