Exam #1

- Hour Exam I, Wed. Sep 28, in-class (50 minutes)
- Material from Chapters 1, 3, 4, 5, 6
- One page of notes (8.5" x 11") allowed. Can write on both sides
- 20 multiple choice question
- Scantron sheets will be used - bring #2 pencils and calculator

On-line review questions for chapters 3-6 at uw.physics.wisc.edu/~rzchowski/phy107

Chapter 1

- How science is done.
- Experience and reason
- Theory should describe the physical world.
- Often required to accept unusual ideas in order to explain experiments.
- Examples of geocentric theories replaced by heliocentric based on
  - Fit to more accurate experimental data.
  - Unwieldy nature of heliocentric theories.

Chapter 3: Post-Aristotle

- Inertia:
  A body subject to no external forces will
  - Stay at rest if it began at rest
  - Will continue motion in straight line at unchanging speed if it began in motion.
- Can explain how moon keeps orbiting around earth, etc.
- But need details to quantify this

Chapter 3: more definitions

Average speed = \frac{\text{distance traveled}}{\text{traveling time}}

As an equation:

Distance traveled = d
Traveling time = t
Average speed = \frac{d}{t}

Acceleration is the rate at which velocity changes:

\text{Acceleration} = \frac{\text{change in velocity}}{\text{time to make the change}}

Instantaneous speed and accel = average values over short time interval.

Chap. 3: momentum

- Momentum = mass \times velocity
- Momentum can be negative.
  - For objects moving in opposite directions, one will have positive momentum and one will have negative momentum
  - The total momentum could be zero, even though there is plenty of ‘motion’.
- Amount of ‘motion’ in a body (but not always positive).
- Conservation of momentum:
  Momentum is not created or destroyed, only transferred from one object to another.

Speed and accel: falling ball

<table>
<thead>
<tr>
<th>TIME ( seconds )</th>
<th>DISTANCE ( meters )</th>
<th>SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.225</td>
<td>0.5</td>
<td>2.6m/s</td>
</tr>
<tr>
<td>0.455</td>
<td>1.0</td>
<td>1.2m/s</td>
</tr>
<tr>
<td>0.69</td>
<td>1.5</td>
<td>0.4m/s</td>
</tr>
<tr>
<td>0.75</td>
<td>2.0</td>
<td>0.1m/s</td>
</tr>
<tr>
<td>0.80</td>
<td>2.5</td>
<td>2.6m/s</td>
</tr>
<tr>
<td>0.85</td>
<td>3.0</td>
<td>2.0m/s</td>
</tr>
<tr>
<td>0.90</td>
<td>3.5</td>
<td>1.4m/s</td>
</tr>
</tbody>
</table>
Falling ball: constant accel.

- Instantaneous speed increases proportionally to time for falling ball
- \( s = at \)
  \( a = 9.81 \text{ m/s}^2 \)
  acceleration of gravity

For constant accel:

\[
d = \frac{1}{2}at^2
\]

Question: acceleration

You throw a ball directly upwards to the ceiling and let it hit to the floor. The acceleration is smallest

A. Near the ceiling
B. Just before it hits floor
C. None of the above

After it leaves your hand, acceleration is constant, and equals acceleration of gravity. Acceleration is different than velocity. The velocity is zero at the top of the arc, but it is still continuously changing, even when it is zero.

Conservation of momentum

- Useful in understanding result of collisions.
- Not concerned with details of collision, only before and after.
- Total amount of momentum before = total momentum after.
- Momentum is transferred from one object to another.

Momentum Question

A 5 kg ball moving at 1 m/s to the right collides with a stationary 10 kg ball. After the collision, the 10 kg ball moves to the right at 0.25 m/s. What is the final speed of the 5 kg ball?

A. 0 m/s
B. 0.5 m/s
C. 1 m/s

Momentum before = 5 kg \times 1 \text{ m/s} + 10 kg \times 0 \text{ m/s} = 5 \text{ kg-m/s}

Momentum after = 5 kg \times ? \text{ m/s} + 10 kg \times 0.25 \text{ m/s} = 5 \text{ kg-m/s}

\( ? = 0.5 \text{ m/s} \) moving to the right

Momentum example

Two 5 kg balls move toward each other, each moving at 1 m/s, but in opposite directions. After the collision, clay on them makes them stick together. Before the collision, the total momentum is

\[ 5 \text{ kg} \times (1 \text{ m/s}) + 5 \text{ kg} \times (-1 \text{ m/s}) = 0 \text{ kg-m/s} \]

After the collision, the total momentum must also be zero. Since the balls are stuck together, this means that the velocity of each must be zero.

Chapter 4

- Principle of inertia:
  - object continues in its state of rest, or uniform motion in a straight line, unless acted upon by a force.
- Defined mass \( m \):
  - amount of inertia of a body
  - Measured in kg
- Define force \( F \):
  - Something that changes a body’s acceleration
- Related force, mass, and acceleration:
  - \( F = ma \), or \( a = F/m \)
  - Subject to the same force, more massive objects accelerate more slowly.
- Weight:
  - Force of gravity on a body = \( mg \)
  - Measured in newtons (N). 1 N = 1 kg-m/s^2
Newton: forces

- Newton changed the emphasis from ‘before and after’ to ‘during’.
- To describe the interaction, he clearly defined forces and their affects:

A force changes the momentum of an object:
Change in momentum = Force × time

Newton: 2nd law

- This is equivalent to
Net Force = Mass × Acceleration

\[
\text{Acceleration} = \frac{\text{Net Force}}{\text{Mass}} = \frac{F}{m}
\]

- Constant force gives constant accel:
  - Velocity increases with time.

Newton & mom. conservation

- The law of force pairs is the same as conservation of momentum.
- An applied force changes the momentum of an object.
- That momentum was transferred from the object applying the force.
- Hence an equal and opposite force had to change the momentum of the force-applying object.

Question: force

A car weighs 10,000 N.
It is moving at a speed of 30 m/s.
You apply the brakes with a force of 500 N. How many seconds will it take to stop?

A. 10 seconds
B. 30 seconds
C. 60 seconds

The force is 100N.
The mass = weight/g = 10,000/10 m/s² = 1000 kg.
So the acceleration is 500 N / 1000 kg = 0.5 m/s/s.
It takes 60 seconds for the speed to drop from 30 m/s to zero.

Newton: 3rd Law- Action/Reaction

- Every force is an interaction between two objects
- Each of the bodies exerts a force on the other.
- The forces are equal and opposite
  - An action-reaction pair.

Question

Two people are on roller chairs, and quickly push off of each other as hard as they can. They have masses of 100 kg and 50 kg. After the push, the 100 kg person is moving

A. Twice as fast as the 50 kg person
B. The same speed as the 50 kg person
C. Half as fast as the 50 kg person

Equal and opposite forces, but \( a = \frac{F}{m} \), so the accel of 100 kg person is half that of 50 kg person.
Accel is applied for same time, and \( v = at \).
Or... by conservation of momentum
Newton’s laws of motion

1) Every object continues in its state of rest, or uniform motion in a straight line, unless acted upon by a force.

2) The acceleration of a body along a direction is proportional to the total force along that direction, and inversely proportional to the mass of the body.

\[ F = ma \] or, \[ a = \frac{F}{m} \]

3) The forces exerted between two interacting objects are equal in magnitude and opposite in direction.

Some equations

- Constant speed (no forces)
  - distance = (velocity) x (time), \( d = vt \)
  - \( v = \text{constant} \)

- Constant accel (constant force)
  - \( d = \frac{1}{2} (a \text{ccel})(\text{time})^2 \), \( d = \frac{1}{2} at^2 \)
  - \( v = at \)
  - \( a = \text{constant} \)

Chapter 5

- Centripetal acceleration: body in circular orbit at constant speed has an acceleration directly inward.
  - magnitude is \( \frac{v^2}{r} \), \( r = \text{orbital radius} \)

- Gravitational force:
  - Force between any two bodies with mass
  - \( F = \frac{GM_1 M_2}{r^2} \)
  - \( r = \text{separation between centers} \)

- Free-fall
  - Accelerating at acceleration of gravity

Acceleration = \[ \frac{\text{change in velocity}}{\text{change in time}} \]

Velocity at time \( t_1 \)

Velocity at time \( t_2 \)

Change in velocity

Properties of gravity

- Gravitational force between two objects proportional to product of masses

- Gravitational force drops with the square of the distance between centers of objects.

Circular orbits

A geosynchronous satellite is one that orbits the Earth once every 24 hours. It orbits at some particular distance from the Earth’s center.

In order for it to orbit twice every 24 hours, it must be

A. Closer to the Earth
B. Farther from the Earth.
C. Same distance but moving twice as fast.

Centripetal acceleration is \( \frac{v^2}{r} \). This acceleration is due to the gravitational force, so equals \( g \). \( v = 2\pi r/T \) means that \( g = \text{constant} = 4\pi^2 r^2/T^2 = 4\pi^2 r^2/T^2 \). \( T \) is two times shorter, so \( r \) must be four times smaller.
Equation for force of gravity

\[ F_{\text{gravity}} = \frac{(\text{Mass of object 1}) \times (\text{Mass of object 2})}{\text{square of distance between them}} \]

For masses in kilograms, and distance in meters,

\[ F = 6.7 \times 10^{-11} \frac{m_1 \times m_2}{d^2} \]

Chaotic motion

- Chaotic systems:
  - Exactly follow Newton’s laws of motion (deterministic)
  - Sensitive dependence on initial conditions
  - Details of this dependence can show fractal (self-similar) behavior.
  - Can have periodic behavior when driven periodically (e.g. driven pendulum)
  - Driven systems go in and out of chaotic behavior depending on details of the drive.
  - Often show period doubling when approaching chaos

Sensitive to initial conditions

- Have three ‘attractors’ for the magnet on the pendulum.
- Release pendulum at diff. points & see where it comes to rest

Periodically driven system

- Driven pendulum

Chap 6: Work, Energy, and Power

- Work = Force \times Distance
- Energy = an object’s ability to do work
- Kinetic energy of motion: \( E_{\text{kinetic}} = \frac{1}{2}mv^2 \)
- Work - energy relation:
  - Change in kinetic energy of a single object
  - net work done on it by all forces.
- Potential energy
  - An additional form of energy
  - Can store energy in a system, to be extracted later.
- Conservation of energy:
  - energy is never lost, but just changes form.
- Power: How fast work is done.

Question: work

You push on a car with a constant force of 10 N for 1 second.
How much work did you do on the car?
A. 10 J
B. 50 J
C. Need more information

Work = (Force)(Distance). But don’t know distance!
Could find distance from \( d = \frac{1}{2}at^2 \), and \( a = \text{Force} / \text{mass} \). But need to know the mass.
An electrical plant produces power from falling bowling balls. The balls weigh 100 N each, fall a distance of 100 m, and 10 balls fall each second. How much power does the plant produce?

A. 100 kW
B. 10 kW
C. 1 kW

Potential energy converted to kinetic. Kinetic energy converted to electrical power.

Pot. E = mgh = (100 N) × (100 m) = 10,000 J

10,000 J × 10 ball/sec = 100,000 J/s = 100,000 W