

HW#8: Work and Energy (Due 11 pm **central time**, 11/4, Tuesday).

HW hint will be posted on course web (<http://web.njit.edu/~kenahn>)

Prof. Ahn will be on travel for a workshop during Nov. 6<sup>th</sup> - 9<sup>th</sup>.

Prof. George Georgiou will give the lecture on Nov. 7<sup>th</sup>, Friday.

So far, we studied

Exam 1: Vector, Units, 1D and 2D motions

Exam 2: Newton's Laws, Forces, Circular motions

Till Exam 3, we will learn

Energy and Work

**Today:**

**Work, Kinetic Energy, Work-Energy Theorem**  
**B1, Ch5 Sec.1-2, B2, Ch7 Sec.3**

Motivation: Why do we learn about work and energy???

Energy : Central concept in science and engineering  
... and in our daily lives...



Energy transforms from one type to other, but conserved.

In Physics 105, we learn about "Mechanical Energy".

3

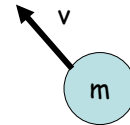
Kinetic energy

Kinetic energy (K.E.): An energy associated with motion

Kinetic energy of an object of mass  $m$  and speed  $v$

$$K.E. = K = \frac{1}{2}mv^2$$

→ Energy is a scalar quantity (No direction!)



SI Unit for energy: J (Joule)

$$J = kg \cdot \frac{m^2}{s^2} = kg \cdot \frac{m}{s^2} \cdot m = N \cdot m$$

4

$$K.E. = K = \frac{1}{2}mv^2$$

The heavier and the faster,  
the kinetic energy gets greater.

(KE of a fast baseball) vs (KE of a slow baseball) ?

(KE of a car at 60 mi/h) vs (KE of a trailer at 60 mi/h) ?

5

What makes kinetic energy change?

Special case: Constant  
Acceleration (1 D motion)

Remember result  
eliminating  $t$ :

$$v^2 - v_0^2 = 2a(x - x_0)$$

Multiply by  
 $\frac{1}{2}m$ :

$$\left(\frac{1}{2}mv^2\right) - \left(\frac{1}{2}mv_0^2\right) = ma(x - x_0)$$

$$= ma\Delta x$$

But  
 $F_{net} = ma$

$$\Delta\left(\frac{1}{2}mv^2\right) = \underline{F_{net} \Delta x}$$

defined as "Net Work",  $W_{net}$ , in 1D

Change in kinetic energy is equal to the "net work"!

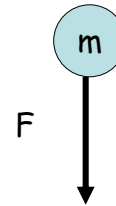
6

Definition of work by a force in 1D:

$$W_F = F \Delta x$$

(Work) = (Force) x (Displacement)

**Work** done **by** a force **F** **on** an object, the displacement of which is  $\Delta x$  .



7

iClicker Quiz 1

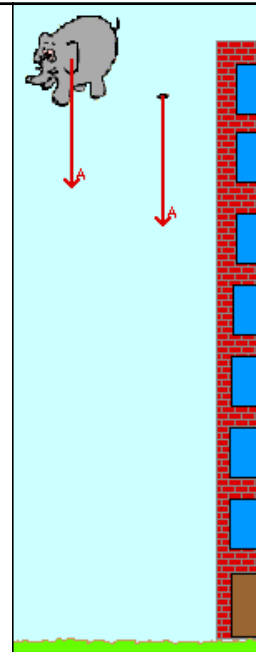
Work done by a gravity on a falling elephant

$$W = F \Delta x$$

is \_\_\_\_\_.

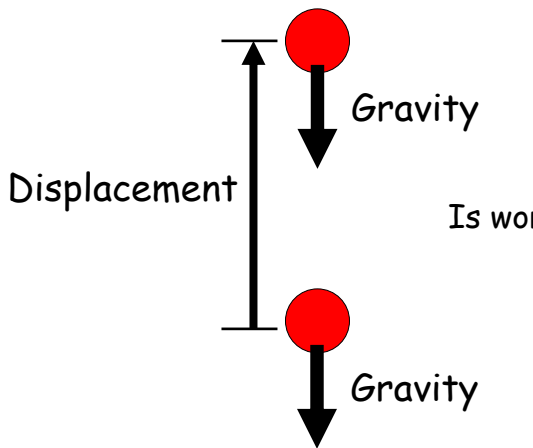
- a) Positive
- b) Negative
- c) zero

If force and displacement point the same direction, the work is \_\_\_\_\_.



8

iClicker Quiz2: Work done by a gravity on a ball that is going up



$W = F \Delta x$

Is work positive, negative, zero?

- a) Positive
- b) Negative
- c) zero

If force and displacement point the opposite directions, the work is \_\_\_\_\_.

9

### Work-Energy Theorem

As shown for 1D motion,

$$K_f - K_i = \Delta K = W_{net}$$

→ Work-Energy Theorem

Positive net work: KE increases (iClicker Quiz 1)

Negative net work: KE decreases (iClicker Quiz 2)

10

### Example 1: Falling elephant

11

For 2D, 3D motion...

Kinetic energy

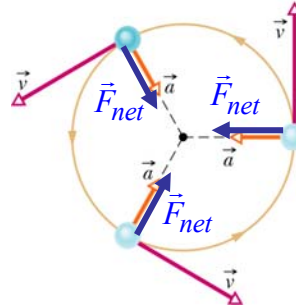
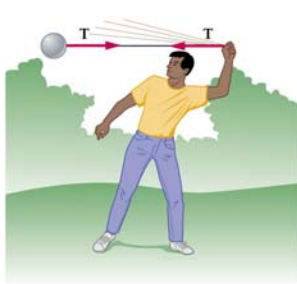
$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}m(v_x^2 + v_y^2 + v_z^2)$$

12

## Work in 2D and 3D

What if force and displacement are *perpendicular*?

Example: Uniform circular motion



No change in speed (magnitude of velocity)  
 → No kinetic energy change → No net work !

13

Displacement



positive work

Force

Displacement



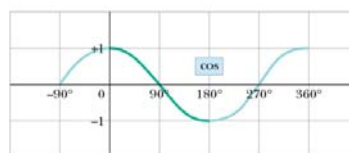
zero work

Displacement



negative work

Work



Cos !

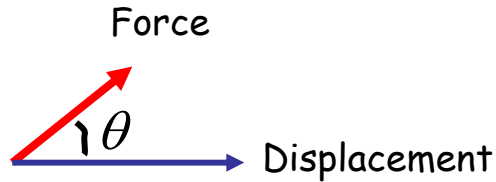
Angle bet./Disp. & Force

14

### Work done by a constant force

$$W = \underbrace{|\vec{F}|}_{\text{magnitude}} \underbrace{|\vec{d}|}_{\text{magnitude}} \cos \theta_{F,d} \equiv \underline{\vec{F} \cdot \vec{d}}$$

Scalar (dot) product  
(B2, Ch7, Sec.3)



15

### Math Review: Scalar (dot) product

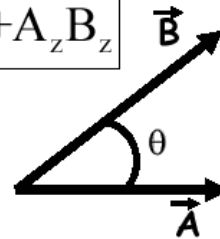
$$\vec{A} \cdot \vec{B} = \underline{|\vec{A}| |\vec{B}|} \cos \theta_{A,B} = A_x B_x + A_y B_y + A_z B_z$$

$$\theta = 180^\circ \rightarrow \vec{A} \cdot \vec{B} = -|\vec{A}| |\vec{B}|$$

$$\theta = 0 \rightarrow \vec{A} \cdot \vec{B} = +\underline{|\vec{A}| |\vec{B}|}$$

$$\theta = 90^\circ \rightarrow \underline{\vec{A} \cdot \vec{B} = 0}$$

$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}, \quad (\vec{A} + \vec{B}) \cdot \vec{C} = \vec{A} \cdot \vec{C} + \vec{B} \cdot \vec{C}$$



16

Examples for work in 2D

Example 1: Forces along different directions

Example 2: Work, scalar product, angle