Formula Sheet for Physics 132

elementary charge $e = 1.6 \times 10^{-19} C$ mass of an electron $m_e = 9.1 \times 10^{-31} kg$

mass of a proton $m_p = 1.67 \times 10^{-27} kg$

mass of a neutron $m_n = 1.68 \times 10^{-27} kg$

permittivity constant $\varepsilon_0 = 8.85 \cdot 10^{-12} \frac{C^2}{Nm^2} = 8.85 \cdot 10^{-12} \frac{F}{m}$

Gravitational force: $F = G\frac{M_1\, M_2}{r^2}$, $G = 6.67 \cdot 10^{-11} \frac{Nm^2}{kg^2}$

Electrostatics:

electric force: $|\vec{F}| = k\frac{|Q_1 Q_2|}{r^2}$, $k = 9.0 \cdot 10^9 \frac{Nm^2}{C^2}$, unit of force: $N = newton$

electric field: $\vec{E} = \frac{\vec{F}}{q}$, unit of electric field: $\frac{N}{C}$, $C = coulomb$, unit of charge, direction defined through the force on a *positive* test charge

$|\vec{E}| = k\frac{|Q_1|}{r^2}$ (generated by a point charge Q_1)

force on a point charge in an electric field: $\vec{F} = q\vec{E}$

line charge density $\lambda = \frac{\text{charge}}{\text{length}}$, area charge density $\sigma = \frac{\text{charge}}{\text{area}}$

volume charge density: $\rho = \frac{\text{charge}}{\text{volume}}$

electric flux through an area A: $\Phi = \vec{E} \cdot \vec{A}$

electric flux through a Gaussian surface: $\Phi = \oint \vec{E} \cdot d\vec{A}$

Gauss' Law: $\Phi = \frac{q_{enc}}{\varepsilon_0}$

Kinetic Energy: $K = \frac{1}{2}mv^2$

Work - Kinetic Energy Theorem: $\Delta K = K_f - K_i = W$

Work (constant force): $W = \vec{F} \cdot \vec{d} = Fd\cos\phi$ Work (general): $W = \int_{x_i}^{x_f} F(x)dx$

Potential energy and work: $\Delta U = -W$

Electric Potential is the electric potential energy per unit charge: $V = \frac{U}{q}$, measured in $1 Volt = 1 Joule/Coulomb$

electric potential difference or "voltage": $\Delta V = V_f - V_i = \frac{\Delta U}{q} = -\frac{W}{q}$, with U: electric potential energy, W: work done by the electric field electric potential due to a point charge q a distance r away: $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

Electric field $\vec{E}$ is always perpendicular to equipotential surfaces.

Finding V from $\vec{E}$: $V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$

Finding $\vec{E}$ from V: $E_x = -\frac{\partial V}{\partial x},\ E_y = -\frac{\partial V}{\partial y},\ E_z = -\frac{\partial V}{\partial z}$

Capacitance $C = \frac{Q}{V}$, measured in $Farad = 1F = 1Coulomb/Volt$

parallel plate capacitor: $C = \varepsilon_0 \frac{A}{d}$, area of the plates A, distance between the plates d

Circuits:

electric **current**: $i = \frac{dq}{dt}$, unit: $1\,Ampere = 1A = \frac{C}{s}$

current density $\vec{J}$: $i = \int \vec{J} \cdot d\vec{A}$, and $\vec{J} = ne\vec{v}_d$ with $\vec{v}_d$ drift velocity, n density of charge carriers

definition of **resistance** of a circuit element: $R = \frac{V}{i}$, with V: voltage across circuit element, i: current through circuit element, unit $\Omega = ohm = \frac{V}{A}$,

resistance of a wire: $R = \rho \frac{L}{A}$ with A: cross-sectional area, L length, ρ resistivity of material

temperature dependence: $\rho = \rho_0[1 + \alpha(T - T_0)]$

power: $P = \frac{dU}{dt} = V \cdot i$, unit $W = watt = \frac{J}{s} = VA$

resistors in series: $R_{eq} = R_1 + R_2 + R_3 + ...$

resistors in parallel: $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$

for two resistors R_1, R_2 in series: $i_1 = i_2 = I$, $V_1 + V_2 = V$

for two resistors R_1, R_2 in parallel: $V_1 = V_2 = V$, $i = i_1 + i_2$

junction rule: the sum of the currents entering any junction must be equal to the sum of the currents leaving that junction.

loop rule: the algebraic sum of the changes in potential encountered in a complete traversal of any loop of a circuit must be zero.

change in potential in traversing a resistance R in the direction of the current is $-iR$; in the opposite direction $+iR$.

change in potential in traversing an ideal battery in the direction of the emf arrow is $+\mathcal{E}$; in the opposite direction $-\mathcal{E}$.

RC circuits: 1) charging the capacitor: ideal battery with emf $\mathcal{E}$, resistance R and capacitance C in series

$q = C\mathcal{E}(1 - \exp[-t/RC])$

time constant $\tau = RC$

2) discharging the capacitor: resistance R and capacitance C in series

$q = q_0 \exp[-t/RC]$

Magnetism

magnetic field $\vec{B}$, unit: $1T = tesla = \frac{N}{Am}$

force on charge in magnetic field: $\vec{F} = q\vec{v} \times \vec{B}$

force on current carrying wire in magnetic field: $\vec{F} = i\vec{L} \times \vec{B}$, and $\vec{L}$ points in the direction of the conventional current

charged particle circulating in a magnetic field: $qvB = \dfrac{mv^2}{r}$

frequency f of the motion: $f = \dfrac{\omega}{2\pi} = \dfrac{1}{T} = \dfrac{qB}{2\pi m}$

Biot - Savart Law $d\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{i\, d\vec{s} \times \vec{r}}{r^3}$; permeability constant: $\mu_0 = 4\pi \cdot 10^{-7} \frac{Tm}{A}$

magnetic field due to a long straight wire with current i, a distance r away: $B = \dfrac{\mu_0}{2\pi} \dfrac{i}{r}$

magnetic field due to a circular arc of wire, at the center of the arc: $B = \dfrac{\mu_0 i \phi}{4\pi R}$

Geometry: area of a circle $A = \pi r^2$, surface area of a sphere: $S = 4\pi r^2$

volume of a sphere: $V = \frac{4}{3}\pi r^3$, surface area of a cylinder of length l and radius r: $S_{cyl} = 2\pi r l$

Quadratic equation: $ax^2 + bx + c = 0$, $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Vector $\vec{a}$: $a_x = a\cos(\theta)$, $a_y = \sin(\theta)$, $\tan(\theta) = \frac{a_y}{a_x}$ $|\vec{a}| = \sqrt{a_x^2 + a_y^2}$

Scalar product: $\vec{a} \cdot \vec{b} = ab\cos(\theta)$, θ: angle between vectors $\vec{a}$ and $\vec{b}$.

Vector product: $\vec{a} \times \vec{b} = \vec{c}$, magnitude $|\vec{c}| = |\vec{a}|\,|\vec{b}|\sin\theta$, θ: angle between vectors $\vec{a}$ and $\vec{b}$. Direction from right hand rule: $\vec{a}$ along thumb, $\vec{b}$ along index finger, $\vec{c}$ along middle finger of right hand; thumb and index finger at right angles to the middle finger.

Trig and right triangle:

$$\sin\theta = \frac{\text{leg opposite } \theta}{\text{hypotenuse}}$$

$$\cos\theta = \frac{\text{leg adjacent to } \theta}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{leg opposite } \theta}{\text{leg adjacent to } \theta}$$