Announcements:
- 1st Midterm 6 - 7 pm Sept. 25th (cover chs. 7-8 with chs. 1-6 implemented)
  Location: Lockett 10
  Nicholson 119 for extra timers (5:15 - 6:45 pm or 5:15 - 7:15 pm)

Lecture notes:
http://www.phys.lsu.edu/classes/fall2012/phys2101-6/

Old Exams:
http://www.phys.lsu.edu/faculty/gonzalez/Teaching/Phys2101/Phys2101OldTests/
Chapter 7 - Kinetic energy and Work

Different energies:
- Kinetic/translation
- Gravitational potential
- Heat energy
- Electromagnetic energy
- Strain or elastic energy

Each energy is associated with a “scalar” which defines a state of a system at a given time.

Kinetic Energy is associated with the state of motion

\[ KE = \frac{1}{2} m v^2 \]

Units of Joules: 1 J = kg·m²/s²

- KE depends on speed not \( \dot{v} \) (here \( v^2 = \ddot{v} \cdot \ddot{v} = |\ddot{v}|^2 \))
- KE doesn’t depend on which way something is moving or even if it’s changing direction
- KE is ALWAYS a positive scalar
How much is “Kinetic Energy”

1) **Electron (e-) moving in Copper**
   \[ m_e = 9.11 \times 10^{-31} \text{ kg} \quad \text{and} \quad v \sim 1 \times 10^6 \text{ m/s} \]
   \[ KE = 7 \times 10^{-19} \text{ J} \quad (\sim 4 \text{ eV}) \]

2) **Bullet traveling at 950 m/s (3100 ft/s)**.
   \[ m = 4.2 \text{ g} \quad \text{and} \quad v \sim 950 \text{ m/s} \quad (3100 \text{ ft/s}) \]
   \[ KE = 2000 \text{ J} \]

3) **Football Linebacker**
   \[ m = 240 \text{ lbs} \quad \text{and} \quad v \sim 18 \text{ mph} \quad (7 \text{ m/s}) \]
   \[ KE = 2800 \text{ J} \]

4) **Aircraft Carrier Nimitz**
   \[ m = 91,400 \text{ tons} \quad \text{and} \quad v \sim 1 \text{ knot} \]
   \[ KE = 10 \text{ MJ} \]
Work

If you apply a net force (\(\sim a \uparrow \rightarrow v \uparrow\)), KE \(\uparrow\) and if you decelerate (\(a \downarrow \rightarrow v \downarrow\)), KE \(\downarrow\)

Somehow force is related to KE energy…

If we *transfer* energy via a **force**, this is **work**.

“Doing work” is the act of transferring energy.

Work (\(W\)) is said to be done **on** an object by a force.

Energy transferred **to** an object is **positive** work.

Energy transferred **from** an object is **negative** work.
Work and Kinetic Energy

How to find an “alternate form” of Newton’s 2nd Law that relates position and velocity?

Start in 1-D (e.g. Bead alongwire $\hat{x}$), we know …

\[
F_{x,\text{net}} = ma_x = m \frac{dv}{dt}
\]

\[
(F_{x,\text{net}}) \left( \frac{dx}{dt} \right) = \left( m \frac{dv}{dt} \right) \left( \frac{dx}{dt} \right) = mv \frac{dv}{dt}
\]

\[
F_{x,\text{net}} \frac{dx}{dt} = d\left( \frac{1}{2} mv^2 \right)
\]

\[
F_{x,\text{net}} dx = d\left( \frac{1}{2} mv^2 \right)
\]

\[
\int F_{x,\text{net}} dx = \int d\left( \frac{1}{2} mv^2 \right) = KE_2 - KE_1
\]

\[
W_{\text{net}} \equiv \int F_{x,\text{net}} dx = KE_2 - KE_1 = \Delta KE
\]

\[
W_{\text{net}} = \Delta KE
\]
Work-Kinetic Energy Theorem

-- Another form of Newton’s 2nd Law

Work-Kinetic Energy Theorem → (change in the kinetic energy of an object) = (net work done on the particle)
Work: Graphic Expression

\[ W_F \equiv \int \vec{F} \cdot d\vec{x} = \text{Area of the } F-x \text{ diagram} \]

If \( \vec{F}_{\text{net}} \) is not a function of \( \vec{x} \) then

\[ W_F \equiv \int \vec{F} \cdot d\vec{x} = \vec{F} \cdot \vec{x} \]  (if \( F \) is a non-variable force)

No work is done on an object by a force unless there is a component of the force along the object's line of motion.
Positive and Negative Work

Weight lifting: apply a **FORCE** up and **DISPLACE** the barbell up…

both the force and displacement are in the +y direction so work is **positive**

On the downward motion the **FORCE** is still up and

the force is in the +y but the displacement is in –y direction so work is **negative**

---

**External Force acts on box moving rightward a distance d.**

**Rank: Work done on box by F**

(a)  
(b)  
(c)  
(d)
Walking across the room at constant velocity, how much work am I doing on the bowling ball?

1. Quite a lot
2. None
Two forces act on the box shown in the drawing, causing it to move across the floor. The two force vectors are drawn to scale. Which force does more work on the box?

1. $F_1$
2. $F_2$
3. They’re both zero ($F_1 = F_2 = 0$)
4. They’re the same, but not zero ($F_1 = F_2 \neq 0$)
A particle moves along an axis. Does the kinetic energy of the particle increase, decrease, or remain the same if the particle’s velocity changes:

(a): from -3 m/sec to -2 m/sec.

1. Increase
2. **Decrease**
3. **Stay the same**
A particle moves along an axis. Does the kinetic energy of the particle increase, decrease, or remain the same if the particle’s velocity changes:

(a): from -2 m/sec to 2 m/sec.

1. Increase
2. Decrease
3. Stay the same
A particle moves along an axis. Does the kinetic energy of the particle increase, decrease, or remain the same if the particle’s velocity changes:

(a) -3 to -2
1. Positive
2. **Negative**
3. Zero

(b) -2 to +2
1. Positive
2. **Negative**
3. Zero

(c): Is the work done Positive, Negative, or Zero
Example Problem 7-3

During a storm, a crate is sliding across a slick, oily parking lot through a displacement $\vec{d} = (-3.0 \text{m}) \hat{i}$ while a steady wind pushes against the crate with a force $\vec{F} = (2.0 \text{N}) \hat{i} + (-6.0 \text{N}) \hat{j}$.

(a) How much work does the force from the wind do on the crate during the displacement?

(b) If the crate has a kinetic energy of 10 J at the beginning of displacement $\vec{d}$, what is the kinetic energy at the end of $\vec{d}$?
Example problem #1
[Question 7-8]

The figure shows the values of a force $F$, directed along an $x$ axis, that will act on a particle at the corresponding values of $x$. If the particle begins at rest at $x=0$, what is the particle’s coordinate when it has (a) the greatest speed; (b) the minimum speed
**Question:** The figure shows the values of a force \( F \), directed along an \( x \) axis, that will act on a particle at the corresponding values of \( x \). If the particle begins at rest at \( x=0 \), what is the particle’s coordinate when it has

(a) the greatest speed

(b) the minimum speed

Greatest speed at \( x=3 \) m  
Minimum speed (zero) at \( x=6 \) m
**Special Case: Work done by Gravitational Force**

\[ W_g = \int \vec{F}_g \cdot d\vec{x} = \vec{F}_g \cdot \vec{d} \]

*where* \( \vec{F}_g = (mg)(\hat{j}) \) *and* \( g = 9.81 \text{ m/s}^2 \)

If an object is displaced **upward** (\( \Delta y \) positive), then the work done by the **gravitational force** on the object is **negative**.

If an object is displaced **downward** (\( \Delta y \) negative), then the work done by the **gravitational force** on the object is **positive**.

**What is the change in KE due to Gravitational Force?**

If the only force acting on an object is Gravitational Force then,

\[ W_{net} = \left( W_g = \vec{F}_g \cdot \vec{d} \right) = \Delta KE = \left( KE_f - KE_i \right) \]

If an object is displaced **upward** (\( \Delta y \) positive), the change in Kinetic Energy is **negative** (it slows down).

If an object is displaced **downward** (\( \Delta y \) negative), the change in Kinetic Energy is **positive** (it speeds up).
Careful with the Notations…

**WORK done by Gravitational Force**

\[ W_g = \int \vec{F}_g \cdot d\vec{x} = \vec{F}_g \cdot d \]

where \( \vec{F}_g = (mg)(-\hat{j}) \) and \( g = 9.81 \text{m/s}^2 \)

\[
\begin{align*}
W &= \text{weight} \\
W &= \text{work}
\end{align*}
\]

} this could be a problem - just keep your wits about you
What work is needed to lift or lower an object?

In order to “lift” an object, we must apply an external force to counteract the gravitational force.

\[ W_{net} \equiv W_g + W_{ext} = \Delta KE \]

If \( \Delta KE = 0 \) (i.e. \( v_f = v_i \)), then \( W_g = -W_{ext} \)

If an object is displaced upward (\( \Delta y \) positive), then the work done by the External force (non-gravitational force) on the object is positive.

If an object is displaced downward (\( \Delta y \) negative), then the work done by the External force (non-gravitational force) on the object is negative.
A 58-kg skier coasts down a 25° slope where the kinetic frictional force is $f_k = 70$ N. If the starting speed is $v_o = 3.6$ m/s then what is the speed after a displacement of 57 m?
Problem 7-17

A helicopter lifts an astronaut of mass $m$ vertically upward a distance $d$ from the ocean by means of a cable. The acceleration of the astronaut is $g/8$.

How much work is done on the astronaut by:

a) the force from the helicopter and  
b) the gravitational force on him?

What are

c) the kinetic energy and  
d) the speed of the astronaut just before he reaches the helicopter.
A ball has a speed of 15 m/s. Only one external force acts on the ball. After the force acts, the ball’s speed is 7.5 m/s. The force on the ball did:

\[ W_{net} = \Delta KE = (KE_f - KE_i) = \frac{1}{2} m \left( v_f^2 - v_i^2 \right) \]

1. Positive work
2. Negative work
3. No work
Example

You are moving out of town and need to load a heavy box of mass $m$ into the back of the moving truck.

You can either pick the box straight up and set it in the truck (a height $h$ above the ground) or slide the box a distance $L$ up a ramp into the back of the truck. Assume the ramp has good rollers on it, so that it is frictionless.

Which way requires more work?

Which way requires a greater force?
**Work due to Friction**

WORK due to friction is ALWAYS NEGATIVE
- Energy is transferred OUT
- Kinetic energy decreases or $\Delta KE < 0$ (slow down)

*Where did the energy go? THERMAL/Sound*
### Special Case: Work done by a Spring Force

**Hooke’s Law (variable force)**

\[ \vec{F} = -kd \]

- \( \vec{F} \) = force from the spring
- \( k \) = spring constant (stiffness) - units \([\text{N/m}]\)
- \( d \) = displacement from equilibrium \((x = 0)\)

**Note:** The force is always directed to “restore” the equilibrium position.

### Work Done by Spring

\[
W_{\text{spring}} = \int F_{\text{spring}}(x) \cdot dx
\]

\[
= \int_{x_1}^{x_2} (-kx) dx = -k \int_{x_1}^{x_2} x dx
\]

\[
= \left(-\frac{1}{2} k\right)[x^2]_{x_1}^{x_2} = -\frac{1}{2} k(x_2^2 - x_1^2)
\]

**Note:** Work done by spring is positive (negative) if block moves towards (away) equilibrium position. It is zero if the block ends up at the same distance from \(x=0\).
For the situation (Figure), the initial and final positions, respectively, along the x axis for the block are given below. Is the work done by the spring force on the block positive, negative or zero?

(a) -3 cm, 2 cm.

1. Positive
2. Negative
3. Zero
For the situation (Figure), the initial and final positions, respectively, along the x axis for the block are given below. Is the work done by the spring force on the block positive, negative or zero?

(b) 2 cm, 3 cm.

1. Positive
2. Negative
3. Zero

\[ W_s = \frac{1}{2} kx_i^2 - \frac{1}{2} kx_f^2 \]
For the situation (Figure), the initial and final positions, respectively, along the x axis for the block are given below. Is the work done by the spring force on the block positive, negative or zero?

(c) -2 cm, 2 cm.

1. Positive
2. Negative
3. Zero

\[ W_s = \frac{1}{2} kx_i^2 - \frac{1}{2} kx_f^2 \]