Purdue University Department of Physics

Physics 22000
General Physics
Lecture 22 – Review

Fall 2016 Semester

Prof. Matthew Jones

Second Midterm Exam

Wednesday, November 16th, 8:00-9:30 pm
Location: Elliot Hall of Music - ELLT 116.

Covering material in chapters 6-10

Multiple choice, probably about 25 questions, 15 will be conceptual, 10 will require simple computations.

A formula sheet will be provided.

You can bring one page of your own notes.

I put a couple exams from previous years on the web page… solutions will be posted soon.

Topics on Midterm #2

- Work and Energy
  - Collisions: elastic and inelastic
- Extended bodies at rest
  - Static equilibrium
- Rotational motion
  - Kinematics
  - Rotational inertia
  - Rotational momentum
- Gases
  - Atomic mass
  - Ideal gas law
- Static fluids
  - Pascal’s laws
  - Archimedes’ principle

SUPPLEMENTAL INSTRUCTION

Free Study Sessions!

Rachel Hoagburg

Come to SI for more help in **PHYS 220**

Tuesday and Thursday	7:30-8:30PM Shreve C113

Office Hour

Tuesday 1:30-2:30 4th floor of Krach

For other SI-linked courses and schedules, visit purdue.edu/si or purdue.edu/boilerguide

Work and Energy

Generalized work-energy principle The sum of the initial energies of a system plus the work done on the system by external forces equals the sum of the final energies of the system:

$$U_i + W = U_f \quad (6.3)$$

or

$$(K_i + U_{gi} + U_{si}) + W = (K_f + U_{gf} + U_{sf} + \Delta U_{int}) \quad (6.3)$$

Note that we have moved $U_{int\,i}$ to the right hand side ($\Delta U_{int} = U_{int\,f} - U_{int\,i}$) since values of internal energy are rarely known, while internal energy changes are.

$$K = \frac{1}{2}mv^2 \qquad U_s = \frac{1}{2}kx^2$$

$$U_g = mgy \qquad U_{int} = \text{(heat, for example)}$$

Momentum and Energy Conservation

- Momentum is always conserved

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

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

- Energy is also always conserved

$$U_i + W = U_f$$

$$\left(K_i + U_{gi} + U_{si}\right) + W$$
$$= (K_f + U_{gf} + U_{sf} + \Delta U_{int})$$

$$\Delta U_{int} = U_{int\,f} - U_{int\,i}$$

- The different types of energy are not necessarily conserved individually.

Elastic Collisions

- Total kinetic energy is conserved in *elastic* collisions
- Linear momentum is always conserved (in both elastic and inelastic collisions)
- Inelastic collisions usually involve kinetic energy being transformed to internal energy
  - For example, frictional forces exerted between the objects

Elastic Collisions

- Linear momentum is conserved:

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

- Kinetic energy is conserved:

$$\frac{1}{2}m_1v_{1i}^2 + \frac{1}{2}m_2v_{2i}^2 = \frac{1}{2}m_1v_{1f}^2 + \frac{1}{2}m_2v_{2f}^2$$

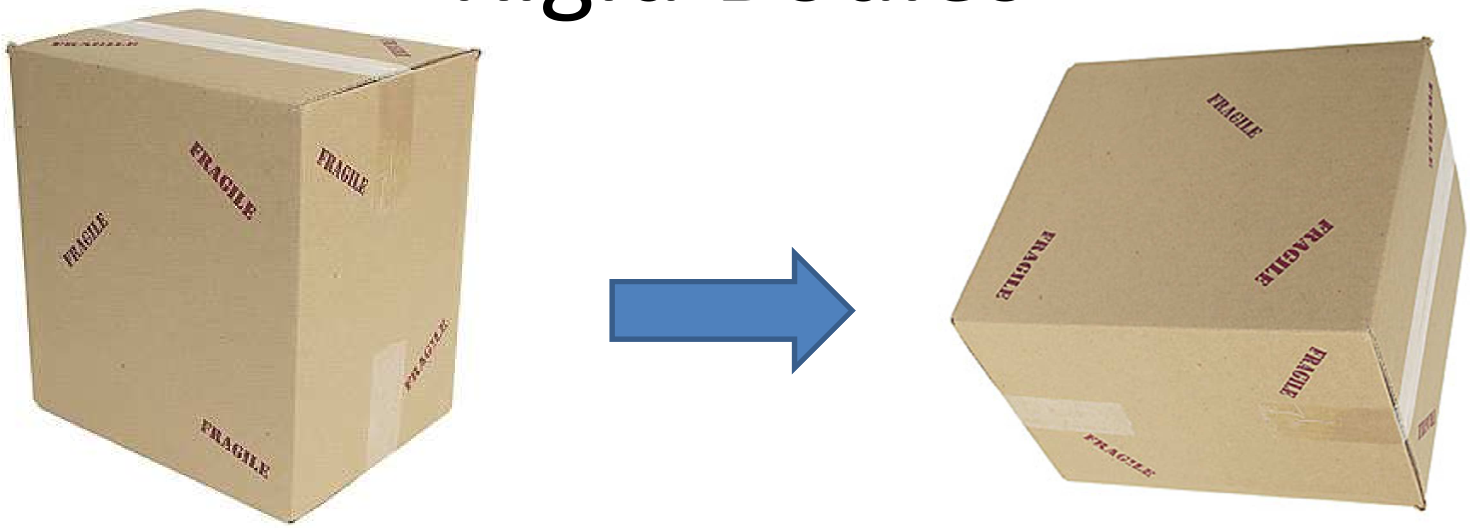
Inelastic Collisions

- Objects might stick together, become bent, deformed, squished, etc...
- Linear momentum is conserved:

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

- Kinetic energy is not conserved.

Rigid Bodies

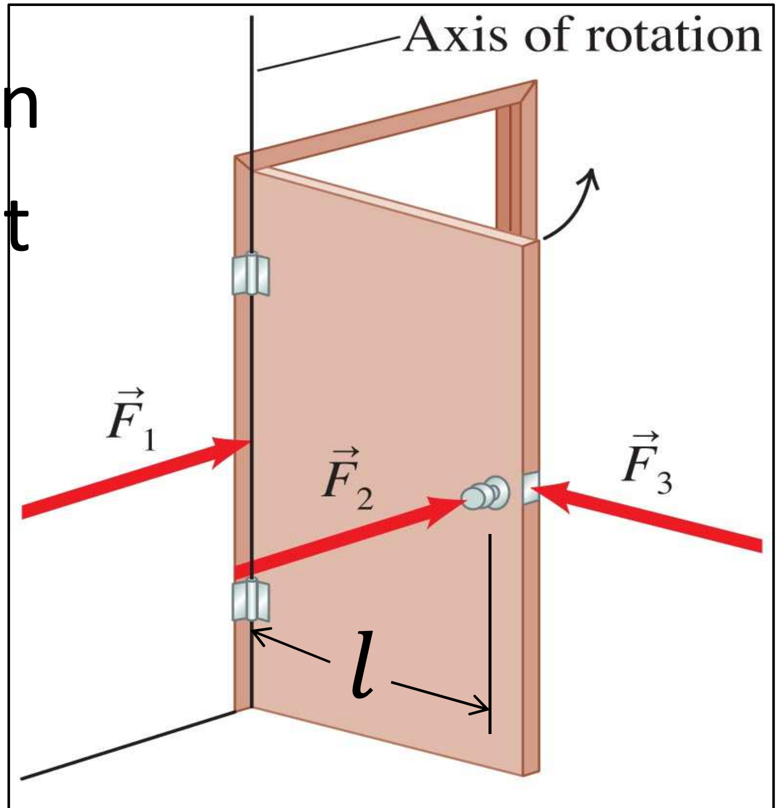


- A rigid body is a model for an extended object.
- We assume that the object has a nonzero size but the distances between all parts of the object remain the same (the size and shape of the object do not change).

Torque Produced by a Force

- Identify the axis of rotation
- Calculate the torque about that axis:

$$\tau = \pm F l \sin\theta$$

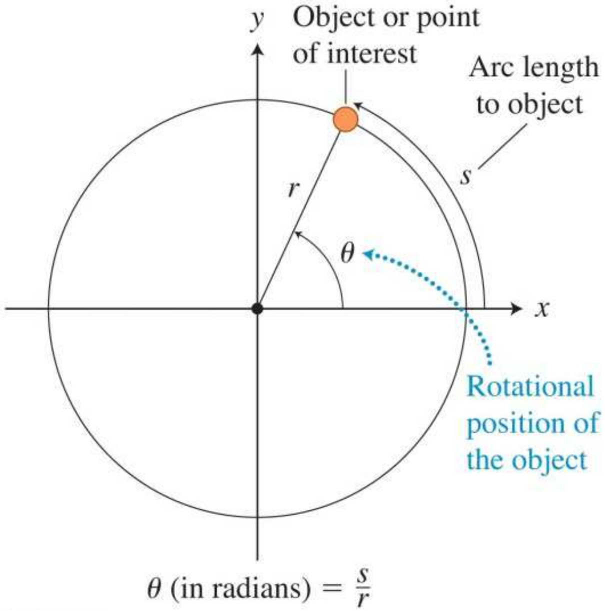


$\vec{F}_1$ and $\vec{F}_3$ do not rotate the door, whereas $\vec{F}_2$ moves it easily.

Extended Bodies at Rest

- Conditions for static equilibrium
  - Net force on the object is zero
  - Net torque on the object is zero
- Center of mass:
  - All the gravitational forces exerted by the earth can be summarized by a single force acting through the center of mass of the rigid body

Rotational Motion



- Description of rotational motion:
  - Arc length:

$$s = r\theta$$

  - Rotational velocity (angular velocity):

$$\omega = \frac{\Delta\theta}{\Delta t}$$

$$v = r\omega$$

  - Rotational acceleration (angular acceleration):

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

$$a = r\alpha$$

Rotational Motion at Constant Angular Acceleration

- θ_0 is an object's rotational position at $t_0 = 0$.
- ω_0 is an object's rotational velocity at $t_0 = 0$.
- θ and ω are the rotational position and the rotational velocity at some later time t.
- α is the object's constant rotational acceleration during the time interval from time 0 to time t.

Translational motion	Rotational motion	
$v_x = v_{0x} + a_x t$	$\omega = \omega_0 + \alpha t$	(8.6)
$x = x_0 + v_{0x} t + \frac{1}{2} a_x t^2$	$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$	(8.7)
$2a_x(x - x_0) = v_x^2 - v_{0x}^2$	$2\alpha(\theta - \theta_0) = \omega^2 - \omega_0^2$	(8.8)

Newton's Second Law

- For linear motion, Newton's 2^{nd} law is

$$a = \frac{\sum F}{m}$$

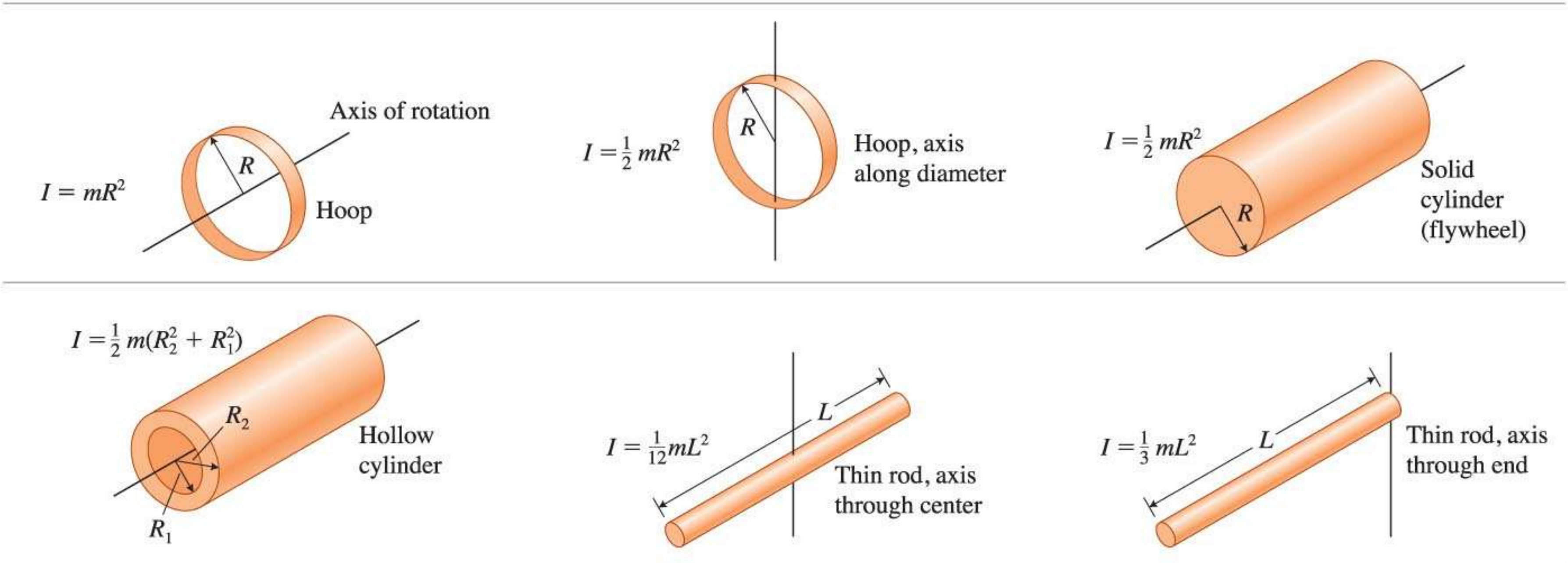
- For rotational motion, this implies that

$$\alpha = \frac{\sum \tau}{I}$$

- The rotational inertia, I, depends on the mass of the object and on where its mass is distributed.

Rotational Inertia

Table 8.6 **Expressions for the rotational inertia of standard shape objects.**



I will provide a figure like this on the exam.

Angular (rotational) Momentum

$$L = I\omega$$

When external torques are applied:

$$L_i + \sum \tau \ \Delta t = L_f$$

When no external torques are applied, angular momentum does not change:

$$I_i \omega_i = I_f \omega_f$$

Changes in rotational inertia:

$$\omega_f = \frac{I_i}{I_f} \ \omega_i$$

Gases

- Relation between temperature and kinetic energy of gas particles:

$$\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$$

- Boltzmann's constant: $k = 1.38 \times 10^{-23}\ J/K$
- Charles' Law (constant pressure):

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

- Boyle's Law (constant temperature):

$$P_1V_1 = P_2V_2$$

Ideal Gas Law

$$PV = NkT$$

- Avogadro's number:

$$N_A = 6.02 \times 10^{23}$$

- One "mole" consists of N_A objects

$$PV = nRT$$

$$R = 8.3\,\mathrm{J/K\,/mole}$$

- Atomic mass scale: a water molecule has an atomic mass of approximately 18 units. One mole of water has a mass of 18 grams.

1 amu = 1 g/mole

Static Fluids

- Pascal's first law:
  - In a static fluid, a change in pressure at one point is "instantaneously" communicated to all points in the fluid
- Pascal's second law:
  - Pressure increases with depth due to the "weight" of liquid above that depth:

$$P_1 - P_2 = \rho g (y_2 - y_1)$$

Static Fluids

- Buoyant forces – Archimedes' principle:

$$F_{F\ on\ O} = \rho_{fluid} V_{fluid} g$$

  – The buoyant force is equal to the weight of displaced fluid.

Have I forgotten anything?