# Physics 152 Summary I

1) Coulomb's Law : $|\vec{F}| = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$ $\begin{cases} \text{repulsive for like charges} \\ \text{attractive for opposite sign charges} \end{cases}$

2) Electric field $\vec{E} = \vec{F}/q_{test}$

$\vec{F}$ = force on "test charge" $q_{test}$

(test charge means we assume $q_{test}$ does not change the electric field)

3) Point charges as sources of E-field.

$\vec{E} = \frac{q}{4\pi\epsilon_0 r^2}\hat{r}$ where $\hat{r}$ points from the charge to the location we calculate the field.

4) For multiple charges, discrete or continuous, we add the field from each charge (vector addition, i.e. superposition).

You should know how to set up the addition (i.e. integrate)

5) $\epsilon_0 = 8.854 \times 10^{-12}\ C^2/N\cdot m^2$

6) Lines of $E$ are sometimes used to represent electric fields. Know how to draw lines of $\vec{E}$ for simple charge distributions.

7) Gauss's Law

$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

$q_{in}$ = net charge inside the surface

$\vec{E}$ = electric field at the surface

$dA$ = outward surface area vector

8) Know how to use Gauss's Law for

i) point charge
ii) spherical symmetry
iii) cylindrical symmetry & line charge
iv) infinite plane

9) Sometimes $q_{in} = 0$, but $\vec{E} \neq 0$. Be sure you can explain why.

10) Conductors:

i) $E = 0$ inside conductors. Why?
ii) all net charge resides on surface of conductor
iii) at surface, $\vec{E} \perp$ surface and $|\vec{E}| = \sigma/\epsilon_0$

11) Potential Difference between two points, $A$ & $B$ $= V_B - V_A$

$V_B - V_A$ = work done by external force in moving a unit (+) charge ($q = 1$) from point A to point B

12) Potential energy of charge $q$, where the electric potential is $V$, is $PE = qV$

13) $V = \frac{1}{4\pi\epsilon_0} \sum \frac{q_i}{r_i}$ or $\frac{1}{4\pi\epsilon_0} \int \frac{dq}{r}$

integrate over all the charge

(Note: these assume charge does not extend to $\infty$, i.e. $V_\infty = 0$)

14) $V_b - V_a = -\int_a^b \vec{E} \cdot d\vec{s}$

15) Be able to calculate $V$ for different charge distributions.

16) Know how to find and draw equipotential surfaces.

- how might you find the direction of $E$ from an equipotential surface?

## Summary II - Magnetism

1. Charges moving in a magnetic field experience a Lorentz force. $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

B has units called Tesla. $1T = \frac{1N}{\text{Coulomb}\ m/s} = \frac{1N}{\text{Amp}\cdot m}$

2) sometimes we write the motion as a <u>current</u> instead of a velocity. In that case, the force in the current is

$$\vec{F} = I \vec{L} \times \vec{B}, \quad \text{or for current segments}$$

$$d\vec{F} = I(d\vec{s} \times \vec{B})$$

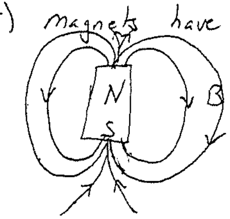
such that $\vec{F} = \int_{\text{current}} I\, d\vec{s} \times \vec{B}$

3) A charged particle moving perpendicular to a uniform magnetic field moves in a circle of radius

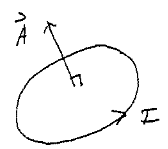
$$R = \frac{mv}{qB} \quad \text{(can you derive this?)}$$

4) Magnetic field lines form closed loops since there are no magnetic monopoles (no magnetic "charges")

5) magnets have north and south poles. The earth has a magnetic field with magnetic "south" at geographic "north".



6) A planar current loop has magnetic moment $\vec{\mu} = I\vec{A}$ where $\vec{A}$ is the area of the loop. $\vec{A}$ is perpendicular to the plane of the loop & found by a right hand rule. (Curl r.h. fingers in direction of current & thumb indicates direction of $\vec{A}$)



7) A magnetic dipole, $\vec{\mu}$, in a uniform magnetic field experiences no net force, but does experience a net torque, $\tau = \vec{\mu} \times \vec{B}$.

8) There is potential energy associated with the orientation of $\vec{\mu}$ in a $\vec{B}$ field, with $U_B = -\vec{\mu} \cdot \vec{B}$.

9) The Hall Effect is an expirement that can be used to determine the sign (+ or −) of moving charges in a current. Know how that experiment works.

10) Currents are sources of magnetic fields. If we know all the currents, we can calculate $\vec{B}$ using the Biot-Savart Law

$$d\vec{B} = \frac{\mu_0}{4\pi} \cdot I \frac{d\vec{s} \times \hat{r}}{r^2}$$

$\mu_0 = 4\pi \times 10^{-7}\ T\ m/Amp$, $\hat{r}$ is vector from small current segment to where you are computing the $\vec{B}$ field.

11) Ampere's Law: $\oint_{\text{closed loop}} \vec{B} \cdot d\vec{s} = \mu_0 I_{enclosed}$

- Know how to use to compute $\vec{B}$ for
  - i) $\infty$ straight line current (or cylinder)
  - ii) solenoid
  - iii) toroid
  - iv) $\infty$ plane [think of this as a collection of $\infty$ straight line currents]

12) Parallel currents attract & opposite current repel.

$\frac{\text{Force}}{\text{length}}$ on segments of two parallel wires

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

13) Know how to use Biot-Savart to compute B for simple geometries
- i) planar circular loop
- ii) straight line segment
- iii) combinations of (i) and (ii)

(this includes understanding how to find the direction of $\vec{B}$ using R.H.R. and symmetry arguments)

14) Faradays Law: $EmF = -\frac{d\Phi}{dt}$

where $\Phi = \oint_{\text{surface}} \vec{B} \cdot d\vec{A}$ = flux of $\vec{B}$

15) Know how to use Lenz's Law to find direction of induced currents for. i) motional emf

ii) changing B fields

16) Understand how changing $\vec{B}$ field cause $\vec{E}$ fields (even where there are no electric charges to cause currents)

- This E-field is really the source of the EmF.

## Summary III - Optics + Light

1) We have now seen all four of Maxwell's Equations.

$$\oint \vec{E}\cdot d\vec{a} = \frac{q_{in}}{\epsilon_0} \qquad \oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B}\cdot d\vec{a} = 0 \qquad \oint \vec{B}\cdot d\vec{s} = \mu_0 I + \mu_0\epsilon_0 \frac{d\Phi_E}{dt}$$

$$\mu_0 = 4\pi \times 10^{-7}\ \frac{T\cdot m}{Amp} \qquad \epsilon_0 = 8.854 \times 10^{-12}\ \frac{C^2}{N\cdot m^2}$$

you should know what these equations are + how to use them.

2) We learned that light is an electromagnetic wave (transverse) with velocity $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$, $\vec{E} \perp \vec{B}$, $\frac{E_{max}}{B_{max}} = c$

3) Poynting vector $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$

$[S] = J/m^2\cdot sec$

4) Intensity, $I = S_{avg} = \frac{E_{max}^2}{2\mu_0 c} = \frac{c B_{max}^2}{2\mu_0}$

5) Light carries momentum. The pressure on a completely:

absorbing surface is $P = \frac{S}{c}$

reflecting surface is $P = \frac{2S}{c}$

6) For waves: $v = \lambda f$, $\omega = v k$, $k = \frac{2\pi}{\lambda}$, $\omega = 2\pi f$

7) Know some basic properties of the electromagnetic spectrum, such as typical $\lambda$ + $f$ values for visible light, X-rays, microwaves, radio waves.

## Geometrical optics

8) reflection: $\theta_i = \theta_r$

refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

or

$v_2 \sin\theta_1 = v_1 \sin\theta_2$ with $v = \frac{c}{n}$

9) Know about total internal reflection

$\sin\theta_c = \frac{n_2}{n_1}$ $(n_1 > n_2)$

10) Be familiar with the mirror/lens equation and know ray tracing techniques (i.e. know the rules for which rays to draw)

$$\boxed{\frac{1}{p} + \frac{1}{q} = \frac{1}{f}}$$

· know the sign conventions for $p$, $q$, and $f$, for mirrors and lenses.

11) Magnification $m = -\frac{q}{p}$. Know the meaning of $m$, and what it tells you about whether images are real or virtual, and inverted or upright.

12) The eye: Know the definitions of near point + far point, and how to correct for "near-sighted" and "far sighted" vision.

$P = \frac{1}{f}$ where $P$ is in Diopters, and $f$ is in meters.

13) Know how to analyze combinations of lenses.

## Interference / Wave Optics

14) Wave period $T = \frac{1}{f}$. Wave travels one wavelength in one period $(\lambda f = c = \frac{\lambda}{T})$

$\frac{\text{path difference}}{\lambda} \cdot 2\pi$ = phase shift

15) when we add waves (superposition) that are coherent - i.e. have well defined phase relationships - then we can get:

a) in phase ⇒ constructive interference ⇒ bright spots

b) out of phase ⇒ destructive interference ⇒ dark spots

16) reflective phase changes: when light reflects at an interface with $n_{incident} < n_{transmitted}$ the reflection introduces a $\frac{\lambda}{2}$ or $\pi$ phase shift

(this does not happen for $n_{incident} > n_{transmitted}$)

17) Know how to work with various examples that generate interference patterns such as:

a) Double Slit - bright fringes $d\sin\theta = m\lambda$ ; $y = L\frac{m\lambda}{d}$

dark fringes $d\sin\theta = (m+\frac{1}{2})\lambda$ ; $y = L(m+\frac{1}{2})\frac{\lambda}{d}$

b) Thin films:

Know why these are different

One phase change (#16) — dark: $2nt = m\lambda$; bright: $2nt = (m+\frac{1}{2})\lambda$

phase change @ each surface — dark: $2nt = (m+\frac{1}{2})\lambda$; bright: $2nt = m\lambda$

18) Intensity for double slit interference pattern:

$$I = I_{max} \cos^2\left[\frac{\pi d \sin\theta}{\lambda}\right]$$

## Diffraction & Polarization

19) Single slit diffraction: minima for $\sin\theta = \frac{m\lambda}{a}$
(for slit width a) or $y = \frac{m\lambda}{a} L$

20) Diffraction Grating: $d \sin\theta_{bright} = m\lambda$

21) For circular apertures, $\theta_{min} = \frac{1.22\lambda}{D}$

22) Polarization refers to the orientation of the electric field. Light transmitted through a polarizer is attenuated according to Malus' Law:

$$I = I_{max} \cos^2\theta$$

23) Light can be polarized by reflection

$$\tan\theta_p = \frac{n_2}{n_1}$$ ($\theta_p$ also called Brewster's angle)

24) Know the orientation of polarization for reflected light, and know how polarized sunglasses work.

## Physics 152 Summary IV

1) Kirchoff's Laws: (Know the sign conventions)
   i) Sum of $\Delta V$ around any closed loop must be zero.
   ii) Sum of currents entering any junction must equal the sum of currents leaving the junction.

2) "$V = IR$"
   resistors in series: $R_{eq} = R_1 + R_2$
   resistors in parallel: $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

3) $P = IV = I^2R = \frac{V^2}{R}$

4) $Q = CV$ parallel plate capacitor: $C = \frac{\epsilon_0 A}{d}$
   - capacitors in parallel: $C_{eq} = C_1 + C_2$
   - capacitors in series: $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$
   - Know when charge is conserved, etc..., like the homework and problems we solved in class.
   - Understand how to calculate capacitance, C, for a given configuration of conductors.
   - $W = \frac{Q^2}{2C}$

5) Inductors: $\mathcal{E}_L = -L\frac{dI}{dt}$, $L = \frac{N\Phi_B}{I}$
   - understand the direction of the induced Emf.
   - Know how to derive L for simple geometries like solenoids ($\mathcal{E} = -\frac{d\Phi_B}{dt}$)
   - $U_B = \frac{1}{2}LI^2$

6) Capacitors and Inductors in D.C. circuits:

C: $\tau = RC$ $\qquad Q(t) = \mathcal{E}C\left(1 - e^{-t/\tau}\right)$

$Q(t) = Q_0 e^{-t/\tau}$ $\quad$ Know why these are different & which one to use.

- Know how to find $I(t)$ from $Q(t)$.
- understand conceptually how capacitors behave in DC circuits.

L: $\tau = L/R$ $\qquad I(t) = \frac{\mathcal{E}}{R}\left(1 - e^{-Rt/L}\right)$

- understand where above equations come from.
- understand conceptually how inductors behave in RL circuits.

7) mutual Inductance: $\quad M_{21} = \frac{N_1 \Phi_{21}}{I_2}$, $\quad \mathcal{E}_2 = -M_{12}\frac{dI_1}{dt}$

how is this useful?

8) LC Circuit:

$\omega = \frac{1}{\sqrt{LC}}$ $\qquad q = Q_{max}\cos\omega t$

$i = -I_{max}\sin\omega t$

$$\frac{Q_{max}^2}{2C} = \frac{L I_{max}^2}{2}$$

- Can you show that energy is conserved?

9) LRC circuit

Know qualitatively how a resistor changes the behavior of the LC circuit.