HW and Exam #1

- Hour Exam 1, February 8, in-class
  - Material from March Chapters 1, 2, 3, 4, 5
  - Griffith Chapter 7
  - One page of notes (8.5" x 11") allowed
  - Questions are multiple choice
  - Scantron sheets will be used - bring #2 HB pencils and calculator
  - Review, Monday Feb 6

On-line review questions are on the 107 web site
Click on: Review Quizzes

From Last Time...

- Gravitational forces are apparent at a wide range of scales.
- Obey the law of universal gravitation:
  \[ F_{\text{gravity}} = \frac{G m_1 m_2}{d^2} \]
  
Gravitational Constant

Something missing

- We need these tools, can think about the world in many ways.
  - Collisions resulting in a momentum transfer
  - Gravitational forces resulting in acceleration of falling bodies and orbits of planets.
- But this leaves something out
  - Think about firing a rifle:
    - Before pulling the trigger, both rifle and bullet are stationary: total momentum is zero.
    - After firing, the bullet and rifle move in opposite directions Total momentum is still zero.
    - But clearly the situation before and after is different.
  - Rifle and bullet momenta are not individually zero
    - They are equal but opposite in direction
    - This shows that things are moving
    - Comes from momentum conservation, and also action-reaction
    - But equal momenta is not what we perceive!
    - And where did the motion come from?

Energy

- In addition to momentum, the energy is physical property of the system.
- We will see that it is also conserved.
- The simplest definition is
  - The energy of an object is the amount of work it can do.
- In the rifle - bullet example
  - Before firing, the energy is stored in the gunpowder.
  - After firing, most of the energy appears as the motion of the bullet and rifle
  - Some of the energy appears as heat.

Discussion so far...

- So far we have talked about
  - Velocity
  - Acceleration
  - Momentum conservation of momentum
  - Momentum transfer changing the velocity of an object
  - Force changing the velocity of an object
  - Newton’s relation: Acceleration = Force / mass

Total momentum says the ‘before’ and after situation is the same: both have zero momentum
- True, but we are missing something.

Other aspects are dramatically different.
- Bullet is moving and rifle is moving!
  - So total momentum doesn’t describe everything.

Rifle and bullet momenta are not individually zero
- They are equal but opposite in direction
- This shows that things are moving
- Comes from momentum conservation, and also action-reaction
- But equal momenta is not what we perceive!
- And where did the motion come from?
**Work**

- Work is done whenever a body is continually pushed or pulled through a distance.
- Twice as much work is done when the body is moved twice as far.
- Pushing twice as hard over the same distance does twice as much work.
- Work = Force x Distance

**Work, cont.**

- Force has units of Newtons (N)
  - Distance has units of meters (m)
  - So work has units of N-m, defined as Joules (J).
- Example:
  - The Earth does work on an apple when the apple falls.
    - *The force applied is the force of gravity*
- Example:
  - I do work on a box when I push it along the floor.
    - *The force applied is from my muscles*

**Question**

A man holds up a bowling ball in a fixed position. The work he does on the ball

A. Depends on the weight of the ball.
B. Depends on how long he holds it.
C. Is equal to zero.

Although the man is exerting force against gravity to hold the bowling ball up, he has not shifted its position. So the work done by him on the ball is zero.

Work = Force x Distance

**Multi-part question**

I lift a body weighing 1 N upward at a constant vertical velocity of 0.1 m/s. The net force on the body is

A. 1 N upward
B. 1 N down
C. 0 N

Since the acceleration is zero, the net force must be zero.

**Question, cont.**

The force I exert on the body is

A. 1 N up
B. 1 N down
C. 0

Since net force is zero, and the gravitational force is 1 N down, I must be exerting 1 N up.

**Question, cont.**

After lifting the 1 N body a total distance of 1 m, the work I have done on the body is

A. 1 J
B. 0.1 J
C. 0 J

Work = Force x Distance

\[ = 1 \text{ N} \times 1 \text{ m} = 1 \text{ N-m} = 1 \text{ Joule} \]
**Energy**

A object’s energy is the amount of work it can do.

Energy comes in many forms:

- Kinetic Energy
- Gravitational Energy
- Electrical Energy
- Thermal Energy
- Solar Energy
- Chemical Energy
- Nuclear Energy

It can be converted into other forms without loss (i.e., it is conserved).

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**Energy of motion**

In outer space, I apply a force of 1 N to a 1 kg rock for a distance of 1 m.

I have done \( \text{Force} \times \text{Distance} = (1 \text{ N})(1 \text{ m}) = 1 \text{ J} \) of work.

After applying the force for 1 m, the rock is moving at some final velocity \( v_{\text{final}} \) as a result of the acceleration \( \frac{\text{Force}}{\text{mass}} \).

So the energy I expended in doing work has caused the body to change its velocity from zero to \( v_{\text{final}} \).

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**Kinetic energy (energy of motion)**

- Work = Force \( \times \) Distance
- A constant applied force leads to an acceleration.
- After the distance is moved, the body is traveling at some final velocity \( v_{\text{final}} \).
- So the result of the work done is to change the body’s velocity from zero to \( v_{\text{final}} \).

**Work-energy relation**

- The acceleration of the body is related to the net force by \( F = ma \)

\[
\text{Work} = F_{\text{net}} \times d = (ma) \times d = m \times (at)
\]

For a body initially at rest, constant acceleration says

\[
\begin{align*}
    d &= \frac{1}{2}at^2, \quad \text{so} \quad t &= \sqrt{\frac{2d}{a}} \\
    v_{\text{final}} &= at = \frac{1}{2}at = \frac{1}{2}\sqrt{2ad} \\
    \text{Work} &= F_{\text{net}} \times d = \frac{1}{2}mv_{\text{final}}^2
\end{align*}
\]

\( \frac{1}{2}mv^2 \) is called Kinetic Energy, or energy of motion.

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**A more general form**

- If the object initially moving at some velocity \( v_{\text{initial}} \) it has kinetic energy \( \frac{1}{2}mv_{\text{initial}}^2 \).
- As the result of a net work \( W_{\text{net}} \), the velocity increases to \( v_{\text{final}} \), and the Kinetic Energy increases to \( \frac{1}{2}mv_{\text{final}}^2 \).

\[
W_{\text{net}} = \frac{1}{2}mv_{\text{final}}^2 - \frac{1}{2}mv_{\text{initial}}^2
\]

The change in kinetic energy is equal to the net work done.
Question

When you do positive work on an object, its kinetic energy

A. increases.
B. decreases.
C. remains the same.

Gravitational energy

- An object in a gravitational field can do work when it falls.
- We might say that energy is stored in the system.

Ball falls down in gravity

- Ball initially held at rest.
  - \( v_{\text{initial}} = 0 \)
  - Kinetic energy = 0
- Ball released.
- Gravitational force = \( mg \), falls with acceleration \( g \)
- Work done by gravitational force in falling distance \( h \) is \( \text{Force} \times \text{Distance} = mgh \).
- Ball final kinetic energy = \( mgh = \frac{1}{2}mv_{\text{final}}^2 \)

Question

Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. Just before hitting the ground, the heavier marble has

A. as much kinetic energy as the lighter one
B. twice as much kinetic energy as the lighter one
C. half as much kinetic energy as the lighter one

Final velocity of the two marbles is the same

Kinetic energy \( \frac{1}{2}mv^2 \) is proportional to mass

Electrical Energy

- Electricity is the flow of charged particles.
- Charged particles have an electromagnetic force between them similar to the gravitational force.
- This force can do work.
- Doing work against this force can store energy in the system.
- The energy can be removed at any time to do work.

Thermal Energy

- Otherwise known as heat.
- The temperature of an object is related to the amount of energy stored in the object.
- The energy is stored by the microscopic vibratory motion of atoms in the material.
- This energy can be transferred from one object to another by contact.
- It can also be turned into work by contact.