12 Physics Cheat Sheet

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Part I

Electrostatics

1 Electric Charges and Fields

$$\text{electric current} = \frac{\text{charge}}{\text{time}}$$

$$\epsilon = K\epsilon_0$$

For a vacuum, $K = 1$. That is, $\epsilon = \epsilon_0$.

$$F = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi K\epsilon_0}\frac{q_1 q_2}{r^2}$$

1.1 Force on a charge due to another charge

1.1.1 Force acting on charge q_1 due to charge q_2

$$\overrightarrow{F_{12}} = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{\overrightarrow{r_{12}}^2}\hat{r_{12}} = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{r^3}\overrightarrow{r_{12}}$$

where $\overrightarrow{r_{12}}$ is the position of q_2 with respect to q_1 and r is $|\overrightarrow{r_{12}}|$.

1.1.2 Force acting on charge q_2 due to charge q_1

$$\overrightarrow{F_{21}} = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{\overrightarrow{r_{21}}^2}\hat{r_{12}} = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{r^3}\overrightarrow{r_{21}} = -\overrightarrow{F_{12}}$$

where $\overrightarrow{r_{21}}$ is the position of q_1 with respect to q_2 and r is $|\overrightarrow{r_{21}}|$.

$$F_1 = \sum_{i=2}^{n} F_{1i}$$

$$\overrightarrow{E} = \frac{\overrightarrow{F}}{q}$$

$$\implies \overrightarrow{F} = q\overrightarrow{E}$$

$$\overrightarrow{E} = \sum \overrightarrow{E_i}$$

1.2 Electric field intensity due to a point charge q

$$E = \frac{1}{4\pi\epsilon}\frac{q}{r^2}$$

$$\overrightarrow{E} = \frac{1}{4\pi\epsilon}\frac{q}{\overrightarrow{r}^2}\hat{r}$$

where $\overrightarrow{r}$ is the position of the test charge with respect to q.

1.3 Intensity of electric field due to a continuous charge distribution

1.3.1 Linear charge distribution

$$\overrightarrow{F} = \frac{q_0}{4\pi\epsilon}\int_L \frac{\lambda l}{\overrightarrow{r_{21}}^2}\hat{r_{21}}$$

where 2 is the position of the test charge and 1 is the position of dL.

$$\overrightarrow{E} = \frac{1}{4\pi\epsilon}\int_L \frac{\lambda dl}{\overrightarrow{r_{21}}^2}\hat{r_{21}}$$

1.3.2 Surface charge distribution

$$\overrightarrow{F} = \frac{q_0}{4\pi\epsilon}\int_S \frac{\sigma dA}{\overrightarrow{r_{21}}^2}\hat{r_{21}}$$

$$\overrightarrow{E} = \frac{1}{4\pi\epsilon}\int_S \frac{\sigma dA}{\overrightarrow{r_{21}}^2}\hat{r_{21}}$$

1.3.3 Volume charge distribution

$$\overrightarrow{F} = \frac{q_0}{4\pi\epsilon}\int_V \frac{\rho dV}{\overrightarrow{r_{21}}^2}\hat{r_{21}}$$

$$\overrightarrow{E} = \frac{1}{4\pi\epsilon}\int_V \frac{\rho dV}{\overrightarrow{r_{21}}^2}\hat{r_{21}}$$

1.4 Electric dipole moment

$$\overrightarrow{p} = q \times 2\overrightarrow{l}$$

$\overrightarrow{p}$ always points from the negative charge to the positive charge.

1.5 Electric field intensity due to a dipole

1.5.1 At an axial point

$$E_1 = \frac{1}{4\pi\epsilon}\frac{q_1}{(r-l)^2}$$

$$E_2 = \frac{1}{4\pi\epsilon}\frac{q_2}{(r+l)^2}$$

$$E = E_1 - E_2$$

$$E = \frac{1}{4\pi\epsilon}\frac{2pr}{(r^2-l^2)^2} = \frac{1}{4\pi\epsilon}\frac{2p}{r^3}$$

if $r \gg l$.

1.5.2 At an equatorial point

$$E_1 = E_2 = \frac{1}{4\pi\epsilon}\frac{q}{r^2+l^2}$$

$$E = E_1\cos\theta + E_2\cos\theta = 2\left[\frac{1}{4\pi\epsilon}\frac{q}{r^2+l^2}\right]\cos\theta$$

$$\cos\theta = \frac{A}{H} = \frac{l}{\sqrt{r^2+l^2}} = \frac{l}{(r^2+l^2)^{\frac{1}{2}}}$$

$$E = 2\left[\frac{1}{4\pi\epsilon}\frac{q}{r^2+l^2}\right]\left[\frac{l}{(r^2+l^2)^{\frac{1}{2}}}\right] = \frac{1}{4\pi\epsilon}\frac{2ql}{(r^2+l^2)^{\frac{3}{2}}} = \frac{1}{4\pi\epsilon}\frac{p}{(r^2+l^2)^{\frac{3}{2}}}$$

If $r \gg l$,

$$E = \frac{1}{4\pi\epsilon}\frac{p}{r^3}$$

$$\overrightarrow{E} = -\frac{1}{4\pi\epsilon}\frac{\overrightarrow{p}}{r^3}$$

1.5.3 1.5.1 vs 1.5.2

$$\overrightarrow{E_{\text{axial}}} = -2\overrightarrow{E_{\text{equatorial}}}$$

1.6 Torque on a dipole in a uniform electric field

$$\tau = qE \times 2l\sin\theta = 2ql \times E\sin\theta = pE\sin\theta$$

$$\overrightarrow{\tau} = \overrightarrow{p} \times \overrightarrow{E}$$

2 Gauss' Theorem

2.1 Solid angles

$$d\omega = \frac{dA}{r^2}$$

1 steridian is the solid angle subtendedd by a part of the surface of a sphere at the centre of the sphere when the $dA = r^2$.

$$\omega = \frac{4\pi r^2}{r^2} = 4\pi\,\text{steridian}$$

$$d\omega = \frac{dA \cos\theta}{r^2}$$

2.2 Electric flux

$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

For a plane surface of area A in a uniform electric field:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \oint EdA \cos\theta = E\cos\theta \oint dA = EA\cos\theta$$

2.3 Gauss' Theorem

$$\Phi_E = \oint \vec{E} \cdot \vec{dA} = \frac{q}{\epsilon_0}$$

2.4 Gaussian surfaces

A gaussian surface is an arbitrary closed surface in space through which the flux of a vector field is calculated.

- The surface must be a closed surface
- The surface must pass through the point at which the flux is to be calculated
- The surface must be shaped according to the symmetry of the source so that the field is normal to the surface at each point and constant in magnitude.
- The surface should not pass through any discrete charge.

2.5 Applications of Gauss' theorem

2.5.1 Electric field due to a point charge

Gaussian surface: sphere.

$$E = \frac{1}{4\pi\epsilon}\frac{q}{r^2}$$

2.5.2 Electric field due to an infinite line of charge

Gaussian surface: cylinder around and parallel to the line of charge.

$$\overrightarrow{E} = \frac{\lambda}{2\pi\epsilon_0}\hat{r}$$

2.5.3 Electric field due to an infinite plane of charge

Gaussian surface: surface with its length through the "centre" of the plane.

$$E = \frac{\sigma}{2\epsilon_0}$$

2.5.4 Electric field due to two infinite parallel sheets of charge

Use results from 2.5.3.

$$E_1 = \frac{\sigma_1}{2\epsilon_0}$$

$$E_2 = \frac{\sigma_2}{2\epsilon_0}$$

$$E_{\pm\pm_{\text{side}}} = \frac{\sigma}{\epsilon_0}$$

$$E_{\pm\pm_{\text{mid}}} = 0$$

$$E_{\pm\mp_{\text{side}}} = 0$$

$$E_{\pm\mp_{\text{mid}}} = \frac{\sigma}{\epsilon_0}$$

2.5.5 Electric field just outside a charged conductor

Practically identical to 2.5.3.

2.5.6 Electric field due to a uniformly charged thin shell

Gaussian surface:

3 Electric Potential and Potential Energy

$$V = \frac{W}{q_0}$$

$$V_A - V_B = \frac{W}{q_0}$$

$$V = \frac{1}{4\pi\epsilon}\frac{q}{r}$$

$$V = \frac{1}{4\pi\epsilon}\sum\frac{q_i}{r_i}$$

$$V = \frac{1}{4\pi\epsilon}\int\frac{\sigma dl}{r}$$

$$V = \frac{1}{4\pi\epsilon}\int_S\frac{\sigma dA}{r}$$

$$V = \frac{1}{4\pi\epsilon}\int_v\frac{\rho dv}{r}$$

3.1 Potential due to a dipole

3.1.1 At an axial point

$$V = \frac{1}{4\pi\epsilon}\frac{p}{r^2 - l^2}$$

If $r \gg l$,

$$V = \frac{1}{4\pi\epsilon}\frac{p}{r^2}$$

3.1.2 At an equatorial point

$$V_! = \frac{1}{4\pi\epsilon}\frac{q}{BP}$$

$$V_2 = \frac{1}{4\pi\epsilon}\frac{q}{AP}$$

$$V = V_1 + V_2 = 0$$

3.1.3 At an arbitrary point

$$V = \frac{1}{4\pi\epsilon}\frac{p\cos\theta}{r^2}$$

3.2 Relation between E and V

$$E = -\frac{\mathrm{d}V}{\mathrm{d}r} = \frac{V_1 - V_2}{d}$$

3.3 Equipotential surfaces

3.4 Electric potential energy

3.5 Work done in rotating a dipole in an electric field

3.6 Potential energy of a dipole in an electrostatic field

4 Capacitors and Dielectrics

Part II

Current Electricity

5 Electric Resistance and Ohm's Law

6 DC Circuits and Measurements

$$E = \frac{\mathrm{d}W}{\mathrm{d}q}$$

$$E = V_1 + V_2 + V_3 + \dots$$

$$V = E - Ir$$

$$r = R\left(\frac{E}{V} - 1\right)$$

Part III

Magnetic Effects of Current and Magnetism

7 Moving charges and magnetism

8 Torque on a current loop: Moving Coil Galvanometer

9 Magnetic Classification of Substances

10 Electromagnetic Induction

Part IV

EM Induction and Alternating Currents

11 Electromagnetic Induction

$$\Phi_B = BA\cos\theta$$

$$\Phi_B = \frac{FA}{Il}$$

$$e_{N=1} = -\frac{\Delta\Phi_B}{\Delta t} = -\frac{\mathrm{d}\Phi_B}{\mathrm{d}t}$$

$$e = -N\frac{\Delta\Phi_B}{\Delta t} - N\frac{\mathrm{d}\Phi_B}{\mathrm{d}t}$$

$$I = \frac{e}{r} = \frac{N}{R}\frac{\Delta\Phi_B}{\Delta t}$$

$$q = I\Delta t = \frac{N}{R}\Delta\Phi_B$$

$$V = Bvl$$

11.1 Self Induction

$$L = \frac{N\Phi_B}{I}$$

$$e = -\frac{\Delta(LI)}{\Delta t} = -L\frac{\Delta I}{\Delta t}$$

$$L = -\frac{e\Delta t}{\Delta I} = -\frac{e}{\Delta I/\Delta t}$$

11.2 Mutual Induction

$$M = \frac{N_2\Phi_2}{I_1}$$

12 Alternating Current

$$V_0 = NBA\omega$$

$$V = V_0 \sin \omega t$$

$$I = I_0 \sin wt$$

$$T = \frac{2\pi}{\omega}$$

$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$

$$I_m = \frac{2}{\pi} I_0$$

$$I_{\mathrm{rms}} = \frac{I_0}{\sqrt{2}}$$

12.1 Types of AC circuits

12.1.1 Circuit containing resistance (R) only

$$V = V_0 \sin \omega t$$

$$I = I_0 \sin \omega t$$

12.1.2 Circuit containing inductance (L) only

$$V = V_0 \sin \omega t$$

$$I = I_0 \sin \left(\omega t - \frac{\pi}{2} \right)$$

$$X_L = \omega L = 2\pi f L$$

$$I_0 = \frac{V_0}{X_L} = \frac{V_0}{\omega L}$$

12.1.3 Circuit containing capacitance (C) only

$$V = V_0 \sin \omega t$$

$$I = I_0 \sin \left(\omega t + \frac{\pi}{2} \right)$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$I_0 = \frac{V_0}{X_C} = \frac{V_0}{1/\omega C}$$

12.1.4 Circuit containing L, R

$$I = I_0 \sin(\omega t - \Phi)$$

$$Z = \sqrt{R^2 + X_L^2}$$

$$I_0 = \frac{V_0}{Z}$$

$$V = \sqrt{V_R^2 + V_L^2}$$

$$\Phi = \tan^{-1}\left(\frac{X_L}{R}\right)$$

$$\cos\Phi = \frac{R}{\sqrt{R^2 + X_L^2}}$$

12.1.5 Circuit containing C, R

$$I = I_0 \sin(\omega t + \Phi)$$

$$Z = \sqrt{R^2 + X_C^2}$$

$$I_0 = \frac{V_0}{Z}$$

$$V = \sqrt{V_R^2 + V_C^2}$$

$$\Phi = \tan^{-1}\left(\frac{X_C}{R}\right)$$

$$\cos\Phi = \frac{R}{\sqrt{R^2 + X_C^2}}$$

12.1.6 Circuit containing L, C

12.1.7 Circuit containing L, C, R

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\Phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Resonance

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{Z}$$

$$X_L = X_C$$

$$L\omega = \frac{1}{\omega C}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

12.2 Power

$$P = \text{Apparent power} \times \text{Power factor} = V_{\text{rms}} I_{\text{rms}} \cos\Phi = I_{\text{rms}}^2 R = \frac{1}{2} V_0 I_0 \cos\Phi$$

12.3 Half Points

Part V

Electromagnetic Waves

13 Electromagnetic Waves

$$I_D = \epsilon_0 \frac{\mathrm{d}\phi}{\mathrm{d}t}$$

$$\oint B \mathrm{d}t = \mu_0 (I_C + I_D)$$

$$\frac{E^2 \epsilon_0}{2}$$

$$\frac{B^2}{2\mu_0}$$

$$\frac{E^2 \epsilon_0}{2} + \frac{B^2}{2\mu_0}$$

$$p = \frac{U}{c}$$

	Wavelength (m)
Gamma	1×10^{-14} to 1×10^{-10}
X Rays	1×10^{-12} to $3 \times 10^{+8}$
Ultraviolet	6×10^{-10} to 4×10^{-7}
Visible	4×10^{-7} to 7×10^{-7}
Infrared	8×10^{-7} to 5×10^{-3}
Micro	1×10^{-3} to 3×10^{-1}
Radio	1×10^{-1} to $1 \times 10^{+4}$
Long	$5 \times 10^{+6}$ to $6 \times 10^{+6}$

Part VI

Optics

14 Spherical Mirrors

15 Refraction of Light at a Plane Interface: (Total Internal Reflectiom — Optical Fibre)

16 Refraction of Light at Spherical Surfaces: Lenses

17 Refraction and Dispersion of Light Through a Prism

18 Optical Instruments

18.1 Simple Microscope

$$M = \frac{D}{u}$$

$$M = 1 + \frac{D}{f}$$

Relaxed eye:

$$M = \frac{D}{f}$$

18.2 Compound Microscope

$$M = m_e \times m_o$$

$$M = -\frac{v_o}{u_o}\left(\frac{D}{u_e}\right)$$

$$M = \frac{f_o}{u_o - f_o}\left(\frac{D}{u_e}\right)$$

Adjustment for clear vision:

$$M = -\frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

$$L = v_o + |u_e|$$

18.3 Refracting (Astronomical) Telescope

18.4 Reflecting Telescope

$$M = -\frac{f_o}{f_e}$$

$$l = 1.22\frac{\lambda}{d}\,\text{radian}$$

19 Wave Nature of Light: Huygens' Principle

20 Interference of Light

21 Diffraction of Light

22 Polarization of Light

Part VII

Dual Nature of Radiation and Matter

23 Photoelectric Effect

$$hv = W + E_k$$

$$E_k = hv - W$$

$$W = hv_0$$

$$E_k = hv - hv_0 = h(v - v_0)$$

$$\frac{1}{2}mv_{\max}^2 = h(v - v_0) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

$$\frac{1}{2}mv_{\max}^2 = eV_0$$

$$eV_0 = h(v - v_0)$$

$$V_0 = \frac{h}{e}(v - v_0)$$

24 Matter Waves

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\lambda = \frac{h}{\sqrt{2mK}}$$

$$\lambda_{\text{electron}} = \sqrt{\frac{150}{V}} \times 10^{-10}\,\text{m}$$

25 X Rays

$$v_{\max} = \frac{eV}{h}$$

$$\lambda_{\min} = \frac{hc}{eV}$$

$$\sqrt{v} = a(Z - b)$$

Part VIII

Atoms and Nuclei

26 Atoms: Origin of Spectra

27 Nuclear Structure

28 Radioactivity

29 Mass energy equivalence: Nuclear energy binding

30 Nuclear Fission and Nuclear Fusion: Source of energy

Part IX

Electronic Devices

31 Semiconductor Electronics

32 Junction Diodes

$$V_{\text{in}} = IR + V_z$$

$$I = I_Z + I_L$$

$$R = \frac{V_{in} - V_Z}{I_Z + I_L}$$

33 Junction Transistors

34 Logic Gates

Part X

Communication Systems

35 Communication Systems

A Constants

$$k_{\text{vacuum}} = 9.0 \times 10^{9}\,\text{Nm}^2\text{C}^{-2}$$

$$\epsilon_0 = 8.85 \times 10^{-12}\,\text{C}^2\text{N}^{-1}\text{m}^2$$

$$\mu_0 =$$

$$h = 6.63 \times 10^{-34}\,\text{Js}$$

$$c = 3 \times 10^{8}\,\text{ms}^{-1}$$

$$e =$$

$$m_e =$$