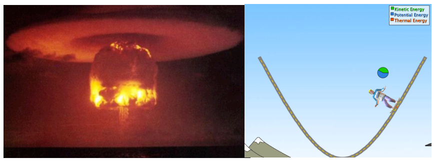
Energy, Work, Power



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

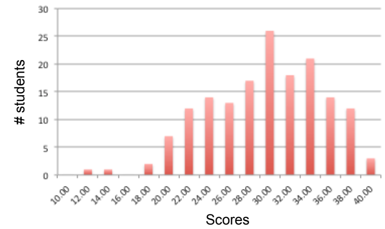
Class 9:
- Conservation of energy
- Work = Force ×distance
- Gravitational Potential Energy

Reminders:
Reading quiz Thurs
HW due next week

Vote: nukes or sound/music?

Midterm 1

CONGRATULATIONS!
- Class average of 74.4%
- This shows that you understand a chunk of physics
- Result of a lot of hard work - keep it up for the rest of the semester!



- Solutions posted on CULearn
- Individual score sheets available
- Don't understand why you got it wrong – take to office hours ASAP

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

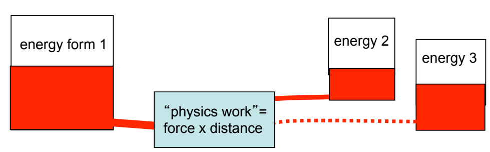
Very useful tool in physics

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?

a. Do experiments: find out that if use conversion 80 quarters = one $20 bill, always get predicted number of $20 bills out, for number of quarters in. If not, get new bank!

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.

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d. no way to tell except asking natives.

e. a. and b. and c.

Energy conservation – background ideas

Why really useful to know that money is conserved going in and out of bank?

Answer:
don't have to keep track of all the details of what is happening in bank,

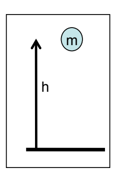
Whatever money you put in in one form, you get out the same amount in another. .
Just have to know the conversion:
e.g. $1 = 3 coconuts, 100 pennies = 1 dollar, 20 1$ bills = 1 $20 bill, …

Energy conservation – background ideas

Answer: don't have to keep track of all the details of what is happening in bank,
Whatever money you put in in one form, you will get out in another
Just have to know the conversion.
$1 = 3 coconuts, 100 pennies = 1 dollar,20 1$ bills = 1 $20 bill, …

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



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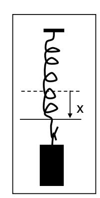

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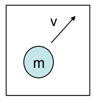

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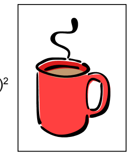
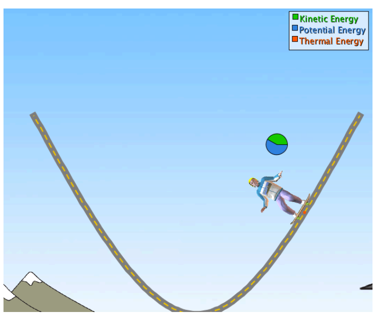




http://phet.colorado.edu/en/simulation/energy-skate-park-basics

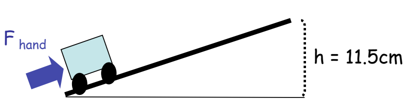
Today we'll look at ramps:

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

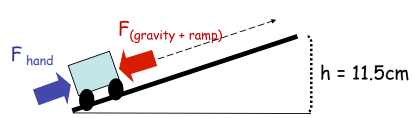
Push frictionless cart up 2 m ramp with constant force at constant velocity.



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

Work done pushing car up ramp

Demo: Push frictionless cart up 2 meter ramp with constant force at constant velocity.

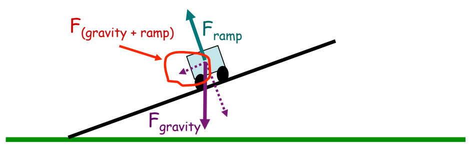


If want to push up ramp at constant velocity, force applied by hand must be:
a. greater than the weight (=mg) of the car
b. less than the weight of the car
c. the same as the weight of the car

Note only a fraction of gravity:

Weight of car = 17.5N   Force to push car up = 1N

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}.

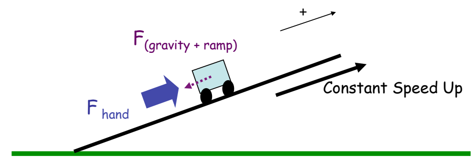
F_{ramp}

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)

Forces in 2 dimensions



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

(Friction force would act parallel to surface)

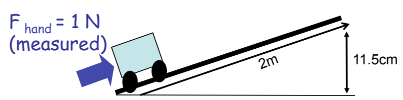
Need NET FORCE = $F_{hand} - F_{gravity + ramp} = 0$

$\Rightarrow F_{hand} = F_{gravity+ramp} < F_{gravity}$

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?

Note: Work is in Joules (J) = Newton (N) x meters (m).



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

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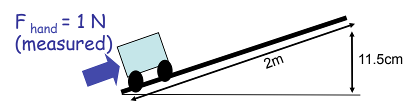

a. 0.5 J b. 1 J c. 2 J d. 10 J
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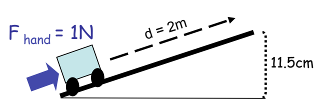
How much work did I have to do to push cart up ramp a distance of 2m?

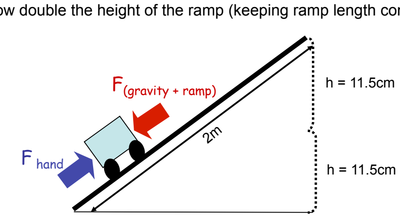
Work = Force applied x distance moved along the direction of the force



Force applied = 1 N, Distance = 2m parallel to applied force
⇒ Work = 1 N x 2 m = 2 J
(JOULE is a unit of ENERGY or WORK)

Work done pushing car up ramp

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

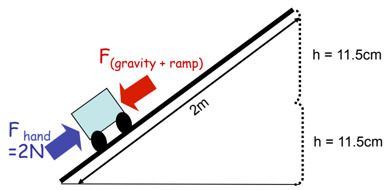


If ramp is **twice as steep**, force applied by hand to push at constant speed will need to be:

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

Hint: twice as steep means Gravity is not cancelled as much

Work done pushing car up ramp



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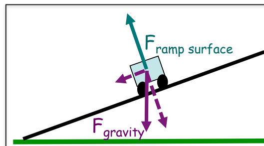
Now 2N…..But still less than weight of car!

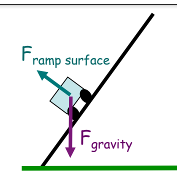
Forces in 2 dimensions



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 $F_{ramp\ surface.}$

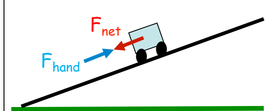


Steep ramp

- 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



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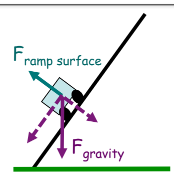

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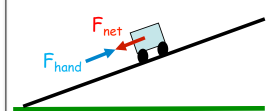

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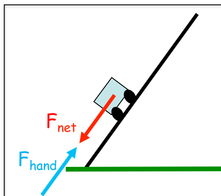


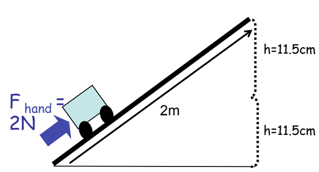
Steep ramp

- 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



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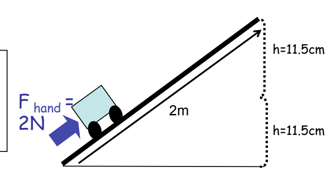
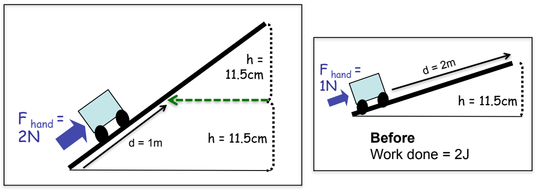


Work done (by me)
= Force applied (by me) x distance moved along the direction of the force

Force applied = 2 N (twice as big)
Distance = 2 m (same as before)
⇒ Work = 2 N x 2 m = 4 Joules .. ..2 times as much as before

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



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

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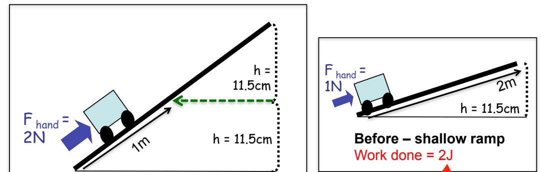
i.e. halfway up steep ramp?



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

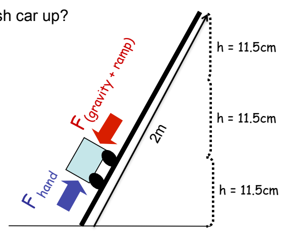
Force applied = 2N
Distance = 1m
Work = F × d
= 2N × 1m = 2J

NOTE: SAME WORK DONE TO GO TO SAME HEIGHT!!!

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



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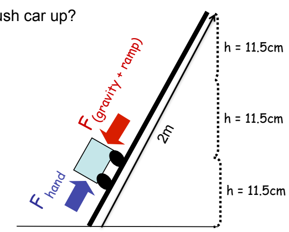
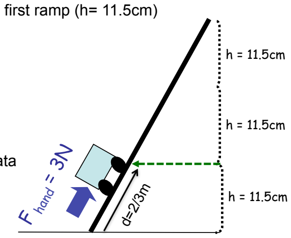


Now make ramp 3 times as steep as at first

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



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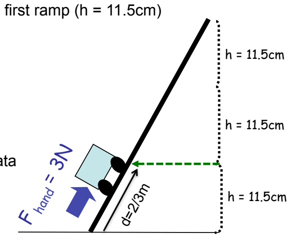
Push cart up to same height as first ramp (h = 11.5cm)
i.e. 1/3 of the way up.
How much work is needed?

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

Force applied = 3N
Distance = 2/3m
Work = F × d
= 3N × 2/3m = 2J



NOTE: SAME WORK DONE TO GO TO SAME HEIGHT AGAIN!!!

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

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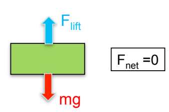
What would be force needed to lift cart straight up at constant velocity?

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 (mg)

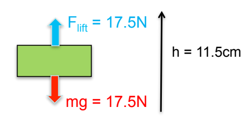
Can measure: Weight =17.5N



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



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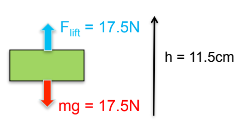
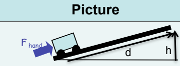
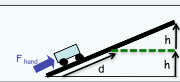
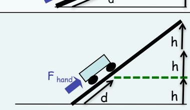
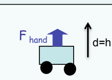


Work done = Force ×$distance_{//}$
= 17.5N ×0.115m
= 2 J

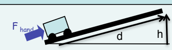
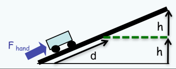
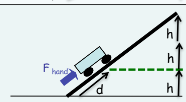
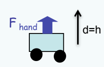
Same work to raise car by same height with or without ramp!!

Summary of data : Work done raising cart by h = 11.5cm

Method	Picture	F_{hand} (N)	d (m)	Work (J)
Shallow ramp		1N	2m	**2J**
Medium ramp		2N	1m	**2J**
Steep ramp		3N	0.66m	**2J**
Lift vertically		17.5N	0.115m	**2J**

However we do it, same work to raise cart by same height

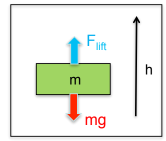
Summary of data : Work done raising cart by h = 11.5cm

Method	Picture	F_{hand} (N)	d (m)	Work (J)
Shallow ramp		1N	2m	**2J**
Medium ramp		2N	1m	**2J**
Steep ramp		3N	0.66m	**2J**
Lift vertically		17.5N	0.115m	**2J**

Very different experiments but always get same answer for work done…..why is that?
Probably some important physics discovered here……..

General formula for work done when lifting stuff

In general, the work done raising any object of mass m by height h is always the same, however we do it.
Can we find a formula for the work done?



Consider lifting vertically:
$F_{lift} = mg$
Work done on object = $F_{lift} \times d_{//}$
$= mg \times h$
$= mgh$

Mass of object
Acceleration due to gravity
Vertical height raised
Really the change in h

But the work done is independent of the lifting method

⇒W = mgh is true for a vertical lift
OR if you use a frictionless ramp of any steepness
OR any other frictionless lifting method