Seating for PHYS 1020 Midterm
Thursday, October 22
7 - 9 pm

Seating is by last name

Room	From	To
111 Armes	A	BJ
200 Armes	BL	GA
201 Armes	GH	KH
204 Armes	KI	OB
205 Armes	OK	SA
208 Armes	SC	Z

20 multiple choice questions, ch 1-5. Formula sheet provided.

This Week
Experiment 2:
Measurement of g by Free Fall

WileyPLUS Assignment 2

Due Monday, October 19 at 11:00 pm

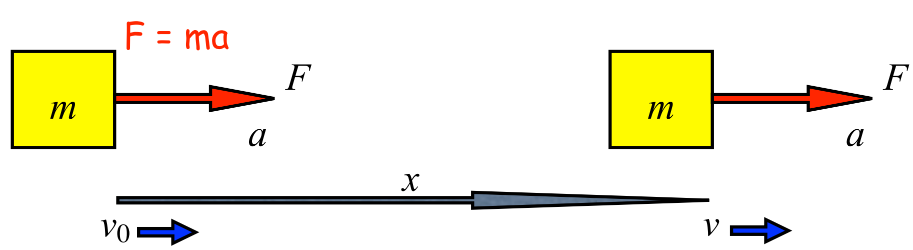
Chapters 4 & 5

Chapter 6: Work and Energy

- Work done by a constant force
- Work-energy theorem, kinetic energy
- Gravitational potential energy
- Conservation of mechanical energy
- Conservative and non-conservative forces
- Work-energy theorem and non-conservative forces
- Power
- Work done by a variable force

Work and Energy

Apply a constant force F to a mass m over a distance x



$$v^2 = v_0^2 + 2ax \quad \text{and } a = F/m \text{ Newton's second law}$$

$$\text{So, } v^2 = v_0^2 + 2(F/m)x$$

$(\times m/2)$

$$Fx = \frac{mv^2}{2} - \frac{mv_0^2}{2}$$

Work done = change in kinetic energy: **Work-Energy theorem**

$$\boxed{Fx = \frac{mv^2}{2} - \frac{mv_0^2}{2}}$$

Fx = "work" done by the force = force × displacement

The work changes the speed of the mass, increasing its *kinetic energy*

Initial kinetic energy: $KE_0 = mv_0^2/2$

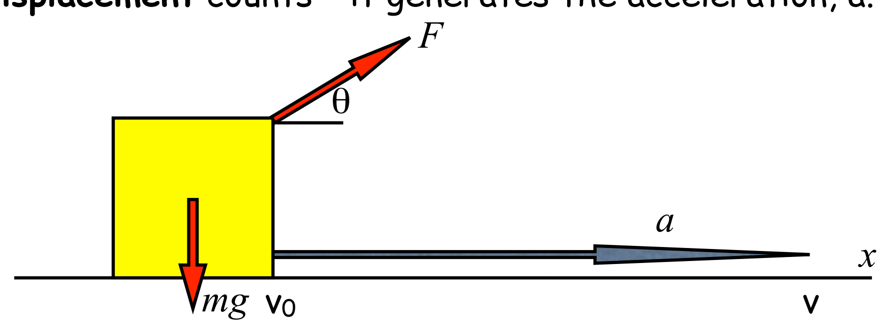
Final kinetic energy: $KE = mv^2/2$

$\boxed{\text{Work done } W = KE - KE_0 = \Delta KE}$

$\boxed{\text{Unit of work and energy: Joule (J)}}$ $\boxed{1 \text{ J} = 1 \text{ N.m}}$

Work

Only the component of the force **in the direction of the displacement** counts – it generates the acceleration, a.



$a = F_x/m = F\cos\theta/m$

So, $v^2 = v_0^2 + 2(F\cos\theta/m)x \quad \rightarrow \quad Fx\cos\theta = mv^2/2 - mv_0^2/2$

$\boxed{\text{Work done}, W = Fx\cos\theta = \Delta KE}$ **Work-Energy Theorem**

$\boxed{\text{Work done = (force in direction of displacement) × (displacement)}}$

Clicker Question: Focus on Concepts, Question 1

The same force F pushes in three different ways on a box moving the same distance at a velocity **v**, as the drawings show. Rank the work done by the force F in ascending order (smallest first).

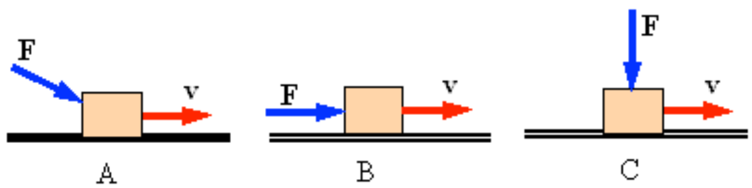
A) A, C, B

B) C, B, A

C) B, A, C

D) C, A, B

E) A, B, C



D) C, A, B: the work done is the **force in the direction of the displacement** multiplied by the displacement

Clicker Question: Focus on Concepts, Question 7

A nonzero net force acts on a particle and does work. Which one of the following statements is true?

A) The kinetic energy and the speed of the particle change, but the velocity of the particle does not change.

B) The kinetic energy of the particle changes, but the velocity of the particle does not change.

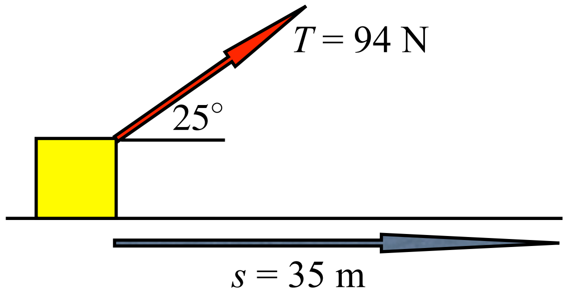
C) The kinetic energy, speed, and velocity of the particle change.

D) The kinetic energy of the particle changes, but the speed of the particle does not change.

E) The kinetic energy of the particle does not change, but the speed of the particle does change.

C) Everything changes

6.6/4: How much work to pull the toboggan 35 m?



$$W = Ts\cos\theta$$

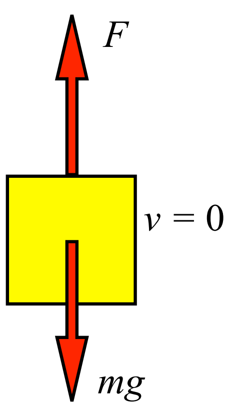
$$W = (94\ \text{N}) \times (35\ \text{m}) \times \cos 25^\circ = 2980\ \text{J}$$

How much work if the rope is horizontal?

$$W = (94\ \text{N}) \times (35\ \text{m}) \times \cos 0^\circ = 3290\ \text{J}$$

Note: The force is more effective when applied horizontally.

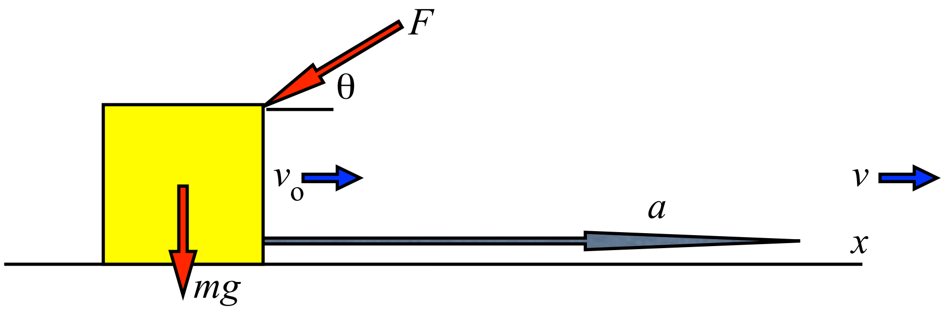
Work and Energy



No work is done in holding an object at rest:

- no displacement, no work
- also no net work in lifting an object up, then returning it to its starting point as the **net displacement is zero**

Negative Work



$$a = -F\cos\theta/m, \qquad v^2 = v_0^2 + 2ax$$

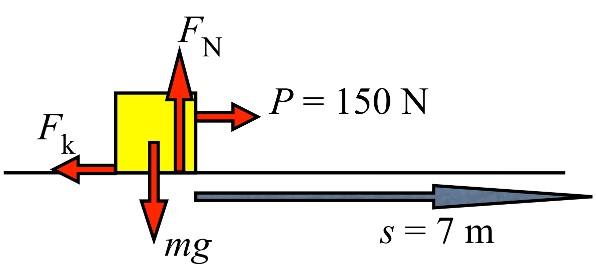
So, $v^2 = v_0^2 - 2(F\cos\theta/m)x$

Work done by force, $W = \dfrac{mv^2}{2} - \dfrac{mv_0^2}{2} = -Fx\cos\theta = \Delta KE$

where force in direction of displacement $= -F\cos\theta$

The force does "negative work".

6.10/10: A 55 kg box is pulled 7 m across the floor.



$\mu_k = 0.25$

How much work is performed by each of the 4 forces?

$\boldsymbol{P}$: $W = Ps = (150\text{ N})\times(7\text{ m}) = 1050$ J

$\boldsymbol{F_N}$: $W = F_N\times(\cos 90^o)\times(7\text{ m}) = 0$

Force at right angles to displacement

$\boldsymbol{mg}$: $W = mg\times(\cos 90^o)\times(7\text{ m}) = 0$

$\boldsymbol{F_k}$: $W = -F_k\times(7\text{ m}) = -\mu_k\, mg\times(7\text{ m}) = -943$ J

($W = F_k \cos 180^o \times 7 = -F_k \times 7$)

Clicker Question: Focus on Concepts, Question 11

A person is riding on a Ferris wheel. When the wheel makes one complete turn, the net work done on the person by the gravitational force:

A) depends on how fast the wheel moves

B) depends on the diameter of the wheel

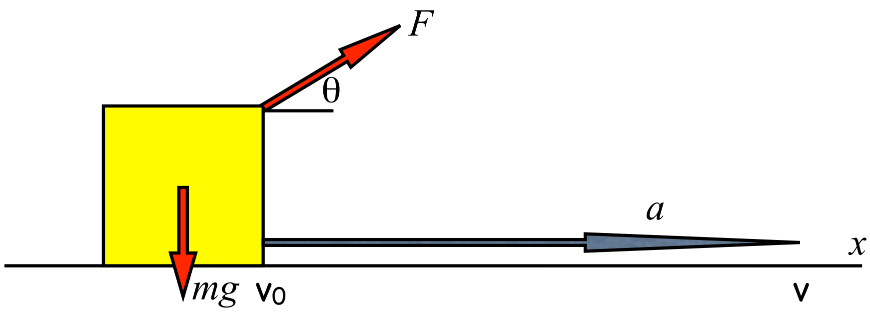
C) is positive

D) is negative

E) is zero

E) The net displacement is zero, so the work done by the gravity force is zero

Work-Energy Theorem

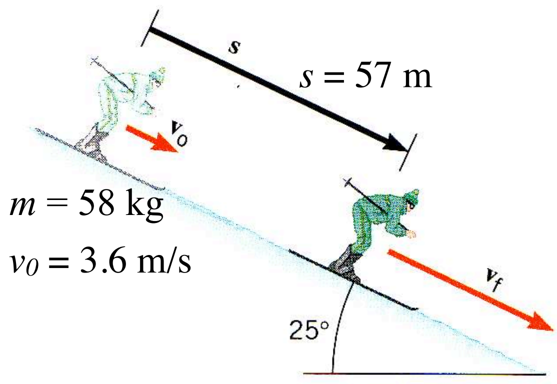


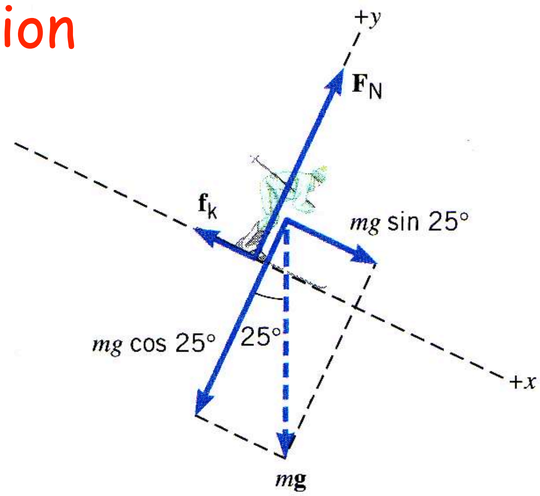
$$\text{Work done, } W = Fx\cos\theta = \frac{mv^2}{2} - \frac{mv_0^2}{2} = \Delta KE$$

Work done = (force in direction of displacement) × (displacement) = ΔKE

Unit of work: 1 Joule (J) = 1 N.m

Friction





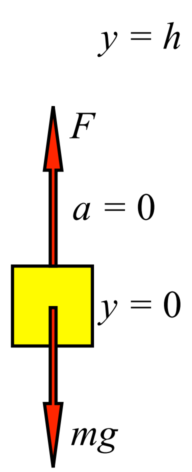
Free body diagram

A friction force f_k = 70 N acts on the skis.
Initial speed, v_0 = 3.6 m/s
Find final speed, v_f , after skiing 57 m down the slope

Work-energy theorem: W = F_{net} x displacement = ΔKE

F_{net} = net force down the slope = mg $\sin 25^0$ - f_k

Work done in lifting an object



A force F lifts the mass at constant speed through a height h - there is no change of kinetic energy.

The displacement is h, upward.

The applied force in the direction of the displacement is:

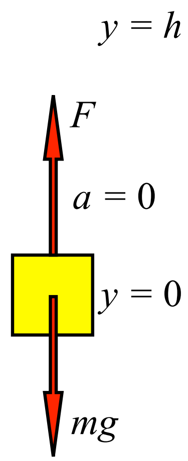
F = mg (no acceleration)

The work done by the force F is:

W = Fh = mgh

But the kinetic energy has not changed – the gravity force mg has done an equal amount of negative work so that the net work done on the mass by all forces (F and mg) is zero.

Work done in lifting an object



Alternative view: define a different form of energy –

Gravitational potential energy, PE = mgy

Define:

Mechanical energy = kinetic energy + potential energy

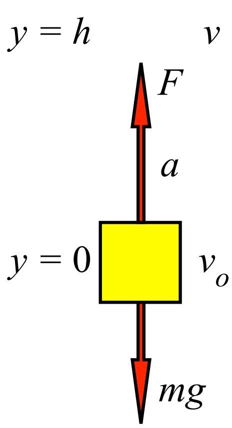
Mechanical energy, E = $mv^2/2$ + mgy

Then:

Work done **by applied force**, F, is (change in KE) + (change in PE)

So $W = Fh = \Delta \mathrm{KE} + \Delta \mathrm{PE}$

Check, using forces and acceleration



Net upward force on the mass is F – mg

Apply Newton's second law to find the acceleration:

F – mg = ma,   (F is any upward force)

so, a = (F – mg)/m

One of famous four equations –

$$v^2 = v_0^2 + 2ah$$

$$\text{So, } v^2 = v_0^2 + \frac{2(F - mg)h}{m}$$

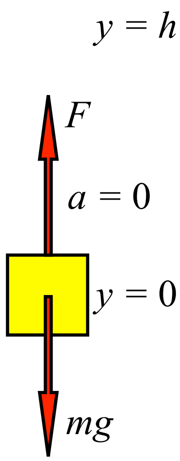
$(\times m/2)$

$$\frac{mv^2}{2} - \frac{mv_0^2}{2} = Fh - mgh$$

That is, $\Delta KE = Fh - \Delta PE$

$\boxed{\text{Or, } W = Fh = \Delta KE + \Delta PE}$

Two viewpoints



1) A net upward force (F - mg) does work and moves the mass upward and changes its **kinetic energy**:

$$(F - mg) \times h = \Delta KE \qquad \text{(work-energy theorem)}$$

2) An **applied force F** does work and changes the **mechanical energy** of the mass:

$$W = Fh = \Delta KE + mgh = \Delta KE + \Delta PE$$

The second is more powerful as it can be turned into a general principle that:

Work done by applied force = change in mechanical energy

If no work is done, then mechanical energy is conserved!

$$\boxed{W = Fh = \Delta KE + \Delta PE}$$

If there is no **external** force, W = 0 and

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

so that $\Delta KE = -\Delta PE$

As a mass falls and loses potential energy, it gains an equal amount of kinetic energy.

Potential energy is converted into kinetic.

Energy is conserved overall.

Conservation of Mechanical Energy

In the absence of applied forces and friction:

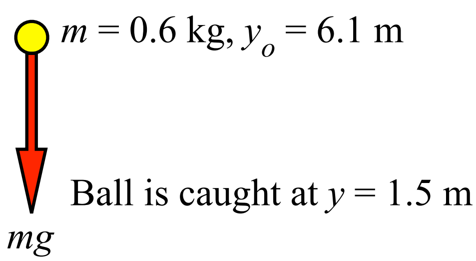
Work done by applied force = 0

So, 0 = (change in KE) + (change in PE)

And KE + PE = E = mechanical energy
= constant

Other kinds of potential energy:
- elastic (stretched spring)
- electrostatic (charge moving in an electric field)

6.33/28



a) Work done on ball by its weight?

Weight force is in same direction as the displacement so,

Work = mg × displacement = 0.6g × (6.1 - 1.5 m) = 27 J

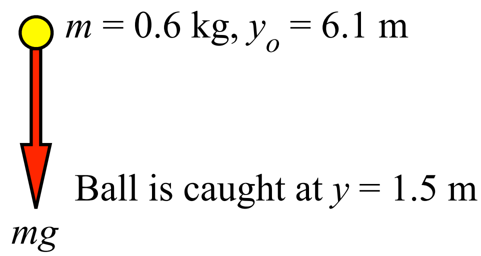
b) PE of ball relative to ground when released?

PE = mgy_o = 0.6g × (6.1 m) = 35.9 J

c) PE of ball when caught?

PE = mgy = 0.6g × (1.5 m) = 8.8 J

From last page:



b) PE of ball when released = mgy_o = 35.9 J

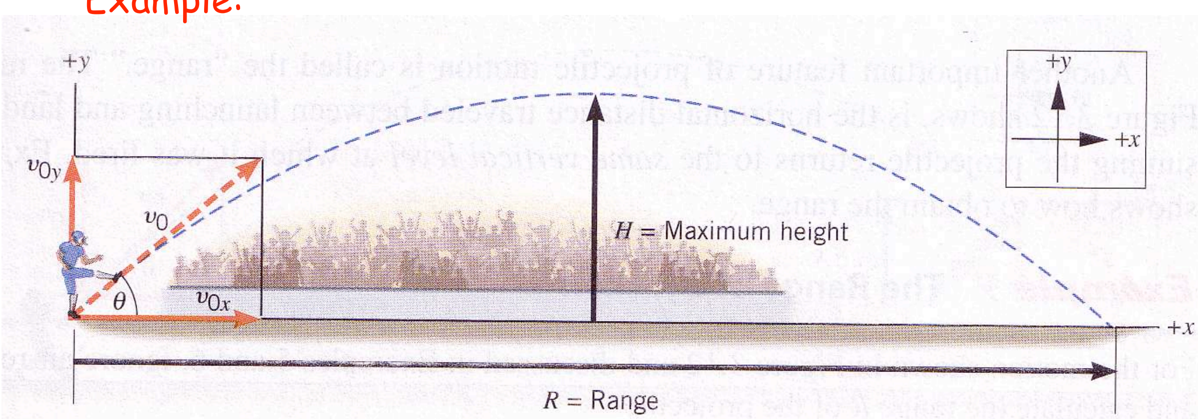
c) PE of ball when caught = mgy = 8.8 J

d) How is the change in the ball's PE related to the work done by its weight?

Change in PE = $mg(y - y_o)$ (final minus initial)

Work done by weight = mg ×(displacement) = $mg(y_o - y) = -\Delta$PE

Example:



No applied (i.e. external) forces

$E = KE + PE$ = constant

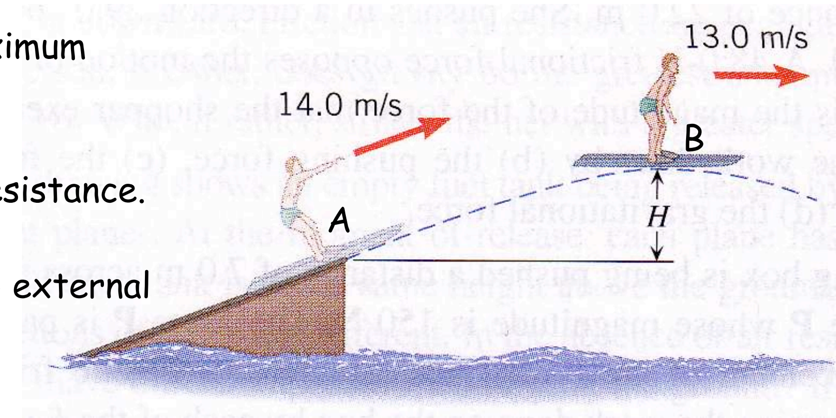
$KE = mv^2/2$
$PE = mgy$

So $E = mv^2/2 + mgy$ = constant, until the ball hits the ground

Find the maximum height, H.

Ignore air resistance.

There are no external forces.



Conservation of mechanical energy: KE + PE = constant

At take-off, at A, set $y = 0$: $E = mv_0^2/2 + 0$

At highest point, at B, $y = H$: $E = mv^2/2 + mgH$

So, $E = mv_0^2/2 = mv^2/2 + mgH$

$$H = \frac{(v_0^2 - v^2)/2}{g} = \frac{(14^2 - 13^2)/2}{9.8} = 1.38 \text{ m}$$