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. 6th - 9th.

Prof. George Georgiou will give the lecture on Nov. 7th, Friday.

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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".

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**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)

\[ J = kg \cdot \frac{m^2}{s^2} = kg \cdot \frac{m}{s^2} \cdot m = N \cdot m \]
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)?

What makes kinetic energy change?

Special case: Constant Acceleration (1 D motion)

Remember result eliminating \( t \):
\[
\frac{v^2}{2} - \frac{v_0^2}{2} = 2a(x - x_0)
\]

Multiply by \( \frac{1}{2} m \):
\[
\frac{1}{2} mv^2 - \frac{1}{2} mv_0^2 = ma(x - x_0)
\]

But
\[
F_{net} = ma, \quad \Delta (\frac{1}{2} mv^2) = F_{net} \Delta x
\]

Change in kinetic energy is equal to the "net work"!
Definition of work by a force in 1D:

\[ W_F = F \Delta x \]

\[ \text{(Work)} = \text{(Force)} \times \text{(Displacement)} \]

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

**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 in the same direction, the work is ________.
iClicker Quiz 2: Work done by a gravity on a ball that is going up

Gravity

Displacement

Gravity

\[ W = F \Delta x \]

Is work positive, negative, zero?

a) Positive  

b) Negative  

c) zero

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

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)
Example 1: Falling elephant

For 2D, 3D motion...

Kinetic energy

\[ K.E. = \frac{1}{2}mv^2 = \frac{1}{2}m(v_x^2 + v_y^2 + v_z^2) \]
**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!
Work done by a constant force

\[ W = |\vec{F}| \cdot |\vec{d}| \cos \theta_{F,d} = \vec{F} \cdot \vec{d} \]

\[ \text{Scalar (dot) product} \]

\( (B2, \text{Ch7, Sec.3}) \)

Math Review: Scalar (dot) product

\[ \vec{A} \cdot \vec{B} = |\vec{A}| \cdot |\vec{B}| \cos \theta_{\vec{A},\vec{B}} = A_xB_x + A_yB_y + A_zB_z \]

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

\[ \theta = 0 \quad \rightarrow \quad \vec{A} \cdot \vec{B} = +|\vec{A}| \cdot |\vec{B}| \]

\[ \theta = 90^\circ \quad \rightarrow \quad \vec{A} \cdot \vec{B} = 0 \]

\[ \vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}, \quad (\vec{A} + \vec{B}) \cdot \vec{C} = \vec{A} \cdot \vec{C} + \vec{B} \cdot \vec{C} \]
Examples for work in 2D

Example 1: Forces along different directions

Example 2: Work, scalar product, angle