

December 17, 2010

Physics 121

Prof. E. F. Redish

■ Cartoon: Lynn Johnson***For Better or for Worse***

12/17/10

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1**■ Final Exam**

- Friday, 12/17, 8-12, Phys1412
- Cumulative
- 200 points
- About 50% on material since Exam 2

■ Q&A Session

- Wednesday, 12/15, 2:00-3:30 PM, Physics 1412

■ Course Center Office hours

- Tuesday 12/14, 12:00-2:00 PM
- Thursday 12/16 12:00-2:00 PM

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Results of Exam Questions

	#1	#2	#3	#4	#5
Ex 1	56%	58%	38%	75%	79%
Ex 1 (MU)	74%	45%	70%	40%	45%
Ex 2	63%	57%	84%	53%	68%
Ex 2 (MU)	65%	46%	63%	57%	50%

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Results of Quiz Questions

	#1	#2	#3	#4
Q1	42%	12%	57%	
Q2	96%	96%	85%	
Q3	68%	69%	93%	63%
Q4	55%	97%	87%	
Q5	90%/68%	95%	66%	60%
Q6	23%/64%	74%	82%	46%
Q7	77%	67%	24%	
Q8	61%	18%	46%	
Q9	96%	61%	25%	
Q10	94%	14%	14%	19%

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Content Summary

- Principles of Motion: The Newtonian Synthesis
 - Description of Motion (Kinematics)
 - Causes of Motion: Newton's Laws (Dynamics)
 - Forces
- Extension and Analysis of Principles of Motion
 - Center of Mass
 - Momentum and Impulse
 - Energy and Work
 - Rotational Motion
- Applications of Principles of Motion
 - Properties of Fluids: Pressure and Flow
 - Heat and Temperature: Thermal Energy

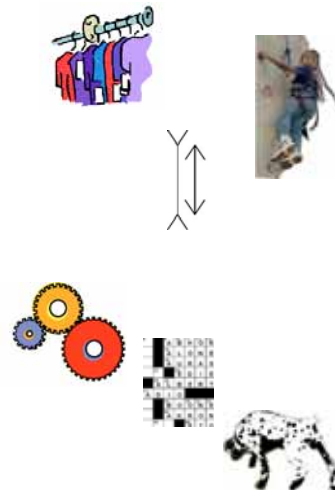
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Knowledge Games

- Shopping for ideas
- Choosing foothold ideas
- Reconciling intuition
- Elaboration / Implication
- Seeking consistency
- Sense making



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Description of Motion

- Coordinate systems
- Vectors
- Velocity and Acceleration

$$\langle \vec{v} \rangle = \frac{\Delta \vec{r}}{\Delta t} \quad \langle \vec{a} \rangle = \frac{\Delta \vec{v}}{\Delta t}$$

- Constructing graphs

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Causes of Motion: Newton's Laws

- **N0:** Objects only respond to forces acting on themselves, at the time the forces are exerted.
- **N1:** Objects change their velocity (perhaps $\neq 0$) only if they are acted on by unbalanced forces.
- **N2:** Each object responds to the forces it feels by changing its velocity according to $\vec{a} = \vec{F}_{net} / m$
- **N3:** When two objects touch, they exert equal and opposite forces on each other. $\vec{F}_{A \rightarrow B} = -\vec{F}_{B \rightarrow A}$

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Kinds of forces

■ There are 2 classes of forces

– Touching

- » Normal — N (perpendicular to surface and pressing in)
- » Tension — T (pulling out of the surface)
- » Friction — f (parallel to surface — opposing sliding)

– Non-touching

- » Gravity — W
- » Magnetic — F^{mag}
- » Electric — F^{elec}

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Properties of Forces

- *Normal* — adjust to oppose compression (like a spring)

- *Tension* — t. force vs. t. scalar, analysis of the chain

$$T = k \Delta l$$

- *Friction* — opposes sliding of surfaces over one another

$$\begin{aligned} f_{A \rightarrow B} &\leq f_{A \rightarrow B}^{\max} = \mu_{AB}^{\text{static}} N_{A \rightarrow B} && \text{not sliding} \\ f_{A \rightarrow B} &= \mu_{AB}^{\text{kinetic}} N_{A \rightarrow B} && \text{sliding} \\ \mu_{AB}^{\text{kinetic}} &\leq \mu_{AB}^{\text{static}} \end{aligned}$$

- *Gravity* — towards the center of the earth, proportional to mass

$$\vec{W} = -\frac{GmM}{R^2} \hat{R} \approx m\vec{g}$$

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Momentum and Impulse

- We can rewrite $\vec{a} = \vec{F}^{net}/m$ to focus on what a moving object "carries".

- Define momentum and impulse

$$\vec{p} = m\vec{v} \quad \vec{\mathcal{J}} = \vec{F}^{net} \Delta t$$

- Rewrite N2

$$\vec{\mathcal{J}} = \Delta\vec{p}$$

- In a system, if the external forces cancel, the total momentum of the system is conserved.

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Energy and Work

- We can rewrite N2 to focus on the part of the forces that change the object's speed.

- Define Kinetic Energy and Work

$$KE = \frac{1}{2}mv^2 \quad \text{Work} = \vec{F}^{net} \cdot \Delta\vec{r}$$

- Rewrite N2 by taking the dot product with the displacement (to select part of force acting along the motion)

$$\Delta\left(\frac{1}{2}mv^2\right) = \vec{F}^{net} \cdot \Delta\vec{r}$$

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Potential Energy

- For some kinds of forces (gravity, springs) the work done by that force can be brought to the other side and treated as a kind of energy. *{Conservative forces}*
- For some kinds of forces (friction, air resistance) you can't do this. *{Non-conservative forces}*

$$\Delta\left(\frac{1}{2}mv^2 + U\right) = \vec{F}_{\text{non-cons}}^{\text{net}} \cdot \Delta\vec{r}$$

$$U_{\text{grav}} = mgh \quad U_{\text{spring}} = \frac{1}{2}k(\Delta x)^2$$
- If a system only contains conservative forces, mechanical energy (KE + PE) is conserved.

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Conservation Equations

■ Momentum

$$m_1\vec{v}_1^i + m_2\vec{v}_2^i = m_1\vec{v}_1^f + m_2\vec{v}_2^f$$

$$\Delta(m_1\vec{v}_1) = -\Delta(m_2\vec{v}_2)$$

■ Energy

$$\frac{1}{2}mv_i^2 + U(\vec{r}_i) = \frac{1}{2}mv_f^2 + U(\vec{r}_f)$$

$$\Delta\left(\frac{1}{2}mv^2 + U(\vec{r})\right) = 0$$

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Center of Mass

- Extend our considerations from point objects to extended rigid objects.
- Identify CM of object.
$$\vec{R} = \sum_i \frac{m_i}{M} \vec{r}_i$$
- An object's CM respond to forces as if all the forces were applied to that point.
- An object's orientation around its CM has to be described by extensions of Newton's laws.

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Rotational Motion

- Description of rotations (kinematics) \longrightarrow θ (radians)
 $\langle \omega \rangle = \frac{\Delta \theta}{\Delta t}$
 $\langle \alpha \rangle = \frac{\Delta \omega}{\Delta t}$
- $\Delta \theta = \frac{\Delta s}{R}$ (radians)
- $\omega = \frac{v}{R}$ \longleftarrow ■ Relation to linear measures
- $\alpha = \frac{a}{R}$

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Circular motion

■ Uniform circular motion

- Radial acceleration
- Centripetal force

$$a_{\text{radial}} = v^2 / R$$

$$F_{\text{radial}} = mv^2 / R$$

■ Accelerated circular motion

- Tangential/angular accel.
- N2 for rotations

$$a_{\text{tangential}} = F_{\text{tangential}}^{\text{net}} / m$$

$$\alpha = a_{\text{tangential}} / R$$

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Rotation of Objects

■ Moment of Inertia

$$I = \sum_i m_i r_i^2$$

■ Torque

$$\vec{\tau} = \vec{R} \times \vec{F}$$

■ Conditions for Statics

$$\vec{F}^{\text{net}} = 0 \quad \vec{\tau}^{\text{net}} = 0$$

■ Rotational Dynamics

$$\alpha = \frac{\tau^{\text{net}}}{I}$$

■ Rotational Energy

$$RE = \sum_i \frac{1}{2} m_i v_i^2 = \frac{1}{2} I \omega^2$$

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Balance Conditions for Extended Objects (in 2D)

$$F_{up} = F_{down}$$

$$F_{left} = F_{right}$$

$$\tau_{clockwise} = \tau_{counter-clockwise}$$

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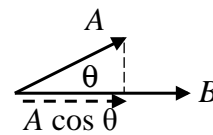
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Vector Products

■ Dot Product (a scalar)

- Picks out the pieces of two vectors in the same direction and multiplies them.

$$\vec{A} \cdot \vec{B} = AB \cos \theta = A_x B_x + A_y B_y$$

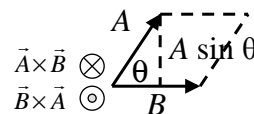


Useful for
finding
Work. (Why?)

■ Cross Product (a vector)

- Picks out the pieces of two vectors in perpendicular directions and multiplies them

$$|\vec{A} \times \vec{B}| = AB \sin \theta = A_x B_y - A_y B_x$$



Useful for
finding
Torque. (Why?)

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Static Properties of fluids

■ Pressure

$$\vec{F} = p\vec{A}$$

■ Pressure under gravity (incompressible fluid)

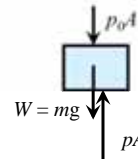
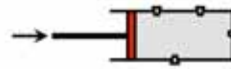
$$p = p_0 + \rho_{\text{fluid}}gd$$

■ Principles

– Archimedes' principle

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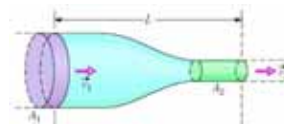


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Dynamic Properties of Fluid Flow

■ Incompressible fluid: conservation of flow.

$$Q = Av = \text{constant}$$



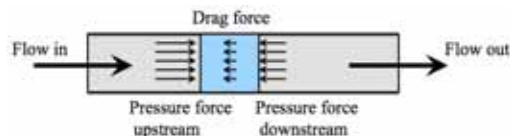
■ Constant flow through a pipe (HP eq.)

$$\Delta p = ZQ$$

$$Z = \frac{8\pi\mu L}{A^2}$$

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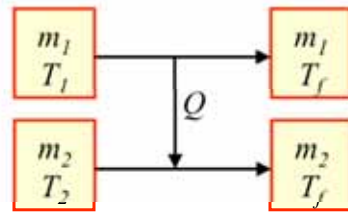
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Heat and Temperature

- Temperature:
a measure of thermal energy density
– 0-th Law of Thermodynamics
- Heat energy transfer between two objects $Q_1 = -Q_2$
 $Q = C\Delta T = mc\Delta T$



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Heat Flow

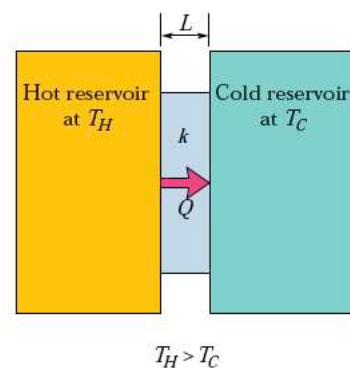
- Fourier's Law

$$\Delta T = T_H - T_C$$

Φ = heat flow (energy/sec)

$$\Delta T = Z\Phi$$

$$Z = \frac{1}{k} \frac{L}{A}$$



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