## PHYS 2211

Look over:
Chapter 7 Sections 1-9
Examples 1, 2, 3, 4, 5, 6, 7, 8,
Chapter 8 Sections 1-5, 7, 8
Examples 1, 2, 3, 4, 5, 6, 7, 8

## PHYS 1111

Look over
Chapter 7 Sections 1-8
Examples 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15

## Topics Covered

1) Work done by a force (General Form)
2) Kinetic Energy
3) The Work-Energy Theorem
4) Power
5) Conservative and Non-conservative forces
6) Potential Energy
7) Conservation Of Mechanical Energy
8) Conservation Of Energy

## How will a Particle Move

We want to know the position as a function of time.

$$\vec{r}(t)$$

For a constant force we can find $r(t)$ by using Newton's 2nd law to give:

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

## What To Do With Changing Forces

Since $F$ and $m$ are constant, $a$ must also be constant so we can find the velocity as:

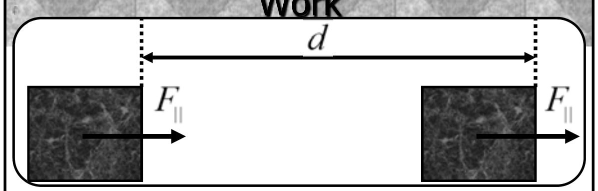
$$\vec{v}_1 = \vec{v}_0 + \vec{a}t$$

and the position as a function of time is given by:

$$\vec{r}(t) = \vec{v}_0 t + \tfrac{1}{2}\vec{a}t^2$$
$$(\text{with } r_0 = 0 \text{ and } r_1 = r)$$

But what can we do if the force is not constant?

## Work




**Work** is the product of the magnitude of the displacement (distance) times the part of the force parallel to the displacement.

When the force and the direction of motion is the same then we can find the work by multiplying the force times the distance.

$$W = F_{||}\, d$$

## Units of Work

The units of work are:

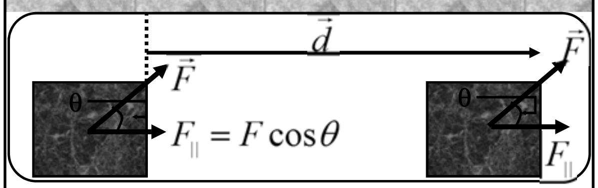
$$\text{(units of force)} \times \text{(units of distance)}$$

In the metric system the unit of work is:

$$N \bullet m = kg\frac{m}{s^2} \bullet m \Rightarrow J \text{ (The Joule)}$$

Where the unit of work is named after James Prescott Joule a British Physicists.

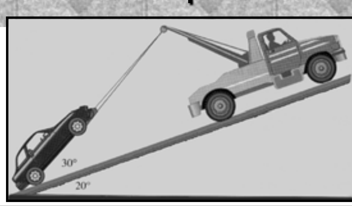
## Work in General




$$W = F_{||}\, d = Fd\cos\theta = \vec{F} \bullet \vec{d}$$

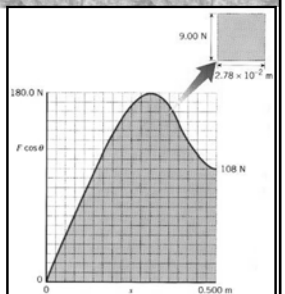
where the product of two vectors times the cosine of the angle between them is called the **Dot Product**.

## Example 1

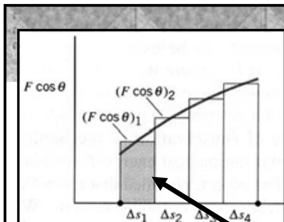


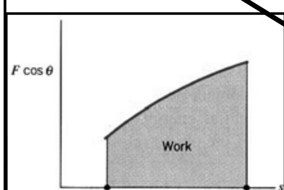

1)The truck shown above is dragging a stalled car up a 20° incline. The force in the tow line is constant, and the vehicles accelerate at a constant rate. If the cable makes an angle of 30° with the road and the force is 1600 N how much work was done by the truck on the car in pulling it 0.5 km up the incline.

## Work Due to a Varying Force




If the force doing the work is not constant then we can not use our definition of work.




To calculate the work due to a variable force we can plot the ***F cos$\theta$* .**VS. the direction (***s***).

We then can divide the distance into small segments $\Delta$s. For each segment, we can indicate the average of  by a ***F cos$\theta$*** horizontal line segment.

The work done for each segment is approximately the area of the rectangle.

The total work done is then the sum of the areas of all the rectangles.

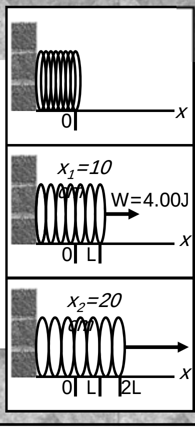
## Work as Area

If we let the distance get very small then the area under the curve will be equal to the work done as:

$$W = \lim_{\Delta x \to 0} \sum_{i=1}^{n} F(x_i)\cos\theta_i \Delta x_i = \int_{x_i}^{x_f} F(x)\cos\theta \, dx$$

So the work is the area under the curve of **(Force$\times$cos$\theta$)** .VS. **the Distance**.

## Example 2




2)If it takes 4.00J of work to stretch a spring 10.0 cm from its unstretched length, determine the extra work required to stretch it an additional 10.0 cm.

## Example 3

3)What is the work done on a 0.5 kg peach that starts at rest and is accelerated to a velocity of 10 m/s.

## Kinetic Energy

**Kinetic Energy** is the energy of motion

$$KE = \frac{1}{2}mv^2$$

The units for Kinetic Energy is the joule (J).

## The Work-Energy Theorem

The work done on the object will be equal to the change in kinetic energy.

$$W = KE_f - KE_i$$

## Example 4

4)A sled of mass *m* is given a kick on a frozen pond. the kick imparts to it an initial speed of *2.00 m/s*. The coefficient of kinetic friction between the sled and the ice is *0.100*. Using energy considerations, find the distance the sled moves before it stops.

## Why We Need Work

The Work-Energy theorem is the starting point for a sweeping generalization in physics.

We will compute separately the work done by certain types of forces and give a special name to the work done by each type.

This leads to the concepts of different types of energy and the principle of conservation of energy which as we will see is one of the most important principles of physics.

## We have the Power

**Power** is the rate at which work is done.

Average Power: $P = \dfrac{W}{\Delta t}$

Instantaneous Power $P = \lim_{\Delta t \to 0} \dfrac{W}{\Delta t} = \dfrac{dW}{dt}$

If the power is constant in time then the average and instantaneous power will be the same.

## Units of Power

The units of power are Work units divide by time units. $\dfrac{J}{s} = W \text{ (Watts)}$

## Example 5

5)A 700 N Marine in basic training climbs a 10.0 m vertical rope at a constant speed in 8.00 s. What is his power output.

## Clown's Need Physics Too

It would be nice to calculate how high the balls will travel with out having to apply Newton's Three Laws of Motion

## All Forces Can Do Work

The Work-Energy theorem states that the work done (**W**) by a resultant force (**F**) acting on a particle is equal to the change in Kinetic Energy (**ΔKE**) of the particle or:

$$W = \Delta KE$$

Often several forces act on a particle, the resulting force **F** being there vector sum.

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \cdots \vec{F}_n$$

The work done (**W**) by the resulting force **F** is the algebraic sum of the work done by these individual forces, or:

$$W = W_1 + W_2 + \cdots W_n$$

If there is no friction between the ball and the floor then the ball's initial ***KE*** and its final ***KE*** will be the same.

## Conservative Forces

The force that the spring exerted on the ball **Conserved** the KE of the ball.

If there is **Friction** between the ball and the floor then the final ***KE*** will be less then the initial ***KE***. So the ball's ability to do work has **not been conserved**.

So the frictional forces do not conserved the KE of the ball.

## Conservative Forces

A force is Conservative if the Kinetic Energy of a particle on which the force it acts returns to its initial value after any round trip.

A force is Nonconservative if the Kinetic Energy of a particle does not return to its initial value after any round trip.

## Conservative Forces Again

If there is no air resistance then the net work done by gravity on the baseball is zero for the round trip (up and back).

## Conservative Forces Again

If we also include the work done by air resistance we see that the work is no longer zero for the complete trip.

This is the second way to tell if a force is conservative or not.

## Conservative Forces -2nd Definition

A force is **Conservative** if the work done by the force on any particle that moves through any round trip is **zero**.

A force is **Nonconservative** if the work done by the force on any particle that moves through any round trip is **not zero**.

## Conservative Forces - One More Time

The Work done by a conservative force **does not depend on the path**, but only on the end points.

## Conservative Forces- 3rd and last Definition

A force is **Conservative** if the work done by it on a particle that moves between two points depends only on these points and not on the path.

A force is **Nonconservative** if the work done by it on a particle that moves between two points depends on the path taken between those two points.

## Potential Energy

In case of a conservative force it is useful to introduce the concept of **Energy of Configuration**, or **Potential Energy**.

## Potential Energy

We can now consider the spring and the ball as a system and say for this system that if the **Kinetic Energy** changes by **ΔKE** as the configuration of the system changes, then the **Potential Energy** (**PE**) must change by an equal but opposite amount so that the sum of the two changes is zero.

$$\Delta KE + \Delta PE = 0$$

or

$$KE + PE = \text{A Constant}$$

## Conservation of Mechanical Energy

Since the sum of **Potential** and **Kinetic Energy** is a constant for a closed system we can define the **Mechanical Energy** of the system as:

$$E = KE + PE = \tfrac{1}{2}mv^2 + U(x)$$

The Potential Energy PE=U(x) will have a different form depending on the associated conservative force.

## Conservation Of Mechanical Energy

Since E is constant even as the particle moves from position $X_0$ to position $X$ and the speed changes from $V_0$ to $V$ we can write:

$$\tfrac{1}{2}mv^2 + U(x) = \tfrac{1}{2}mv_0^2 + U(x_0)$$

This is the **Law of Conservation of Mechanical Energy** for conservative forces.

## Two Types of Potential Energy

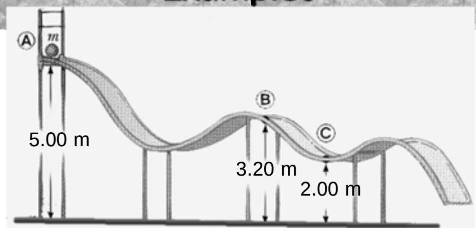
1)Gravitational Potential energy.

$$U(y) = mgy$$

2)Elastic Potential Energy (like a spring)

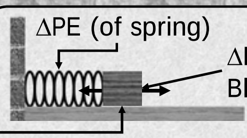
$$U(x) = \tfrac{1}{2}kx^2$$

## Example6




6)A particle of mass *5.00 kg* is released from point **A** and slides on the frictionless track shown above. Determine a) the particle's speed at the points **B** and **C** and b) the net work done by the force of gravity in moving the particle from **A** to **C**

## Conservation of Energy




For an isolated system:

$$\Delta KE + \Delta U + \Delta E_{\text{int}} = 0$$

The values of KE, U and $E_{int}$ might change for one or more objects within the isolated system, but their total for the system does not change.

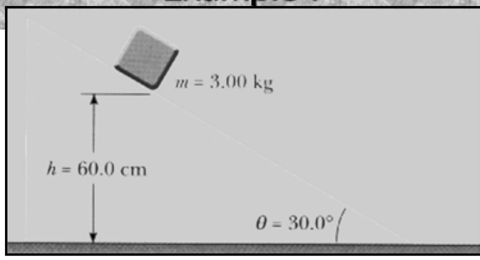
## Conservation of Energy

It turns out that in all physical situations we can always identify additional energy quantities like $E_{int}$ that permit us to expand the scope of our definition of energy and to retain in a more generalized form, the **Law of Conservation of Energy.**

$$\Delta KE + \Delta U + \Delta E_{\text{int}} + \left( \frac{\text{Changes in other}}{\text{Forms of Energy}} \right) = 0$$

**In an isolated system, energy can be transformed from one form to another, but the total energy of the system remains constant.**

## Example 7




7)The block above slides down the incline and onto the flat surface. If the coefficient of friction on both surfaces is *0.200*, how far does the block slide on the horizontal surface before coming to a stop?

## Summary of Chapter 7 and 8

- **Work:** $W = Fd\cos\theta$
- **Kinetic energy is energy of motion;** $\text{KE} = \frac{1}{2}mv^2$
- **Potential energy is energy associated with forces that depend on the position or configuration of objects.**
- $\text{PE}_{\text{grav}} = mgy$ elastic $\text{PE} = \frac{1}{2}kx^2$
- **The net work done on an object equals the change in its kinetic energy**
- **If only conservative forces are acting, mechanical energy is conserved**
- **Power is the rate at which work is done**