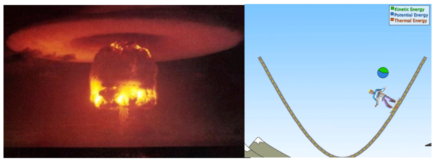
Energy, Work, Power



Can I use the same physics principles to describe these two rather different phenomena?

Class 9:
- Conservation of energy
- Work = Force ×distance
- Gravitational Potential Energy

Reminders:
Reading quiz Thurs
HW due next week

Vote: nukes or sound/music?

Class Resources

Class website:
- lecture notes (pre / post)
- link to video of these lectures
- reading assignments, hw assignments, calendar
- simulations
- feedback

D2L:
- HW solutions (and assignments)
- HW you turned in / scored
- Exam solutions

Help Room (me, TA, LAs)

Office Hours

Book

Each other

Energy and Work

- **New topic –**
- **What do you know of Energy and Work?**

Conservation of energy:

Energy and Work

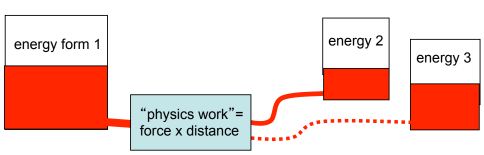
Very useful tool in physics

Conservation of energy:
Energy is never created or destroyed, just converted from one form to another

Provides alternative (easier) way to answer mechanics problems
e.g. how fast will ball travel if dropped,
how far will my car take to stop when braking, etc
without *ever* worrying about details of forces or what happens in between!

Energy and Work

Conservation of energy: Energy is never created or destroyed, it is just converted from one form to another



Work can "pump" from one form of energy to another.
Conservation of Energy:
Amount gained or lost from 1 = amount lost or gained from 2 and 3

Amount of work done = Amount of energy converted
= Force applied ×Distance moved in direction of force

Units: Energy and work have units of Joules (J)

Energy conservation – background ideas

What do we mean by conserved?
How do we decide something is conserved?
How is this a useful concept?
Work with these ideas every day-- money.

- You give your friend money – she has more and you have exactly that amount less. There is still the same amount money in the world.
- Put money in into bank in one form- quarters, Get out money in other form ($20 bills).
  - Is there a connection between in and out?
  - How do you know what it is?

Energy conservation – background ideas

Move to tropical island
Currency = coconuts (tied to dollar).
Now putting in dollars to local bank, getting out coconuts
Is bank any good? Is number of coconuts out connected with dollars in?

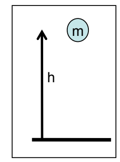
What experiments could you do to check?

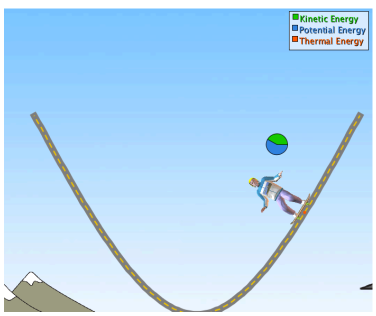
a. try converting $50 several times into coconuts, see if number is same.
b. try converting i) $100 dollars and then ii) 10$ dollars to coconuts, see if ratio with $50 is x2 in case (i) and and 1/5 in case (ii)?
c. convert $20 to coconuts and back see if $20.
d. no way to tell except asking natives.
e. a. and b. and c.

Energy conservation – background ideas

Energy conservation is useful for similar reasons:
- Don't have to know details of how energy is converted from one form to another
- Just know that SAME amount of energy put in in form 1 comes out in form 2 i.e. conversion factor is 1.
- Can do a bunch of experiments to check this

Different forms of energy:
- gravitational potential = mass x g x height
- spring potential = ½ × spring constant × (amount stretched)^2
- kinetic = ½ mass x speed^2
- thermal = constant x temperature





http://phet.colorado.edu/en/simulation/energy-skate-park-basics

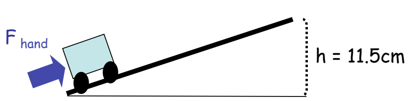
Today we'll look at ramps:

Compare pushing carts up short steep ramps and longer flatter ones:
- How does the pushing force compare?
- How does the work done compare?
- How fast will it be moving if it gets lose and rolls down?

- Work (connection between forces and work)
- Conservation of energy
- Gravitational PE
- Kinetic Energy

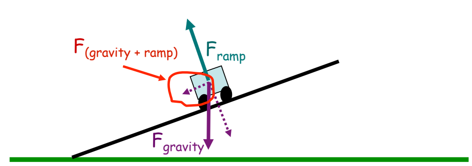
Work done pushing car up ramp

Push frictionless cart up 2 m ramp with constant force at constant velocity.



If I push cart up ramp at constant velocity, force applied by hand is:
a. greater than the weight (=mg) of the car
b. less than the weight of the car
c. the same as the weight of the car

Forces in 2 dimensions



$F_{gravity}$= weight = mg
- Acts straight down
 ⇒ part acts along the ramp
 ⇒ part acts ⊥ to the ramp.
- Part that acts ⊥ canceled by F_{ramp}.

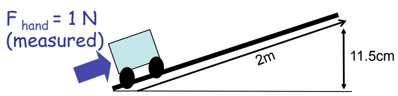
F_{ramp}
Force from ramp is like spring flexing … can only push ⊥ to it's surface.

Often called a 'normal' force

(Friction force would act parallel to surface)

Work done pushing car up ramp

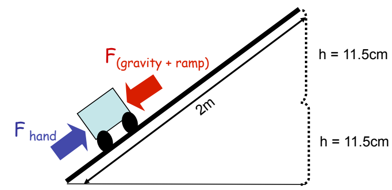
How much "work" (force applied x distance moved in direction of force) did I have to do to push cart up ramp a distance of 2 m at a constant velocity?



a. 0.5 J b. 1 J c. 2 J d. 10 J
e. impossible to tell from this data

Work done pushing car up ramp

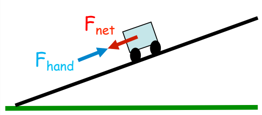
Now double the height of the ramp (keeping ramp length constant)



If ramp is **twice as steep**, force applied by hand to push at constant speed will need to be:

a. The same as for the shallower ramp
b. Between the force for the shallower ramp and two times that force.
c. Two times greater than for shallow ramp
d. Four times greater than for shallow ramp
e. ½ that for shallow ramp

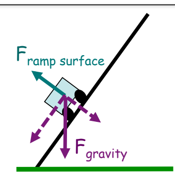
Forces in 2 dimensions



Shallow ramp

- Smaller part of $F_{gravity}$ is acting along the surface of the ramp.
- Larger part is acting perpendicular to the ramp

⇒ larger portion of $F_{gravity}$ is canceled by $F_{ramp\ surface}$.

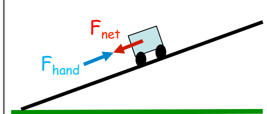


Steep ramp

- Larger part of $F_{gravity}$ is acting along the surface of the ramp.
- Smaller part is acting perpendicular to the ramp,

⇒ smaller portion of $F_{gravity}$ is canceled by $F_{ramp\ surface}$.

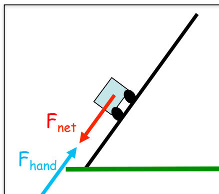
Forces in 2 dimensions



Shallow ramp

- Smaller part of $F_{gravity}$ is acting along the surface of the ramp.
- Larger part is acting perpendicular to the ramp

⇒ larger portion of $F_{gravity}$ is canceled by $F_{ramp\ surface}$.



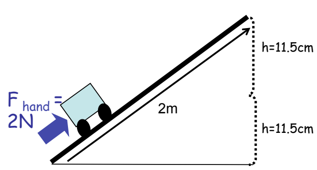
Steep ramp

- Larger part of $F_{gravity}$ is acting along the surface of the ramp.
- Smaller part is acting perpendicular to the ramp,

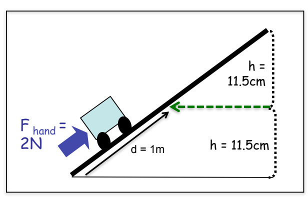
⇒ smaller portion of $F_{gravity}$ is canceled by $F_{ramp\ surface}$.

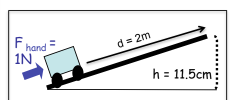
How much work did I have to do to push cart up new ramp (now twice as steep) a distance of 2 m?

a. same amount as before
b. two times as much
c. four times as much
d. ½ as much
e. ¼ as much



How much work to go to same height as before (h = 11.5cm) i.e. halfway up steeper ramp?





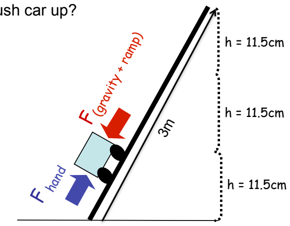
Before
Work done = 2J

a) 0.5J
b) 1J
c) 2J
d) 4J
e) Can't tell from information given

Now make ramp 3 times as steep as at first

How big a force is needed to push car up?

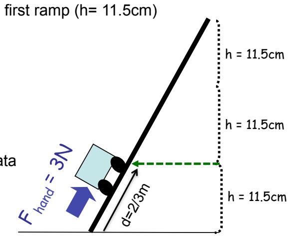
a. 1 N
b. 2 N
c. 3 N
d. 15.5 N
e. 9.8 N



Now make ramp 3 times as steep as at first

Push cart up to same height as first ramp (h= 11.5cm)
i.e. 1/3 of the way up.
How much work is needed?

a. 0.5 J
b. 1 J
c. 2 J
d. 4 J
e. impossible to tell from this data



Summary of data from ramp:

1) Measured force required to push cart up frictionless ramp at constant velocity:
Conclusion: Force changes proportional to steepness.

2) Measured distance travelled up ramp to get to the same height
Conclusion: Changes as 1/steepness.

3) Calculated: Amount of work done
= force of push along ramp x distance along ramp,

Conclusion :

Same work done to push car to same height!
(independent of ramp steepness)

What about just lifting the car vertically?

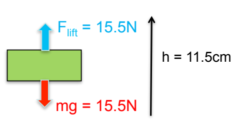
What would be force needed to lift cart straight up at constant velocity?

a. greater than the weight (=mg) of the car
b. less than the weight of the car
c. the same as the weight of the car

What about just lifting the car vertically?

What would be work required to lift straight up a distance h = 11.5cm?

a.I don't know
b.1 J
c.2J
d.5 J



Introducing Gravitational Potential Energy (GPE)

Work done raising an object by height h = mgh

But work done = amount of energy changed

Chemical energy in my muscles (- mgh J)	Work (mgh) →	Gravitational PE of object (+ mgh J)

GPE is the stored energy that an object has due to its vertical position (height)

⇒ Raising an object by height h raises its GPE by mgh

GPE = mgh (relative to h=0)