# FINAL EXAM REVIEW

## Kinematics

position, $\vec{r} = \begin{bmatrix} x \\ y \end{bmatrix}$ - in m - vector

velocity, $\vec{v} \equiv \frac{d\vec{r}}{dt} = \begin{bmatrix} \frac{dx}{dt} \\ \frac{dy}{dt} \end{bmatrix} = \begin{bmatrix} v_x \\ v_y \end{bmatrix}$

- m/s
- vector

acceleration $\vec{a} \equiv \frac{d\vec{v}}{dt} = \begin{bmatrix} a_x \\ a_y \end{bmatrix} = \begin{bmatrix} \frac{dv_x}{dt} \\ \frac{dv_y}{dt} \end{bmatrix}$

- $m/s^2$
- vector

special case $\vec{a} = \text{const} = \vec{a}_0$

$$\vec{v} = \vec{v}_0 + \vec{a}t$$

$$\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$$

$$v^2 = v_0^2 + 2\vec{a}\cdot\Delta\vec{r}$$

Recall you can write these as col. vector

$$\vec{v} = \vec{v}_0 + \vec{a}t$$

$$\begin{bmatrix} v_x \\ v_y \end{bmatrix} = \begin{bmatrix} v_{0x} \\ v_{0y} \end{bmatrix} + \begin{bmatrix} a_x t \\ a_y t \end{bmatrix}$$ ← Each row is a 1D kinematic eq.

Displacement, $\Delta\vec{r} \equiv \vec{r}_f - \vec{r}_i$

- in m
- vector

$\Delta \equiv$ change in (usually final - initial)

All the <u>averages</u> get def'd this wa

$$\vec{v}_{ave} = \frac{\Delta\vec{r}}{\Delta t}$$

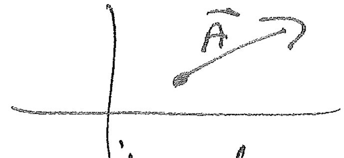
$$\vec{a}_{ave} = \frac{\Delta\vec{v}}{\Delta t}$$

F19 skip

$$P_{ave} = \frac{\Delta W}{\Delta t} = \frac{\Delta KE}{\Delta t} = \frac{\Delta PE}{\Delta t} \ldots$$

units Watt $= \frac{J}{s}$

## Vectors




$\equiv$ quantity with magnitude & direction

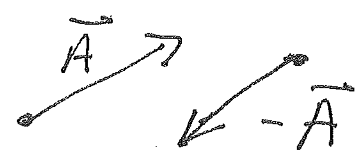
ex: position, displacement, velocity, acc, force, momentum, ang. mom., torque, ...

Scalar $\equiv$ quantity w/ magnitude only

ex: distance, speed, mass, temp,

## Vector rules

1. Negation




- flip the vector by 180°

- negate all comp.s

$$\vec{A} = \begin{bmatrix} A_x \\ A_y \end{bmatrix} \qquad -\vec{A} = \begin{bmatrix} -A_x \\ -A_y \end{bmatrix}$$

2. Addition

- put them tail-to-tip, sum goes from tail of first vector to tip of final vector in sum.

- Add like components

$$\vec{C} = \vec{A} + \vec{B}$$

$$\boxed{\begin{bmatrix} C_x \\ C_y \end{bmatrix} = \begin{bmatrix} A_x \\ A_y \end{bmatrix} + \begin{bmatrix} B_x \\ B_y \end{bmatrix}}$$

3. Subtraction

= Negate vector(s) to be subtracted then add.

4. Mult by a scalar

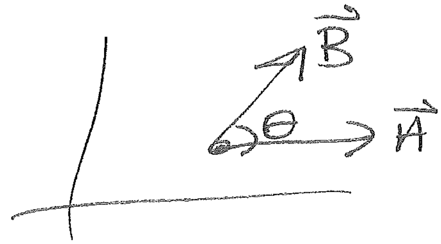
= scale length of vector by scalar

= mult each comp by scalar

ex $\quad 2\vec{A} = \begin{bmatrix} 2A_x \\ 2A_y \end{bmatrix}$

5. Dot prod / Scalar product

$$C = \vec{A} \cdot \vec{B}$$




$$= AB\cos\theta$$

$$= A_x B_x + A_y B_y$$

ex: Work $\quad W = \vec{F} \cdot \vec{d}$

6. Vector Product / Cross Product

$$\vec{C} = \vec{A} \times \vec{B}$$

$$|\vec{C}| = C = AB\sin\theta$$

dir of $\vec{C}$ from Right Hand Rule

ex: Torque, $\vec{\tau} = \vec{r} \times \vec{F}$

ang mom, $\vec{L} = \vec{r} \times \vec{p}$

Force, $\vec{F}$ $\equiv$ push or pull
- vector
- units $N = kg \frac{m}{s^2}$

Newton's Three Laws

1. An object in uniform motion remains in uniform motion unless acted on by a net, external force.

2. $\Sigma \vec{F} = m\vec{a}$

3. $\vec{F}_{12} = -\vec{F}_{21}$

Forces we learned

Gravity, $\vec{F}_g = m\vec{g}$ (acts at c-m)

Normal force, $\vec{F}_N$ alway $\perp$ to surface
must use 2nd Law to find it.

Tension, $\vec{F}_t$ dir = along "string" away from object
use 2nd Law to find.

# Forces (cont.)

## friction, $\vec{F}_{fr}$

dir:

mag: $F_{fr} = \mu F_N$

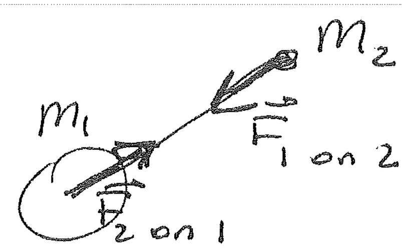
$\mu$ = const dep on materials

## Spring Force (Hook's Law), $\vec{F}_s$

$F_x = -kx$ $\quad$ $x \equiv$ dist from equil

## Universal Grav

$$F_G = G\frac{m_1 m_2}{r^2}$$




dir: along line between them, toward other

## Buoyant Force, $\vec{F}_B$

$F_B = m_f g$ $\quad$ $m_f$ = (mass of fluid displaced)

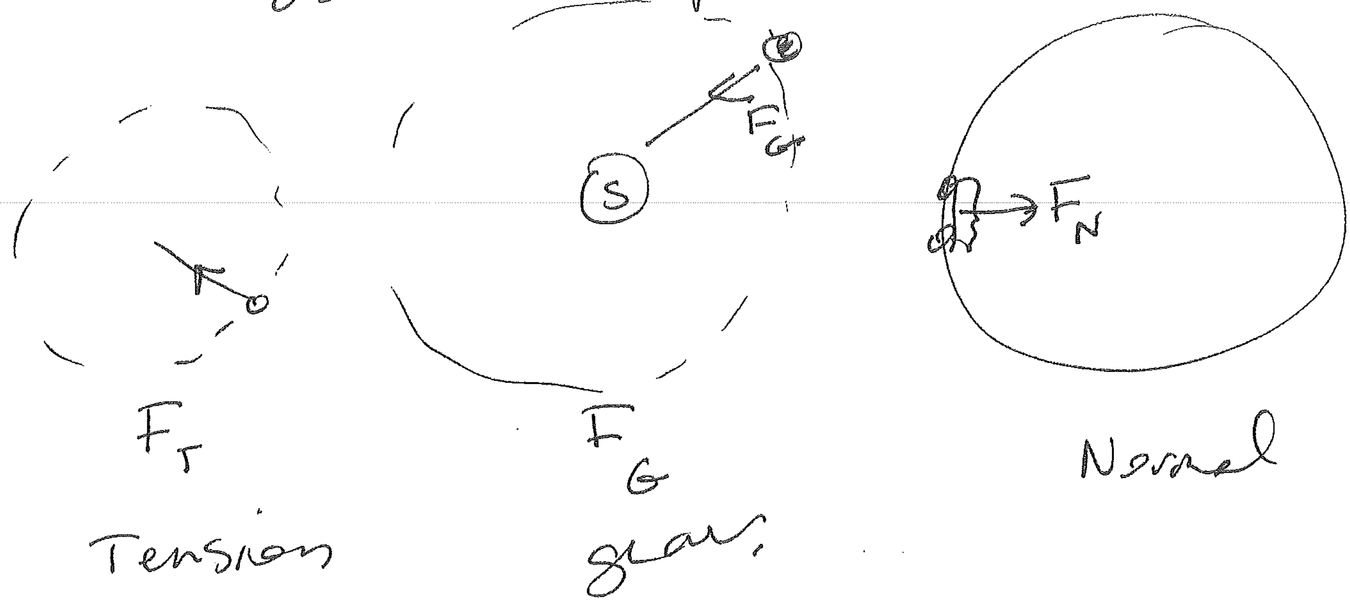
Free body diagrams!

# Circular motion

$$a_c = \frac{v^2}{r}$$ ⟸ toward the center

centripetal is a <u>direction</u>

we have seen many forces act as a centripetal force



# Work, W

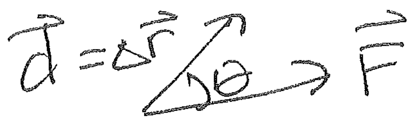
- scalar
- units Joules, J = Nm

Best def: $W \equiv \int \vec{F} \cdot d\vec{r}$

if $\vec{F}$ is const $\Leftarrow$ (not springs, not univ. grav)

$$W = \vec{F} \cdot \Delta\vec{r}$$

$\uparrow$ book uses $\vec{d}$




$$W = F d \cos\theta = F_{\parallel} d$$

Conservative forces $\equiv$ those for which work done by the force is path ind.

ex: gravity (both forms)
spring force

## Work - Kinetic Energy Thm

$$W_{net} = \Delta KE$$

$$KE = \frac{1}{2}mv^2$$

- scalar
- units, J

[later also $KE_{rot} = \frac{1}{2}I\omega^2$]

## Potential Energy, PE

$$\Delta PE_c = -W_c$$

$$PE_g = mgh$$

$$PE_s = \frac{1}{2}kx^2$$

## Cons of Energy

$$E = KE + PE$$

← Total mech. energy, E

## Cons of E

$$\boxed{E_i + W_{nc} = E_f}$$

if $W_{nc} = 0$

$$\boxed{E_i = E_f}$$

## Momentum, $\vec{p}$

$\vec{p} \equiv m\vec{v}$

- vector
- units $kg\frac{m}{s}$

Rewrite $2^{nd}$ Law: $\sum \vec{F} = \frac{d\vec{p}}{dt}$

$\vec{p}$ is cons if no net, ext force

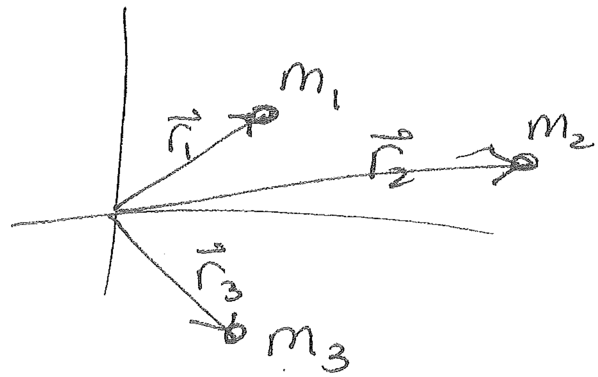
## Collisions

$\vec{p}_{tot}$ is conserved (include all objects that "collide")

KE may or may not be cons.

Center of mass

$$\vec{R}_{cm} = \frac{\sum m_i \vec{r}_i}{\sum m_i}$$

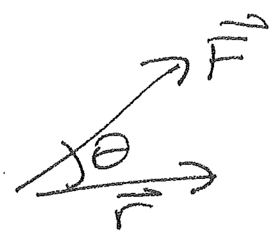



## Rotational Motion

kinematics

dynamics

Torque, $\vec{\tau} \equiv \vec{r} \times \vec{F}$




vector
units m·N

$$\boxed{\tau = rF\sin\theta}$$

$$\tau = r_\perp F$$

dir: CW or CCW is fine

(also Right Hand Rule)

# Moment of Inertia & 2nd Law for Rotation

$$\boxed{\sum \vec{\tau} = I\vec{\alpha}}$$

where $\boxed{I = \sum_i m_i r_i^2}$

for point pts

$I =$ look up on table
for solid objects
(given on exams)

## Angular momentum, $\vec{L}$

$$\vec{L} \equiv \vec{r} \times \vec{p}$$

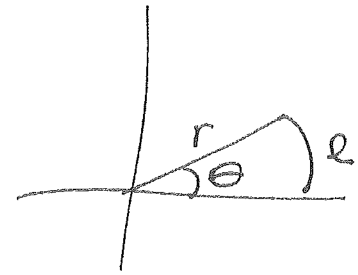
for circ motion, $L = rmv$

$$L = rp\sin\theta$$

$$\boxed{\vec{L} = I\vec{\omega}}$$

skip
F'19

# Rotational kinematics




ang position, $\theta$

arc length $l = r\theta$

- units radians
- is a vector (we use CW or CCW)

ang velocity, $\omega$

$$\omega \equiv \frac{d\theta}{dt}$$

- vector
- $\text{rad}/s = 1/s$

ang acceleration, $\alpha$

$$\alpha \equiv \frac{d\omega}{dt}$$

- vector
- $\text{rad}/s^2 = \frac{1}{s^2}$

for const r (circ motion rot motion)

$$l = r\theta$$

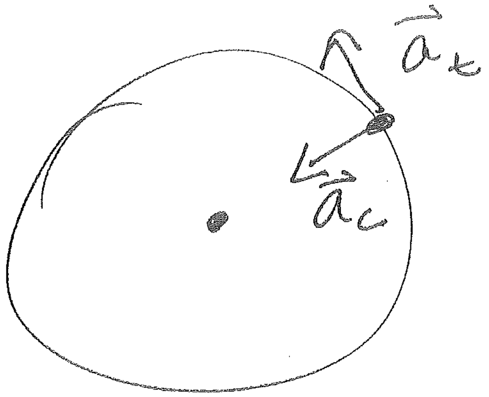
take deriv

$$v_l = r\omega$$

take deriv

$$a_l = r\alpha$$

$\vec{a}$ in tangential (along arc length)




$\vec{a}$ can have a comp along motion <u>and</u> toward center.

$$a_t = r\alpha \qquad a_c = \frac{v^2}{r}$$

Rotational kinematic eq's (const $\vec{\alpha}$)

$$\vec{\theta} = \vec{\theta}_0 + \vec{\omega}_0 t + \frac{1}{2}\vec{\alpha} t^2$$

$$\vec{\omega} = \vec{\omega}_0 + \vec{\alpha} t$$

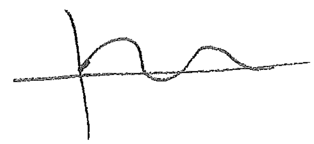
$$\omega^2 = \omega_0^2 + 2\vec{\alpha}\cdot\Delta\vec{\theta}$$

# Simple Harmonic Motion

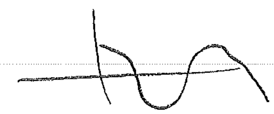
Def: $F \propto -x$

$$F = -m\omega^2 x$$

Has solutions:

$$x = A\sin(\omega t)$$ 

or

$$x = A\cos(\omega t)$$ 

## Cases:

Spring: $F = -kx$

$$\omega^2 = \frac{k}{m}$$

Simple Pendulum: (for small $\theta$)


$$\omega^2 = \frac{g}{\ell}$$

$$v_{max} = \omega A$$

$$E = \frac{1}{2}kA^2 = \frac{1}{2}mv_{max}^2 = \frac{1}{2}m\omega^2A^2$$

## Waves

≡ transport energy & momentum w/o transfering matter

each "piece" of medium oscillates around an equilibrium position (could be SHM)

$$y = A\sin(kx - \omega t)$$

$$k = \frac{2\pi}{\lambda} \qquad \omega = \frac{2\pi}{T}$$

$\lambda$ ≡ wavelength

= distance between

speed of any wave

$$v = \lambda f = \frac{\lambda}{T}$$

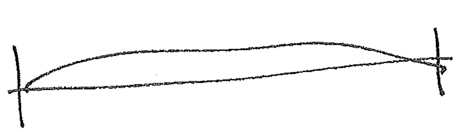
speed of wave on string

$$v = \sqrt{\frac{F_T}{\mu}}$$

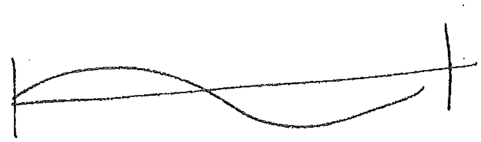
where $\mu = \dfrac{\text{mass}}{\text{length}}$

Standing waves

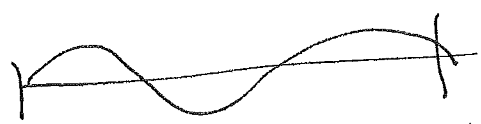
Rope fixed at both ends



$L = \lambda/2$



$L = \lambda$



$$L = \frac{3\lambda}{2}$$

$\vdots$

$$L = \frac{n\lambda}{2}$$

$$v = \lambda f$$

$$f = \frac{v}{\lambda} = \frac{v}{\frac{2L}{n}}$$

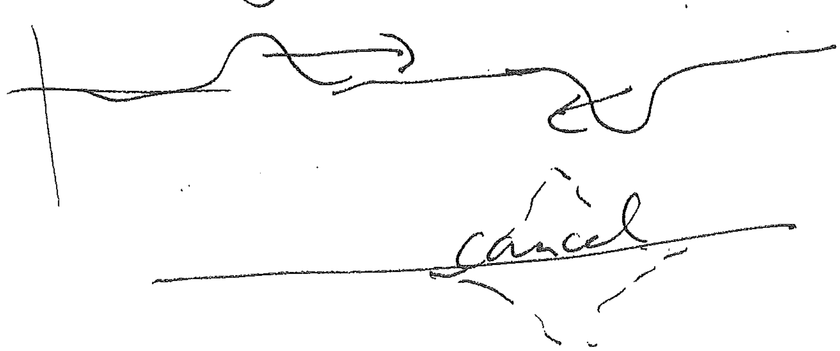
$$\boxed{f_n = n \frac{v}{2L}}$$

$n$ = # of antinodes = # of harmonic

nodes ≡ points remain still

antinodes ≡ constructive interference

Superposition of waves
(They add algebraically)



# Fluids

density, $\rho$ $\qquad \rho \equiv \frac{M}{V} = \frac{\text{mass}}{\text{volume}}$

pressure, $P \equiv \frac{F}{A} = \frac{\text{force}}{\text{area}}$

units $= \frac{N}{m^2}$

gauge pressure in fluid

$P = \rho g h$

absolute Pressure

$P = P_{atm} + P_{gauge}$

Buoyant force, $F_B = m_f g$