CH. 16 : Electric Charge & Field

$F = k\frac{Q_1 Q_2}{r^2}$ $k = \frac{1}{4\pi\varepsilon_0}$ $k = 8.988 \times 10^9\ N\cdot m^2/C^2$

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N\cdot m^2$

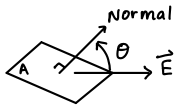
$E = \frac{F}{q} = k\frac{Q}{r^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2}$ {Point Charge}

↑ {Force per unit charge}

* Both E & F are vector quantities and add respectively.

* Charge lives on surface of conductors

$\Phi_E = EA\cos\theta$



Gauss's Law: $\sum E_\perp A = Q_{enclosed}/\varepsilon_0$

Surface of Conductor: $E = \sigma/\varepsilon_0$ σ = surface charge density

CH. 17 : Electric Potential

Work $= Fd = qEd$

Change in PE (U): $\Delta PE = -qEd$

Electric Potential: $V = U/q$ {PE per unit charge}

Potential Difference: $\Delta V_{ba} = \Delta U/q = -\frac{W_{b\ to\ a}}{q}$

Uniform Field: $E = V/d$

Capacitor: $Q = CV$

ll-Plate Capacitor: $C = K\varepsilon_0\frac{A}{d}$

↑ dielectric constant

Permittivity of material: $\varepsilon = K\varepsilon_0$

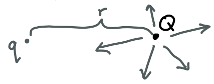
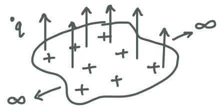
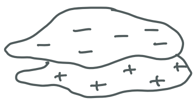
Work to add charge: $W = Q\frac{V_f}{2}$ $\Delta W = V\Delta q$

↑ move from one plate to other plate

$PE = U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}Q^2/C = \frac{1}{2}\varepsilon_0 E^2 Ad$

↑ ll-plate cap

Energy Density $u = \frac{PE}{Vol.} = \frac{1}{2}\varepsilon_0 E^2$

	FORCE	E-FIELD	POTENTIAL	VOLTAGE
POINT CHARGE 	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$	$U = \frac{Qq}{4\pi\varepsilon_0 r}$	$V = \frac{Q}{4\pi\varepsilon_0 r}$
LINE CHARGE	$F = \frac{\lambda q}{2\pi\varepsilon_0 r}$	$E = \frac{\lambda}{2\pi\varepsilon_0 r}$	$U = \frac{\lambda q}{2\pi\varepsilon_0} \ln\left(\frac{r_0}{r}\right)$	$V = \frac{\lambda}{2\pi\varepsilon_0} \ln\left(\frac{r_0}{r}\right)$
SINGLE PLATE 	$F = \frac{\sigma}{2\varepsilon_0} q$	$E = \frac{\sigma}{2\varepsilon_0}$	$U = \frac{\sigma}{2\varepsilon_0} q x$	$V = \frac{\sigma}{2\varepsilon_0} x$
PARALLEL PLATES 	$F = \frac{\sigma}{\varepsilon_0} q$	$E = \frac{\sigma}{\varepsilon_0}$	$U = \frac{\sigma}{\varepsilon_0} q x$	$V = \frac{\sigma}{\varepsilon_0} x$

CH. 18: Electric Currents

$I = \Delta Q / \Delta t$ $\quad V = IR$ voltage drop across resistor {electric potential decrease}

$R = \rho \ell / A$, Electrical Conductivity $= \frac{1}{\text{resistivity}}$

$\rho_T = \rho_0 [1 + \alpha (T - T_0)]$ Temperature Coefficient of Resistivity

Power $= QV/t$, $\quad P = IV = I^2 R = V^2/R$

AC Current: $V = V_0 \sin(2\pi f t)$, $\omega = 2\pi f$

Peak Current (I_0):
$I = I_0 \sin(\omega t)$
$P = I^2 R = I_0^2 R \sin^2(\omega t)$
$P_{ave} = \frac{1}{2} I_0^2 R = \frac{1}{2} V_0^2 / R$

RMS: $I_{rms} = \sqrt{\overline{I^2}} = I_0/\sqrt{2} = 0.707\, I_0$

$V_{rms} = \sqrt{\overline{V^2}} = V_0/\sqrt{2} = 0.707\, V_0$

$\overline{P} = I_{rms}^2 R = V_{rms}^2 / R = I_{rms} V_{rms}$

Drift Velocity: $\Delta Q = n V e = n A V_d \Delta t\, e$

CH. 19: DC Circuits

$V = IR$, $P = IV$, $E = F/q$, $R = \rho \ell / A$

$V_{ab} = \mathcal{E} - I r_{internal}$

Series: $R_{TOT} = R_1 + R_2 + R_3$, $\quad \frac{1}{C_{TOT}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Parallel: $\frac{1}{R_{TOT}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$, $\quad C_{TOT} = C_1 + C_2 + C_3$

Kirchoff Rules:

- Sum of i @ junction is zero
- change in potential (voltage) is zero around any loop

$Q_{cap} = Q_{max}(1 - e^{-t/R \cdot C})$

CH. 20: Magnetism

$F = I l B \sin\theta$

$F = q v B \sin\theta$

Charges in B-Field $r = \frac{mv}{qB}$, $T = \frac{2\pi m}{qB}$ (period) (m: mass), $f = \frac{1}{T}$ (freq)

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$ (straight wire)

$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d} l_2$

$B = \frac{\mu_0 N I}{l}$

$\tau = NIAB \sin\theta$

Mass spectrometer: $v = E/B$

Ch. 21: EM Induction & Faraday's Law

$\Phi_B = BA\cos\theta$

$\mathcal{E} = -\frac{\Delta \Phi_B}{\Delta t}$

Lenz's Law: A current produced by an induced emf moves in a direction so that the magnetic field created by that current opposes the original change in flux.

or... An induced emf is always in a direction that opposes the original change in flux that caused it.

$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$

$U_B = \frac{1}{2}\frac{B^2}{\mu_0}$

Ch. 22: EM Waves

Pressure $= a \cdot \frac{I}{c}$ $\begin{cases} a=1 & \text{fully absorbed} \\ a=2 & \text{fully reflected} \end{cases}$

Point Source E & B decay as $1/r^2$

$E = cB$, $c = \frac{1}{\varepsilon_0 \mu_0}$

$c = \lambda f$

$I = \varepsilon_0 c E^2$

$\bar{I} = \frac{1}{2}\varepsilon_0 c E_0^2 = \frac{1}{2}\frac{c}{\mu_0}B_0^2 = \frac{E_0 B_0}{2\mu_0}$

$\bar{I} = \frac{E_{rms}B_{rms}}{\mu_0}$

$u = \varepsilon_0 E^2 = \varepsilon_0 c^2 B^2 = \frac{B^2}{\mu_0} = \sqrt{\frac{\varepsilon_0}{\mu_0}} EB$

CH. 23: Light, Geometric Optics

$f = \frac{r}{2}$　　Power $= \frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$,　$\sin\theta_c = \frac{n_2}{n_1}$ ← source medium

CH. 24: Wave Nature of Light

$\lambda_n = \frac{\lambda}{n}$

Double Slit: * BRIGHT: $d\sin\theta = m\lambda$ $(m = 0, 1, 2, \ldots)$
* DARK: $d\sin\theta = (m + \frac{1}{2})\lambda$
* WIDTH OF MIDDLE BULGE $= m\lambda L/d$ $(m = 1)$

Single Slit: $\sin\theta = \frac{m\lambda}{D}$ (1st min = 1)

Grating: $\sin\theta = \frac{m\lambda}{d}$ $(m = 0, 1, 2, \ldots)$ * MAXIMA

Wedge: $2t = m\lambda$ $(m = 0, 1, 2, \ldots)$ * DARK BANDS

Polarization: $I = I_o \cos^2\theta$

Polarized Reflection @ $\tan\theta_p = \frac{n_2}{n_1}$ ← source medium

CH. 25: Optical Instruments

Angular Magnification: $M = \frac{N}{f}$

Telescope: $M = -f_o / f_e$ (o = objective, e = eyepiece)

Microscope: $M = N\ell / f_o f_e$

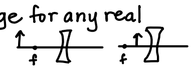
Rayleigh Criterion: $\theta = 1.22\lambda / D$ (D = aperture of instrument)
Angular separation of 2 objects

Nearsightedness (Myopia) → image forms before retina
Farsightedness (Hypermyopia) → image forms behind retina

CONVENTIONS

1) $f > 0$ for (+) converging lens
$f < 0$ for (−) diverging lens

* (−) Div. lenses → always produce upright virtual image for any real object, no matter the location of object. (single)



(+) Converging lenses → real inverted images OR virtual upright, depending on object position

2) $d_o > 0$ for object on same side as light source (default (+) unless 2 lenses)

3) $d_i > 0$ for images on opposite side as light source
$d_i > 0$ for real images, $d_i < 0$ for virtual images

4) $h_i > 0$ for upright images, $h_i < 0$ for inverted images (relative to object)

5) Converging lenses have $D > 0$ (diopters), diverging lenses $D < 0$

CH. 27

Blackbody Radiation (Wien's Law): $\lambda_{peak} \cdot T = 2.9 \times 10^{-3}\ m \cdot K$

Planck's Hypothesis: $E = hf = \frac{hc}{\lambda}$

Work Function: $hf = KE_{max} + W_0$

Momentum of Photon: $p = \frac{h}{\lambda}$

Compton Effect (scattering): $\lambda' = \lambda + \frac{h}{m_e c}(1 - \cos\phi)$

de Broglie Wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$ {non-relativistic}

λ of e^-: $\frac{1}{2} m_e v^2 = e \cdot V$

Lyman Series: $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$ $n = 2, 3, \dots$

Balmer Series: $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ $n = 3, 4, \dots$ $(R = 1.0974 \times 10^7\ m^{-1})$

Paschen Series: $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$ $n = 4, 5, \dots$

Bohr Orbit: $r_1 = \frac{h^2}{4\pi^2 m_e k e^2}$ $r_n = \frac{n^2}{Z}(r_1)$ $n = 1, 2, 3 \dots$

$E_n = (-13.6\,eV)\frac{Z^2}{n^2}$ $hf = E_{up} - E_{lower}$

$KE_{ave} = \frac{3}{2}kT$ $(k = 1.38 \times 10^{-23}\ J/K)$

CH. 28

Heisenberg Uncertainty: $(\Delta x)(\Delta p_x) \gtrsim \frac{h}{2\pi}$

$(\Delta t)(\Delta E) \gtrsim \frac{h}{2\pi}$ $(h = 6.626 \times 10^{-34}\ J \cdot s)$

Principal Quantum Number: $E_n = \frac{-13.6\,eV}{n^2}$ $n = 1, 2, \dots$

Angular Momentum: $L = \sqrt{\ell(\ell+1)}\,\hbar$ $[\hbar = \frac{h}{2\pi},\ \ell = 0 \text{ to } (n-1)]$

Zeeman Effect: $L_z = m_\ell \hbar$ $(m_\ell = -\ell \text{ to } +\ell)$ * Magnetic Field applied

Spin: $m_s = -\frac{1}{2}$ or $+\frac{1}{2}$

Aufbau Principle

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f

Selection Rule: transitions to $\pm 1\ \Delta\ell$ away

Pauli Exclusion: no two e^- can occupy same quantum state

Hund: each state receives an e^- before doubling up w/ opposite spin

Quantum State (n, ℓ, m_ℓ, m_s), n^2 orbitals, $2e^-$ each

X-ray Collision – cut-off $\lambda_0 = \frac{hc}{eV}$

CH. 29

Quantized Diatomic Molecule Rotational Energy

$$E_{ROT} = \ell(\ell+1)\frac{\hbar}{2I}$$

$\ell = 0, 1, 2, 3 \ldots$

I = moment of inertia

$\Delta \ell = \pm 1$ only

$\Delta E_{rot} = \frac{\hbar^2 \ell}{I}$

Vibrational Modes:

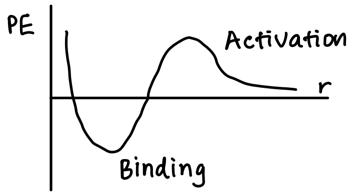
$$E_{VIB} = \left(v + \tfrac{1}{2}\right)hf$$

$v = 0, 1, 2, 3 \ldots$

v = vibrational quantum number

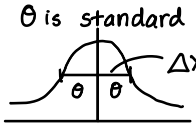
$\Delta v = \pm 1$ only

$\Delta E_{vib} = hf$



Some uncertainty formulas show $\theta_x \theta_p \gtrsim \frac{\hbar}{2} = \frac{h}{4\pi}$

θ is standard deviation



$\Delta x = \sqrt{2}\,\theta$

$$\begin{cases} \Delta x = \sqrt{2}\,\theta_x \\ \Delta p = \sqrt{2}\,\theta_p \end{cases} \quad \Delta x \Delta p \gtrsim \frac{h}{2\pi}$$

CH.30 Nuclear Physics and Radioactivity

Radius of nuclei of atomic # A: $r \approx 1.2 \times 10^{-15}\,m\,\sqrt[3]{A}$, $V = \frac{4}{3}\pi r^3$

$931.5\ MeV/u = 1.66 \times 10^{-27}\,kg$

Disintegration Energy: $Q = M_P c^2 - (M_D + m_\alpha)c^2$ (↑ M_P parent, ↑ M_D daughter)

α Decay: ${}^{A}_{Z}N \rightarrow {}^{A-4}_{Z-2}N' + {}^{4}_{2}He$ [α-Decay]

β Decay (β^-): ${}^{A}_{Z}N \rightarrow {}^{A}_{Z+1}N' + e^- + \bar{\nu}$ [β^- Decay]

(β^+): ${}^{A}_{Z}N \rightarrow {}^{A}_{Z-1}N' + e^+ + \nu$ [β^+ Decay]

(EC): ${}^{A}_{Z}N + e^- \rightarrow {}^{A}_{Z-1}N' + \nu$ [Electron Capture] (e^- from innermost shell)

γ Decay: ${}^{A}_{Z}N^* \rightarrow {}^{A}_{Z}N + \gamma$ [γ Decay]

Half-Life

Rate of Decay: $\frac{\Delta N}{\Delta t} = -\lambda N$ [λ = decay constant]

$N = N_0 e^{-\lambda t}$

Half-Life: $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$

Activity (Rate): $A = N_0 \lambda e^{-\lambda t}$ {derivative}

Nomenclature

* Nuclear process: we call the photon γ-ray
* Electron-Atom interaction: we call the photon X-ray

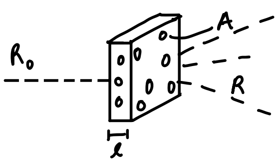
CH.31: NUCLEAR ENERGY AND RADIATION

$a + X \rightarrow Y + b$

Reaction Energy: $Q = (M_a + M_X - M_b - M_Y)c^2$

Threshold Energy = min energy to make reaction go

Cross Section: Effective target area $= \sigma = \frac{R}{R_0 n \ell}$



n = nuclei/volume

ℓ = thickness

R_0 = rate of projectiles

R = rate of collisions

Fusion Ignition: $n\tau \geq 3 \times 10^{20}\ s/m^3$ (↑ n ion density, ↖ τ confinement time)

	RBE
X- and γ rays	1
β Particles	1
Protons	2
Slow neutrons	5
Fast neutrons	10
α Particles	20

1 Ci = 3.7×10^{10} decays/sec

1 Gy = 1 J/kg = 100 rads

1 Bq = 1 decay/sec

Effective Dose (rem) = Dose (in rads) × RBE (relative biological effectiveness)

1 Sv = 100 rem

CH. 32 ELEMENTARY PARTICLES

Wavelength of projectile particle: $\lambda = \frac{h}{p}$ $\hbar = \frac{h}{2\pi}$

$E^2 = (pc)^2 + (mc^2)^2$ for Relativistic Speeds

$p \approx \frac{E}{c}$ if speed much greater than rest mass

$\rightarrow \lambda = \frac{hc}{E}$

Cyclotron Frequency: $f = \frac{qB}{2\pi m}$, $v = \frac{qBr}{m}$

$KE = \frac{q^2 B^2 R^2}{2m}$

Relativistic $KE = (\gamma - 1)mc^2$ where $\gamma = \frac{1}{\sqrt{1-(v/c)^2}}$

Heisenbergs: $\Delta E \Delta t \approx \frac{h}{2\pi}$, $\Delta x \lesssim c\Delta t \approx \frac{c\hbar}{\Delta E}$

Max distance felt of a force: (d) $mc^2 \approx \frac{hc}{2\pi d}$

Fundamental Particles

Gauge Boson (force carrier) Gluons, Photons, W, Z

Higgs Boson (mass carrier)

Leptons $e^-, \nu_e, \mu, \nu_\mu, \tau, \nu_\tau$

Quarks

u	$+\frac{2}{3}e$
d	$-\frac{1}{3}e$
s	$-\frac{1}{3}e$
c	$+\frac{2}{3}e$
b	$-\frac{1}{3}e$
t	$+\frac{2}{3}e$

Hadrons (composite)

Mesons (quark + antiquark) $\pi^+, \pi^0, K^+, K^0_S, K^0_L, \eta, \rho^+, \rho^0 \ldots$

Baryons (fermions) $p, n, \Lambda^0, \Sigma^+, \Sigma^0, \Sigma^-, \Xi, \Omega, \ldots$

Conserved Properties: B, S, charm, bottom, top