Themed: 12-01

Physics Work, Energy, Power

What is energy?

- Energy: A conserved quantity representing the capacity of a system to do work
- Without energy, mass would be motionless
- When work is done, energy balances change. Examples:
  - You lift a weight and put it on a high shelf. The weight now has gravitational potential energy.
  - You pull on bow’s string, giving it elastic potential energy.
  - You push on a cart, making it move, giving the cart kinetic energy (energy of motion)

What is work? More details

- Work: When a force is applied in same direction as an object is moved by that force
- Ask yourself: Did I increase the energy of the system?
  - Yes: you did work
  - No: you did no net work if energy did not change
  - You did negative work if you reduced energy of system
- What does this mean exactly? Examples….
  - Pushing a heavy cart parallel to the floor vs. perpendicular
  - Pushing an object slowly on ice
  - Lifting a box onto desk
  - Putting a box onto floor (any force you exert, just slows down this process)

How does work relate to energy?

- Energy: the ability to do work
- Work: increases energy of the system
  - Makes something go faster (more KE)
  - Lifts something higher (more GPE)
- Many forms of energy and can be "exchangeable"
  - KE, GPE, Electrical, Chemical, Heat (internal), Elastic

Energy definitions

- **Work** – Applying a force on an object to give it more energy (force x distance)
- **Joule** – Physics unit of energy = 1 newton of force x 1 meter of distance
- **Kinetic energy** – energy of motion: $KE = \frac{1}{2} mv^2$
- **Gravitational potential energy** – energy of position (GPE, or often called just PE): $GPE = mgh$
- **Mechanical energy** – called "ME", the sum of KE and GPE
- **Potential energy** – stored energy of many varieties including GPE, elastic energy, chemical energy, etc.
- **Internal energy** – Energy of heat (the "wasteland" of energy), usually from friction
- **Deformation energy** – Energy that goes into bending, breaking, etc. an object (car crash, smashed clay ball, etc.)
- **Conservation of energy** – energy cannot be created nor destroyed, just converted between different forms
- **Pendulum** – an efficient mechanical device in which KE and PE constantly exchange
- **Perpetual motion machine** – An ideal (frictionless) machine in which no energy is ever converted to heat
- **Watts** – SI unit for power: 1 W = 1 Joule/1 second
- **Horsepower** – American power units (746 watts = 1 hp

Different kinds of energy to recognize

- Kinetic energy (KE)
- Gravitational potential energy (GPE or PE)
- Mechanical energy (ME) or Total energy: ME = GPE + KE
- Elastic potential energy (springs, rubber bands)
- Chemical energy (batteries, outlets)
- Nuclear energy (power plants, sun, bombs)
- Electrical energy (from batteries, power plants, etc.)
- Internal energy or Thermal energy (heat, often from friction)
- Deformation energy (energy put into damaging an object)
- Sound energy (energy contained in sound medium)
- Light energy (photons, how we see things)

Is this work or isn't it?
Energy changed?
Force **in direction** of displacement?

Work or not?
Zach holds a large weight above his head for a really long time
Charlie puts away plates in a high cabinet
David throws a bounce pass
Mary Kate jumps into the air
Gabby spends two hours writing a paper (What a waste! Physics is sooo much better!)
Nick pushes a cart along level floor at constant speed
Alex climbs stairs at constant speed
Annie slows down her car by applying the brakes
Alex spends hours researching a trip to France
Jenna hits a serve horizontally
Jarred launches a bowling ball at high speed down a lane

How is energy useful?

- It lets us predict things and explain the world around us
  - If I lift a 5 kg bowling ball 2 m in the air, I can predict how fast it will be going when it comes back down
  - If it rolls over some silly putty and smashes it, I can measure how much energy went into smashing, by knowing how much energy the ball lost
  - I can drop a 200 g book to the floor and see how much energy it will impart on the floor AND find how fast it's going **without** using NIFTY

Examples (don’t forget SI units!)

- KE = ½ mv^2
  - A 100 kg linebacker runs 40 m in 5.1 seconds, how much KE does he have? (assume constant speed)
- GPE = mgh
  - A 55 kg cheerleader is lifted 3.0 m into the air. How much gravitational potential energy does she have?
- ME = KE + GPE
  - A 600 kg rollercoaster going 12 m/s is still 6.0 m above the low point on the track. How much mechanical energy does it possess?
- Conservation of Energy:

Energy before = Energy after

  - Our cheerleader is let go and drops to 1 m where she is caught. Just before impact, how many joules of PE will be converted to KE? How fast will she be going?
- You push on a 150 g pendulum hard enough to get it moving 3 m/s at it’s lowest point. How high above its low point is it when it’s moving only 1 m/s?

Relationships

- $KE = \frac{1}{2} mv^2$
  - Doubling mass doubles KE
  - Doubling speed quadruples KE (square of speed)
- $GPE = mgh$
  - Doubling mass doubles GPE
  - Doubling height doubles GPE
- $ME = KE + GPE$
  - If assumed “frictionless”, however much KE is lost is PE gained
- Conservation of Energy:

Energy before = Energy after

  - Less energy after means some energy converted to heat (“internal energy”)
  - Heat energy generally cannot be recovered for useful work again

Power

- Power: The **<u>RATE</u>** at which work is being done
- Rate means: <u>divide</u> by time, P = W/t
- Remember, positive work increases PE or KE
- Examples (answers on next slide):

1. How much work do you do to climb 10 stairs in 3 seconds if your mass is 60 kg and each stair is .15 m tall? How much is your average power?
2. How much work do you do to get your 10 kg bike up a 3 m tall hill where your final speed is 6 m/s in 5 seconds (your still the same person as in question 1)?
3. How much work did you do by walking 500 m along a flat track?

Answers to problems

1. How much work do you do to climb 10 stairs in 3 seconds if your mass is 60 kg and each stair is .15 m tall? How much is your average power? 882 J,294 W
2. How much work do you do to get your 10 kg bike up a 3 m tall hill where your final speed is 6 m/s in 5 seconds (your still the same person as in question 1)? (3318 J: 2058 J PE + 1260 J KE)
3. How much work did you do by walking 500 m along a flat track? (0 J, no change in PE or KE)

Themed: 12-02

Cost of energy

Cost of energy

- Power is defined as the rate at which work is done, $P = W/t$
- Does the power company charge you for the power you consume or not?
- Lets take a look at a local bill from the power company (ComEd) and see if they do!

Look at a power bill – Fall 2013

Page 1 of 2

Account Number
Name
Service Location
Phone Number

Bill Summary	
Previous Balance	$136.17
Total Payments - Thank You	$136.17
Amount Due on October 25, 2013	**$85.25**

Issue Date October 3, 2013

Late payment charges will continue until bill is paid.

Meter Information

Read Date	Meter Number	Load Type	Reading Type	Meter Reading Previous	Meter Reading Present	Difference	Multiplier X	Usage
10/1	093666741	General Service	Total kWh	94611 Actual	95316 Estimate	705	1	705

Service from 9/5/2013 to 10/1/2013 - 26 Days **Retail Delivery Service - Res Single**

Electricity Supply Services - ResCom				**$49.28**
RES CHARGES 705 kWh X 0.06990				49.28

ResCom 1-855-572-8374
Please refer to your supplier contract for details.

Delivery Services - ComEd				**$30.16**
Customer Charge				12.79
Standard Metering Charge				2.86
Distribution Facilities Charge	705 kWh	X	0.01937	13.66
IL Electricity Distribution Charge	705 kWh	X	0.00120	0.85
Taxes and Other				**$5.81**
Environmental Cost Recovery Adj	705 kWh	X	0.00039	0.27
Energy Efficiency Programs	705 kWh	X	0.00186	1.31
Franchise Cost	$29.59	X	3.71200%	1.10
State Tax				2.33
Municipal Tax				0.80
Total Current Charges				**$85.25**

- ComEd charges for kW-hr, NOT kW!
- You don't get charged for power, you get charged for energy: Prove it by solve P = W/t for kW-hr
- Rate is $85.25/705 kW-hr = 12¢ per kW-hr, you need to **MEMORIZE** this value!

Cost of energy - example

- How much does it cost to do your physics HW for an entire year!
  - Assume 180 days of HW
  - Assume 30 min of HW per day
  - Tell me how many watts your light bulb is
    - Find the hrs,
    - find the watts,
    - convert to kW,
    - multiply kW x hrs to find kW-hrs
    - $0.11 per kW-hr
- It practically solves itself!

Cost of energy – example, part deux

- How much does to play two hours of indoor tennis? (assume six 1,000 W lights & their commercial rates are ½ of your residential rate)

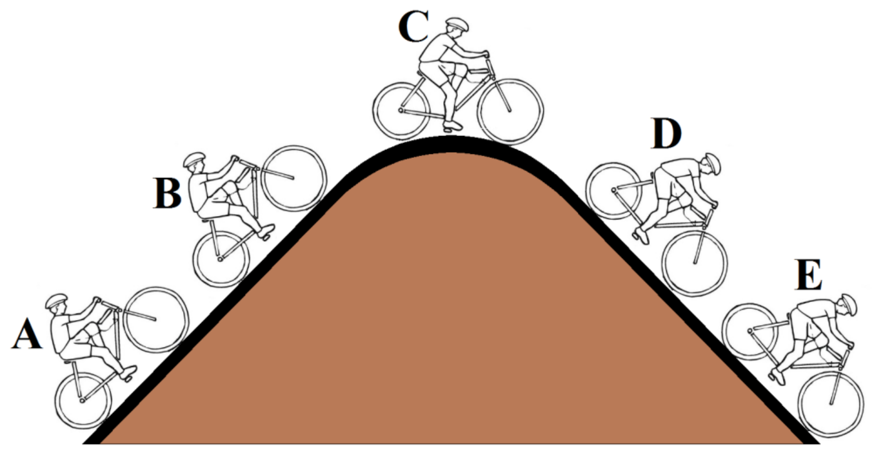
12-03

Rollercoaster Physics

Energy types, exchanges & weight computation

Conservation of energy
Real-world energy exchanges

- Many types of energy & many ways to exchange it
- Four common cases in coasters:
  1. KE (kinetic energy): energy of motion
  2. GPE (gravitational potential energy): energy of position
  3. Friction: transfer KE to heat by rubbing 2 surfaces
  4. Work: Apply force to increase energy (speed or height)
- What's energies are there at positions A – E?
- What kind of energy exchanges are going on?
- NOTICE: Energy changes form, but TOTAL = constant
- Special name for TOTAL: Mechanical energy (ME for short)

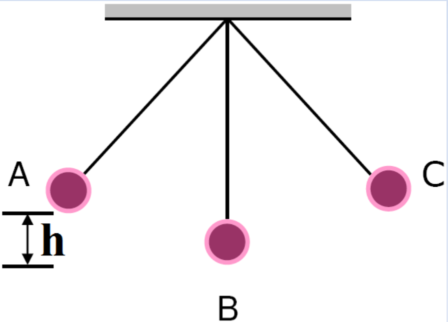


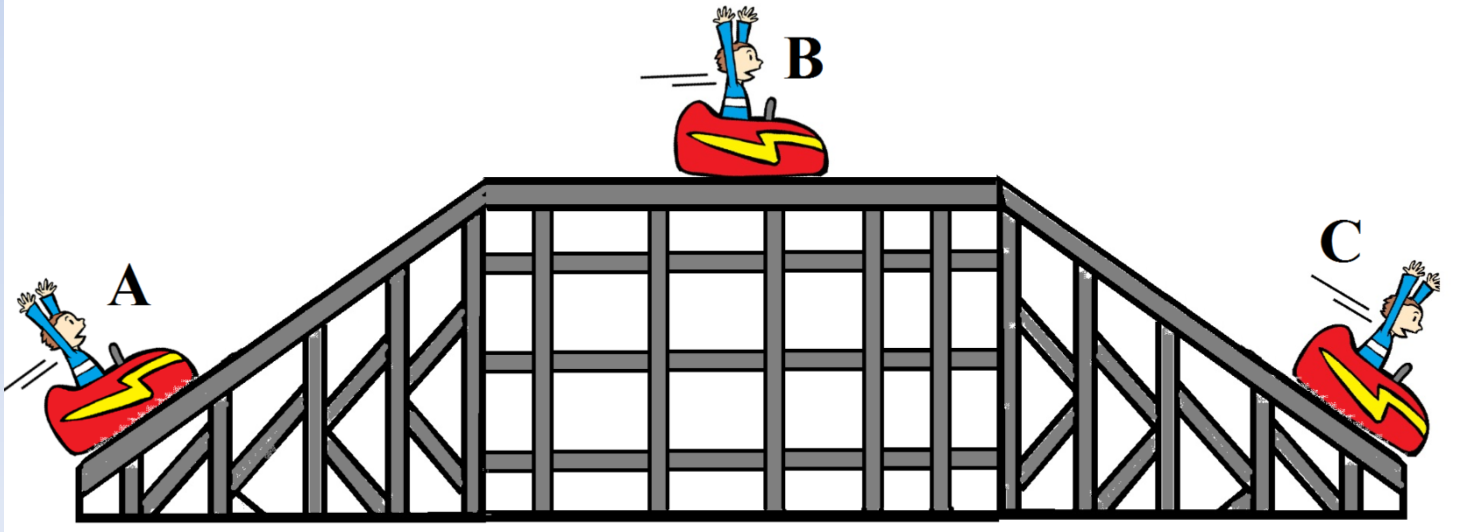
Conservation of energy
Friction – The energy graveyard

- GPE turns to KE downhill
- KE turns to GPE uphill
- Friction steals from cycle
- Energy converted by friction to internal energy (heat) is usually "dead" for our purposes

Conservation of energy
Roller coaster energy exchange

- No pedals or chains now…just coasting
- Assume no friction (to make it simpler)
- A and C are same height. Answer these
  1. Which position is the rider going fastest?
  2. Which position is the rider going slowest? Has most GPE?
  3. What can you say about the GPE gained from A to B compared to the KE lost? (remember, ME stays same, so one gains same as other loses)
  4. Which position on the frictionless coaster has the most ME?
  5. Would #1's answer change with friction around? Rank ME of ABC with friction present.
  6. Why must first hill be tallest hill if coaster truly "coasts" after first hill?
  7. How is a pendulum any different than a coaster or coasting bike?





Weight

- Many energy problems lift weight of a mass against gravity to store GPE
- Weight is the ***force*** of gravity on a mass - NOT mass itself!
- Mass is how much "stuff" there is and doesn't change if you're on the moon or earth, etc.
- Weight depends on what planet the mass is on (the gravitational field the mass reside in)
- Weight is measured in Newtons (N)
- Wt = mg (m is in kg, g is 9.8 m/s^2)
- Why do we care? We often specify things by weight (how many pounds is a coaster?) instead of the mass
- Example: my mass if 75 kg, how much do I weigh? How much would I weigh on mars (g = 3.7 m/s^2)