Past HW solutions are available at HW website.

http://geocities.com/kenahn7

HW #7 due: March 23, Friday, tomorrow

Good news: We will curve!

So far, we learned
  Vector, Units: Ch.1, Ch.3
  Motion: Ch.2, Ch.4
  Force: Ch.5, Ch.6 (+circular motion)

During the next 3 weeks, we learn
  Energy and Work: Ch.7, Ch.8

Ch.7, Kinetic Energy and Work
Ch.8, Potential Energy and Conservation of Energy
ENERGY

Energy is a property of the state of an object.

Energy is a scalar quantity. It does not have a direction associated with it.
Kinetic Energy

Kinetic Energy = Energy of motion

\[ K = \frac{1}{2}mv^2 \]  for object moving with velocity \( v \)

Note:  \( J = kg \cdot \frac{m^2}{s^2} \cdot m = N \cdot m \)  (Joule)

Kinetic Energy: Orders of Magnitude

\[ K = \frac{1}{2}mv^2 \]  for object moving with velocity \( v \)

- Earth orbiting sun:  \( 2 \times 10^{29} \) J
- Car at 60 mph:  \( 100,000 \) J
- Fast flying baseball:  \( 300 \) J
- Professor walking:  \( 40 \) J
- Angry bee:  \( 0.005 \) J
Why $K = \frac{1}{2}mv^2$?

It's good that $K = \frac{1}{2}mv^2$, not $mv^2$....

**Special case: Constant Acceleration**

- $v$ vs. $x$:
  \[
  v^2 - v_0^2 = 2a(x - x_0)
  \]

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

- But $F = ma!$
  \[
  \Delta \left( \frac{1}{2}mv^2 \right) = F \Delta x
  \]
What is so special about 
\[ F \Delta x = (\text{Force}) (\text{Displacement}) \] 

Example: 
Gravitational force & Projectile motion

Force increases Kinetic energy in *this* case. 
Why do we need displacement? 
Does force always increase kinetic energy?

A ball thrown up

Displacement

Gravitational force

If the displacement is opposite to the force, the kinetic energy decreases!
Both *Force & Displacement* are important!
Why \( K = \frac{1}{2}mv^2 \)?

**Special case: Constant Acceleration**

\[ v^2 - v_0^2 = 2a(x - x_0) \]

Multiply by \( \frac{1}{2}m \):

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

\[ = ma\Delta x \]

But \( F=ma \)!

\[ \Delta\left(\frac{1}{2}mv^2\right) = F\Delta x \]

“Work”, \( W \), in 1D

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**Work in 2D and 3D**

What if force and displacement are **perpendicular**?

**Example: Uniform circular motion**

No change in “magnitude” of velocity

\( \rightarrow \) No kinetic energy change \( \rightarrow \) No work, sorry!

(Velocity does change, because the “direction” changes.)
Displacement  
\[ \text{positive work} \]

Force  
\[ \text{Displacement} \]
\[ \text{zero work} \]

Force  
\[ \text{Displacement} \]
\[ \text{negative work} \]

Work vs. Disp.-Force angle  
\[ \cos! \]

Force and Displacement with an angle
Work done by a constant force

\[ W = Fd \cos \theta \equiv \vec{F} \cdot \vec{d} \]

Note: \( F \cos \theta \) is component of force along displacement
\( d \cos \theta \) is component of displacement along force

Scalar (dot) product
(Ch.3, Sec.8)

Work–kinetic energy theorem

If work is done on an object, \( W = Fd \cos \theta \equiv \vec{F} \cdot \vec{d} \), kinetic energy,

\[ K = \frac{1}{2}mv^2 \quad \left( J = \text{kg m}^2/\text{s}^2 \right) \], changes by

\[ \Delta K = K_f - K_i = W \]
Scalar(dot) product

\[ \vec{A} \cdot \vec{B} = AB \cos \theta = A_x B_x + A_y B_y + A_z B_z \]

\[ \theta = 0 \rightarrow \vec{A} \cdot \vec{B} = AB \]

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

Dot product measures how much vectors are along each other

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

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Work Done by a Gravitational Force

Work done by gravitational force

\[ W_g = mgd \cos \theta \]

Tomato thrown upward

\[ W_g < 0 \quad W_g > 0 \]

Lifting/lowering an object

Change in kinetic energy:

\[ \Delta K = K_f - K_i = W_a + W_g \]
A tomato thrown up

\[ F_g = mg \]

Gravitational force

Work done by gravitational force

\[ W_g = mgd \cos \theta = -mgd = K_f - K_i = \frac{1}{2} mv^2 - \frac{1}{2} mv_0^2 \]

A tomato falling down

\[ F_g = mg \]

Gravitational force

Work done by gravitational force

\[ W_g = mgd \cos \theta = mgd = K_f - K_i = \frac{1}{2} mv^2 - \frac{1}{2} mv_0^2 \]
Work done in lifting an object

Work done by \textit{weightlifter} on weight:
\[ W_{\text{Lifter}} = F_{\text{Lifter}} d \cos \theta = mgh \]

Work done by \textit{gravity} on weight:
\[ W_g = F_g d \cos \theta = -mgh \]

Net work
\[ = W_{\text{Lifter}} + W_g = K_f - K_i \]

If multiple forces are applied on an object,

\[ W_{\text{total}} = \vec{F}_{\text{net}} \cdot \vec{d} = (\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots) \cdot \vec{d} \]
\[ = \vec{F}_1 \cdot \vec{d} + \vec{F}_2 \cdot \vec{d} + \vec{F}_3 \cdot \vec{d} + \ldots = W_1 + W_2 + W_3 + \ldots \]
\[ = K_f - K_i = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \]
Example (Somewhat related to HW#9-Prob.1)

\[ F = T = 10 \text{ N} \]

2 kg

\( \theta = 30^\circ \)

d = 5 m

Frictionless surface

a. Find the forces on the box.
b. Find the work by each force.
c. Find the total work
d. If initial velocity is zero, what is the final velocity?

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**Homework Help!!**

001 (part 1 of 1) 10 points

Given: \( g = 9.8 \text{ m/s}^2 \).

Your teacher placed a 3 kg block at the position marked with a “+” (horizontally, 0.5 m from the origin) on a large incline outlined on the graph below and let it slide, starting from rest.

The kinetic coefficient of friction for the block on the incline is 0.91.

Calculate the horizontal distance from the bottom edge (right-hand edge) of the incline to where the block hits the floor (i.e., \( y = 0 \)). Answer in units of \( \text{N} \). Your answer must be within \( \pm 2\% \).

Analyze the motion in two parts.

Velocity at right edge is initial velocity for projectile motion.
002 (part 1 of 2) 10 points
A car is traveling at 66.6 mi/h on a horizontal highway. The acceleration of gravity is 9.8 m/s².
If the coefficient of friction between road and tires on a rainy day is 0.068, what is the minimum distance in which the car will stop? (1 mi = 1.609 km) Answer in units of m.

003 (part 2 of 2) 10 points
What is the stopping distance when the surface is dry and μ_{dry} = 0.59? Answer in units of m.

See Sample Prob 6-1, studied during class.

004 (part 1 of 2) 10 points
A 1.67 kg block is placed on top of a 6.03 kg block. The coefficient of kinetic friction between the 6.03 kg block and the surface is 0.28. A horizontal force \( F \) is applied to the 6.03 kg block. The acceleration of gravity is 9.8 m/s².
Calculate the magnitude of the force necessary to pull both blocks to the right with an acceleration of 3.69 m/s². Assume no slipping between the two blocks. Answer in units of N.

Two blocks moving together → Treat like big one block

Ah...tough one
Focus on upper block.
Net force on it should be the static friction.

005 (part 2 of 2) 10 points
Find the minimum coefficient of static friction \( \mu_s \) between the blocks such that the 1.67 kg block does not slip under an acceleration of 3.69 m/s².
**006 (part 1 of 2) 10 points**
The coefficient of static friction between the person and the wall is 0.69. The radius of the cylinder is 5.34 m.
The acceleration of gravity is 9.8 m/s².
An amusement park ride consists of a large vertical cylinder that spins about its axis fast enough that any person inside is held up against the wall when the floor drops away.

\[ \omega = \frac{2\pi}{T} \]

Angular velocity

\[ v = \frac{2\pi r}{T} = \omega r \]

Velocity

What is the minimum angular velocity \( \omega_{\text{min}} \) needed to keep the person from slipping downward? Answer in units of rad/s.

**007 (part 2 of 2) 10 points**
Suppose the person, whose mass is \( m \), is being held up against the wall with an angular velocity of \( \omega' = 2\omega_{\text{min}} \).
The magnitude of the frictional force between the person and the wall is

**See Sample Prob 6-8**

**Period**

\[ T = \frac{2\pi r}{v} \]

**Angular velocity**

\[ \omega = \frac{2\pi}{T} \]

**Velocity**

\[ \frac{2\pi r}{T} = \omega r \]

**008 (part 1 of 2) 10 points**
A small metal ball is suspended from the ceiling by a thread of negligible mass. The ball is then set in motion in a horizontal circle so that the thread describes a cone.
The acceleration of gravity is 9.8 m/s².

\[ g = 9.8 \text{ m/s}^2 \]

Tension and Gravitational force acting on the ball.

Net force should be centripetal force, pointing horizontally to the center of circle.

What is the speed of the ball when it is in circular motion? Answer in units of m/s.

**009 (part 2 of 2) 10 points**
How long does it take \( T_{\text{period}} \) for the ball to rotate once around the axis? Answer in units of s.

**Period**

\[ T = \frac{2\pi r}{v} \]
Don’t give up!

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http://geocities.com/kenahn7

Private tutoring
Visit my office

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