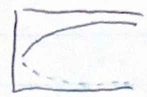
# Phys 158 Course Summary

1 —— Standing Waves

Closed: 

Open: 

$l = \frac{m\lambda}{2}$ $\qquad$ $l = \frac{m\lambda}{4}$

Formulas:
$f_m = m f_1$
$v = \lambda f$ where $v$ is constant

note: harmonic refers to $m$ value

displacement nodes = pressure antinodes

2 —— Beats

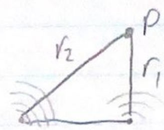
Formulas: $f_{avg} = \frac{1}{2}(f_1 + f_2)$, $f_{beat} = f_1 - f_2$

$f_{avg}$ is the frequency we hear, $f_{beat}$ is how often it goes from loud to quiet

3 —— Interference

$\Delta r = m\lambda$: constructive

$\Delta r = (m - \frac{1}{2})\lambda$: destructive




For complicated geometry, analyze endpoints and use reasoning.

4 —— Double Slit

always assume $d$ is very small

- $\Delta r_g \approx d\sin\theta \approx d\tan\theta = \frac{d y_m}{R}$


- if in different medium, $\Delta r = m\lambda_{med} = \frac{m\lambda}{n_{med}}$
- If glass pane infront of slit:
  - find $\Delta t = \frac{1}{c}(s_2 n_2 - n_1 s_1)$
  - find $\Delta r_f = v_{med}\Delta t = \frac{1}{n_{med}}(n_2 s_2 - n_1 s_1)$

* normally, $\Delta r_f = \frac{s}{n_{air}}(n_2 - n_{air})$

- For questions with both, $\Delta r = \Delta r_{film} + \Delta r_{geometric}$

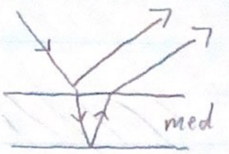
$\Delta r \approx \frac{1}{n_{med}}(n_2 s_2 - n_1 s_1) + d\sin\theta$

- If $d$ gets smaller, $\Delta y$ increases $\quad \Delta y \propto \frac{1}{d}$

If $n_{med}$ increases, $\Delta y$ gets smaller $\Delta y \propto \frac{1}{n}$

$y_0$ ↑ moves up because of glass

5 —— Thin Film




fast to slow = $\pi$ shift $\quad$ $\Delta arg = 2\pi m$ : constructive

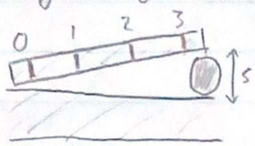
slow to fast = no shift $\quad$ $\Delta arg = (2m-1)\pi$ : destructive

most cases: $\Delta arg = k_{med}(2s) \quad (-\pi)$

$$\Delta arg = \frac{4s\pi n_{med}}{\lambda} \quad (-\pi)$$

"reflect" means constructive, "transmit" means destructive

- Angled film




$0^{th}$ fringe : extra distance = 0

$1^{st}$ fringe: extra distance = $\lambda$

$2^{nd}$ fringe: extra distance = $2\lambda$

$n^{th}$ fringe = $n\lambda = 2s$

also include same principles such as phase shift.

6 —— Traditional Circuits

- Fundamental Laws:
  - sum of voltage in a loop is 0
  - current in and out of a junction is equal
  - for no battery, charge is always conserved $(Q_i = Q_f)$

  (note that a battery can add charge to the circuit)
- Series/Parallel rules

| | | | | | |
|---|---|---|---|---|---|
| Series: | $V_{eq} = \sum V$ | $I_{eq} = I$ | $R_{eq} = \sum R$ | $\frac{1}{C_{eq}} = \sum \frac{1}{C}$ | $L_{eq} = \sum L$ |
| Parallel: | $V_{eq} = V$ | $I_{eq} = \sum I$ | $\frac{1}{R_{eq}} = \sum \frac{1}{R}$ | $C_{eq} = \sum C$ | $\frac{1}{L_{eq}} = \sum \frac{1}{L}$ |

- Equations

$V_R = IR$, $V_C = \frac{q}{C}$, $V_L = -L\frac{di}{dt}$

$i = \pm\frac{dq}{dt}$, $P = IV = IR^2$ $\quad$ * power is proportional to brightness of a bulb

* power is only dissapated through resistors

$U_C = \frac{Q^2}{2C} = \frac{1}{2}CV^2$, $U_L = \frac{1}{2}LI^2$

- Time Dependence

at $t=0$, capacitors act as a wire
inductors act as a short

at $t \to \infty$, capacitors act as a short
inductors act as a wire

- Functions of time:

use voltage loops to set up differential equation

Charging capacitor: $i(t) = i_0 e^{-t/RC}$, $q(t) = Q_f(1 - e^{-t/RC})$

Discharging capacitor: $i(t) = i_0 e^{-t/RC}$, $q(t) = Q_0 e^{-t/RC}$

All equations should be some form of exponential decay.

RC circuits: $\tau = RC$, RL circuits: $\tau = L/R$

7 —— LC and RLC circuits

- LC circuits

$q(t) = Q_m \cos(\omega_0 t + \phi_0)$, $i(t) = \omega Q_m \sin(\omega_0 t + \phi_0)$

$\omega_0 = \frac{1}{\sqrt{LC}}$ * oscillates forever

- RLC circuits

$q(t) = Q_m e^{-t/\tau} \cos(\omega t + \phi_0)$ where $\tau = \frac{2L}{R}$ and $\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

to find current and charge use:

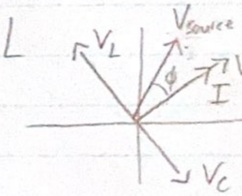
$E_{total} = U_C + U_L$ where $E_{total} \propto$ amplitude $(Q_m e^{-t/\tau})$

$U_C = \frac{Q^2}{2C}$, $U_L = \frac{LI^2}{2}$

8 —— AC Circuits

- find reactance

$V_C = IX_C$, $V_L = IX_L$ where $X_C = \frac{1}{\omega C}$, $X_L = \omega L$




- find impedence

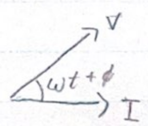
$|Z|^2 = R^2 + (X_L - X_C)^2$

- find max current

$V = IZ$ (can then use current to find max voltage through components. i.e. $V = IX$)

- find phase angle

$\tan\phi = \frac{X_L - X_C}{R}$




$i(t) = I\cos(\omega t + \phi)$

$v(t) = V\cos(\omega t)$

in general, $\arg(v) - \arg(i) = \phi$

* watch out for when $\phi < 0$. It changes the appearence of the diagram

* look carefully in case you are given RMS voltage.

$V_{RMS} = \frac{1}{\sqrt{2}} V_{max}$ and $I_{RMS} = \frac{1}{\sqrt{2}} I_{max}$

$\langle P \rangle = I_{RMS}^2 R = V_{RMS} I_{RMS} \cos\phi$ where $\cos\phi = \frac{R}{Z}$

- AC Frequency

as $\omega \to \infty$, $X_L = \infty$ and $X_c = 0$
as $\omega \to 0$, $X_L = 0$ and $X_c = \infty$
Resonance is when $X_c = X_L$ and $\omega = \frac{1}{\sqrt{LC}}$

9 —— Electric Fields and Force

- Electric force: $\vec{F} = \frac{k|q_1||q_2|}{r^2}\hat{r}$ and $\vec{F} = q\vec{E}$

  $k = 9 \cdot 10^9$, $\epsilon_0 = 8.854 \cdot 10^{-12}$, $k = \frac{1}{4\pi\epsilon_0}$

  - for a system of objects, calculate each force individually and then sum vectorally.
- Electric Fields:

  $\vec{E}_{point} = \frac{kq}{r^2}\hat{r}$ points away from ⊕, points toward ⊖ } goes in direction a positive test charge would go.

  To derive the field of an object use $d\vec{E} = \frac{k\,dq}{r^2}\hat{r}$
  - we may break $\hat{r}$ into $\hat{r} = \cos\theta\,\hat{i} + \sin\theta\,\hat{j} = \langle \hat{i}, \hat{j} \rangle$
  - we can break $dq$ into $dq = \lambda\,ds$ where $s$ = arclength or $dq = \sigma\,dA$
  - if dealing with a ring: $s = R\theta \Rightarrow ds = R\,d\theta$
- Torque on electric dipoles.
  - often easiest to break it into forces like a Phys 12 problem

10 —— Gauss's Law

$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\epsilon_0}$ ($EA = \frac{Q_{enc}}{\epsilon_0}$ with symmetry)

$\vec{E}_{plane} = \frac{\sigma}{2\epsilon_0}\hat{n}$, $\vec{E}_{rod} = \frac{\lambda}{2\pi\epsilon_0 r}\hat{r}$

* when adding electric fields be very careful which direction they point.

$\leftarrow \oplus \rightarrow \quad \rightarrow \ominus \leftarrow$

For most shapes we can enclose them in a sphere/cylinder/block and use the charge enclosed.

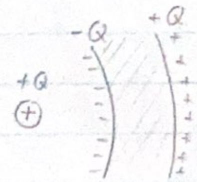
- Object Interiors

  for interiors of an object, $Q_{enc}$ is changing
  - use $q_{enc} = \rho(r)V(r)$
  - if $\rho$ is uniform then we can set $\rho = \frac{Q_{total}}{V_{total}}$, otherwise we have to intgrate

* note that the field <u>inside</u> a circular shell is 0 at all points.

- If there is a cavity inside an object we can say it has charge of $-\rho$ and use superposition of the two objects to find net field

• Conductors




- $\vec{E}$ is always 0 in a conductor
- charges will be distributed on surface
- potential in conductor will be constant

11 —— Potential Energy

$U = \frac{kq_1q_2}{r}$, $\vec{F} = -\vec{\nabla}U$ if $U > 0$ the system wants to release energy
if $U < 0$ the system resists change

Potential energy of a system is the sum of the system

$U_{sys} = \Sigma U_i$

* if asked to calculate velocity, use $(U+K)_i = (U+K)_f$

• Work: $\Delta U = -W_{sys} = W_{ext}$

the system always wants to decrease potential energy

also can use $\Delta U = q\Delta V = W_{ext}$

12 —— Potential

def: a point in space with an assigned value (like elevation)

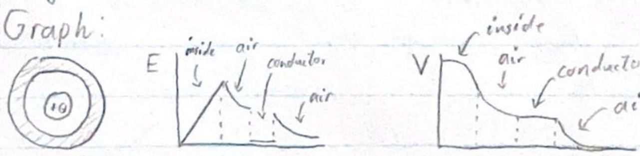
note, V is a scalar

$V = \frac{kq}{r}$, $U = qV$, $\vec{E} = -\vec{\nabla}V$, $V = -\int \vec{E} \cdot d\vec{r}$

* don't forget the negative in the equations

- if two conductors are in contact and have different V, charge will flow

Graph:




* it's easy to calculate work using $\Delta V$.

13 —— Dielectrics

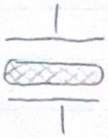
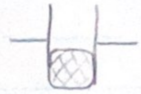
$C = \frac{Q}{V}$, $C_{\parallel} = \frac{A\epsilon_0}{d}$, $U_C = \frac{Q^2}{2C} = \frac{1}{2}CV^2$

if connected to a battery, V is constant

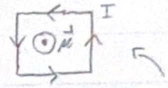
$K = \frac{E_0}{E}$, $\Phi_E = \oint K\vec{E} \cdot d\vec{A} = \frac{Q_{conductor}}{\epsilon_0}$

$C = KC_0$ and $\sigma_i = \sigma(1 - \frac{1}{K})$

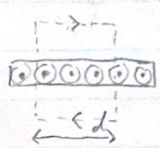
if dielectric does not completely fill space, add capacitances to get $K_{eff}$.

 add in series $\frac{1}{C_{eq}} = \frac{1}{C_{air}} + \frac{1}{C_{dielec}}$  add in parallel $C_{eq} = C_{air} + C_{dielec}$

14 —— Magnetic Force, Torque, and Cyclotron Motion

- cyclotron motion: $\omega = \frac{qB}{m}$, $R = \frac{mv_\perp}{qB}$
  - use RHR for direction
- Force
  on particle: $\vec{F} = q\vec{v} \times \vec{B}$
  on wire: $\vec{F} = \int I d\vec{l} \times \vec{B}$, straight wire: $\vec{F} = IlB$
- Torque
  
  
  $|\vec{\mu}| = NIA$, $\vec{\tau} = \vec{\mu} \times \vec{B}$, $U = -\vec{\mu} \cdot \vec{B}$
  $\vec{\mu}$ points in the normal direction following the curl of the current

15 —— Magnetic Fields

For complicated shapes: $d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$
For infinite shapes: $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$
note that the magnetic field is perpundicular to direction vector so almost aways use $\sin\theta$.
Ampere's law is useful for: - long straight wire, solenoids, infinite sheets.
Ex:  $\rightarrow \vec{B} = \frac{\mu_0 I_{enc}}{2d}$

- Solenoids
  for infinite solenoids use $B = \mu_0 I n$ for all calculations
  B is constant inside and $B = 0$ outside

16 —— Magnetic Flux

$\vec{B}_{induced}$ is opposite to $\frac{d\Phi_B}{dt}$, $\mathcal{E} = -\frac{d\Phi_B}{dt}$
Things that can change $\Phi_B$ are B, A, and $\theta$
↳ set one of them as a function of time and take derivative
Solenoid emf: $\mathcal{E} = -\mu_0 n A \frac{dI}{dt}$

- Motional emf: $\mathcal{E} = vBl = \oint (\vec{v} \times \vec{B}) \cdot d\vec{l}$
  - use $F_e = F_B$ to get $E = \vec{v} \times \vec{B}$ and integrate $\vec{E}$ to get $\mathcal{E}$.
- Displacement current: same idea but calculate $\frac{d\Phi_E}{dt}$ to get $i$.