HW and Exam #1

HW: 3
Chap. 5 Concept: 22, Problems: 2, 4
Chap. 6 Concept: 18, Problems: 2, 6

- Hour Exam I, Wednesday Sep 29, in-class
- Material from Chapters 1, 3, 4, 5, 6
- One page of notes (8.5" x 11") allowed
- Questions are multiple choice
- Scantron sheets will be used - bring #2 HB pencils and calculator

On-line review questions added to web site uw.physics.wisc.edu/~rzchowski/phy107

From Last Time... Chaos

- Although Newton’s laws are deterministic, some dynamical systems depend so sensitively on the initial conditions that the final outcome is almost impossible to predict.
- e.g. models for forecasting weather, a single planet orbiting two suns, etc.
- ‘Chaotic’ systems have this property.
- The motion can be quite complicated, but can be understood to some degree.
- In a driven system, chaos is often approached in a process where the period of motion doubles, quadruples, etc, before becoming chaotic.

Today’s lecture

- Work
- Energy
- Relation between work and energy
- Different forms of energy
- Transferring energy from one object to another.
- Conservation of energy.

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 \times 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. Cannot be calculated without more information.
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 \times 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 N x 1 m = 1 N-m = 1 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 is convertible into other forms without loss (i.e it is conserved)

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 Force x Distance = (1 N)(1 m) = 1 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 $\text{Force/mass}$.
So the energy I expended in doing work has caused the body to change its velocity from zero to $v_{\text{final}}$.

Kinetic energy (energy of motion)

- Work = Force x 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 $F = ma$

  $Work = F_{\text{net}} \times d = (ma) \times d = m \times (ad)$

  For a body initially at rest, constant accel. says

  \[
  v_{\text{final}} = at = \frac{md}{a} \implies \frac{1}{2}mv_{\text{final}}^2 = \frac{1}{2}mv^2_{\text{final}}
  \]

  \[
  Work = F_{\text{net}} \times d = \frac{1}{2}mv_{\text{final}}^2
  \]

  $\frac{1}{2}mv^2_{\text{final}}$ is called Kinetic Energy, or energy of motion

Work-energy relation

- The kinetic energy of a body is

  \[
  \frac{1}{2}mv^2_{\text{final}}
  \]

  - The kinetic energy will change by an amount equal to the net work done on the body.

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 $Force \times Distance = mgh$.
  - Ball final kinetic energy = $mgh = \frac{1}{2}mv_{\text{final}}^2$
Ball moved up in gravity

- Work done by me on ball
  - Ball initially held at rest by me.
  - I move the ball slowly upward a distance h.
  - Force applied by me is mg upward.
  - Work done by me on ball is Force x Distance = mgh
- Work done by gravity on ball
  - Force x Distance = -mgh
- Net (total) work done on ball = mgh-mgh = 0
- Consistent with zero change in kinetic energy of ball during this time (i.e. ending velocity is same as starting velocity).

Work Done by Gravity

- Change in gravitational energy,
  \[ \text{Change in energy} = mgh \]
  true for any path : \( h \), is simply the height difference, \( y_{\text{final}} - y_{\text{initial}} \)
- A falling object converts gravitational potential energy to its kinetic energy
- Work needs to be done on an object to move it vertically up - work done is the same no matter what path is taken

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

1. as much kinetic energy as the lighter one
2. twice as much kinetic energy as the lighter one
3. 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

The pendulum

- An easier way to investigate this energy change is in a pendulum.
- I do work on the bowling ball by increasing its height above the floor.
- Releasing the ball lets gravity do work on the ball:
  - Positive work when it swings down.
  - Negative work when it swings up.
  - Energy flows into and out of the ball.

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.
Storing energy

* Energy is neither created nor destroyed, but is just moved around.
* Or more accurately, it changes form.
* I did work by lifting the body.
* If the body now drops, it can do work when it hits (pounding in a nail, for instance).

Could say that the work I did lifting the body is stored until the body hits the nail and pounds it in.