Introduction to Work:

**WORK** is defined as a change in energy. If work is positive it implies an increase in energy, if work is negative it implies a decrease in energy. Work, like energy, is a SCALAR and is measured in Joules (J).

In order to change the energy of a massive object we must either change its speed, and therefore its kinetic energy, or we must alter its position in order to change the potential energy of the system.

In either case the force must act over some displacement; the object must move. The force could cause an object to speed up or slow down, changing the kinetic energy. The force could lift an object up, or lower an object down, within a gravitational field, changing the gravitational potential energy. The force could compress or extend a spring. In any case *the force must have a component in the direction of motion*. We can find the work done by a particular force with a simple equation:

$$W=\vec{F}\_{||} \vec{d}= \vec{F} \vec{d}\_{||}$$

Notice that both **F** and **d** are vector in this equation. The subscript || means ‘parallel’, so we only consider the components of **F** and **d** that are parallel to one another. Because we are only considering parallel components this equation will be 1D and we can indicate direction with a + or a – sign.

*Example 1:*

 136N

 38o

3.40m

Find the work done by the force shown:

*Solution:*

 $W=\vec{F}\_{||} \vec{d}$ = 136N(cos(38o))(3.40m)= 364.3761725J

 W=360J

Above I have chosen left to be the positive direction as both **F**|| and **d** are left.

If I choose right as positive the solution will look like:

 $W=\vec{F}\_{||} \vec{d}$ = **-**136N(cos(38o))(**-**3.40m)= 364.3761725J

 W=360J

So I get the same result either way

*Example 2:*

 136N

 38o

3.40m

Find the work done by the force shown:

* Notice the displacement is in the opposite direction. Think about what this means; the object is traveling to the right with a force pulling it to the left. What will the object do?

*Solution:*

 $W=\vec{F}\_{||} \vec{d}$ = 136N(cos(38o))( **-** 3.40m)= **-** 364.3761725J

 W= **-** 360J

Above I have chosen left to be the positive direction to be consistent will example 1.

If I choose right as positive the solution will look like:

 $W=\vec{F}\_{||} \vec{d}$ = **-** 136N(cos(38o))( 3.40m)= **-** 364.3761725J

 W= **-** 360J

What does the negative on the work mean?

There is a slightly different form of the Work equation that looks like:

$$W=F d \cos(θ)$$

At first glance this may appear the same as what we did in example 1 and 2, but there is a key difference. In this form there are no vector signs. In this form F and d are MAGNITUDES and $θ $ is the angle between the vectors **F** and **d**. Let’s re-do examples 1 and 2 with this formula:

*Example 1:*

 136N

 38o

3.40m

Find the work done by the force shown:

*Solution:*

 W Fdcosθ= 136N (3.40m)(cos(38o))= 364.3761725J

 W=360J

I do not worry about directions, just magnitudes. The θ term handles the direction for me!

*Example 2:*

 136N

 38o

3.40m

Find the work done by the force shown:

 I know the answer should be negative from earlier, but how does the negative show up in the formula W=Fdcosθ ? It comes from the definition of θ. **F**

 142o

 **d**

 218o

There are two angles between **F** and **d**, 142o or 218o. We can choose either (convention is to use the smaller angle)

*Solution:*

 = 136N(cos(142o))(3.40m)= **-** 364.3761725J

 W= **-** 360J

What does the negative mean? Left? NOOOOO! Work is a SCALAR, remember?

The negative tells you that the force is taking energy away from the object. As the object moves to the right, the parallel (leftward) component of the force **slows the object down** and it **loses kinetic energy**.

Try it with θ=218o.

Try these:

 2.0kg

1. 31o

 26N

 27m

2.

 24o

125.0kg

 5.0N

 8.8m

3.

 2.0kg

 264N

 51o

 4.0m

4.

 66N

 19o

 6.0kg

 1.6m

5.

 2.0kg

3.1m

 23o

Find the work done by gravity as this object travels 3.1m down the ramp.

9.0m/s

6.

 2.0kg

 27o

The mass shown is sliding up the ramp at 9.0m/s. The force of friction on the mass is 8.50N.

As this object travels 2.0m up the ramp, find:

 A. The work done by gravity

 B. The work done by friction

 C. The work done by the normal force

 D. The sum of all work done the object

 E. The net work done to the object

 F. The $\sum\_{}^{}W$

7. Find the work done by each of the following forces. Show your work, including proper notation.

A. B. C.

45N

3.0m

45N

3.0m

45N

3.0m

49o

45N

3.0m

45N

3.0m

65N

D. E. F.

39o

49o

112N

14m

29o

1.1m

F2= 210N

31o

G. H. I.

F1= 17N

F2= 17N

3.0m

F3= 99N

F1= 128N

64o

12.0m

J. For QH and QI find the net work done to the object. (Wnet, ΣW).