Final review
more than we can possibly cover

THINK ABOUT WHAT YOU WANT

Reminders:
Final: Tuesday 1;30 -4, G1B30. MANDATORY.
Total scores to be posted this week (with HW 11 in)
Loads of details about the final on Thursday

Day 29:
Review Part 1

Midterm 1 topics - Motion

- Position, velocity and acceleration
  - Definitions, Units
  - Scalars and vectors
  - Graphs of x, v, a vs time and relationships between graphs
  - Equations of motion and how to use them:
    - Constant velocity: $x = x_0 + vt$
    - Constant acceleration: $v = v_0 + at$
    - $x = x_0 + v_0 t + ½ at^2$
- Forces
  - Definition, units, vector
  - $\underline{F}_{gravity}$ = mg downwards
  - $\underline{F}_{friction} \approx 0.3 \times$ weight in direction opposing motion
  - $\underline{F}_{spring} = -k\underline{x}$ in direction opposing extension/compression
  - $\underline{F}_{net} = m\underline{a}$ ⇒ If a = 0, $F_{net} = 0$
  - Free body diagrams and finding F_{net}

Midterm 2 summary

- Conservation of energy

  $W_{ext} - |W_{friction}| = \Delta PE + \Delta KE$

  - Work done by a force = F × $d_{//}$
  - Looked at work done by external forces and by friction
  - GPE = mgh, KE = ½ mv², PPE = PV, SPE= ½ kx², Thermal energy = constant × T
  - Ramps, roller coasters, balls…….
  - Power = energy/s
- Bernoulli's equation

  $E_{tpv} = P + ½ \rho v^2 + \rho gh$

  - Conservation of energy for an incompressible fluid
- Nuclear Energy
  - potential energy wells of nucleus
  - Alpha decay
  - Fission & Fusion
  - Radioactivity

Review Topics – midterm 3

Light and E/M Radiation

Blackbody spectrum
- Introduction to EM waves and the EM spectrum
- Kelvin temperature scale
- Stefan-Boltzman law
- Shape of BB spectrum at different temperatures –
  ⇒ why the sun produces visible light efficiently and incandescent light bulbs don't.

Static electricity
- Coulomb's law for force between point charges
- Voltage and electric potential energy (EPE)

Electric circuits
- Ohm's Law
- Power dissipation law
- Batteries in series and Parallel

Last sections of lectures review

Sound / Music
- Wave basics: f, T, λ, v (and relationships)
- Sound as pressure waves
- Amplitude of waves and associations
- How to get different notes from a violin
- Harmonics on a violin string

Lasers / Quantum Physics
- Atomic discharge lamps
- Energy levels of electron in an atom
- How light is produced from atom
- Conditions of a laser
- Unique characteristics of a laser

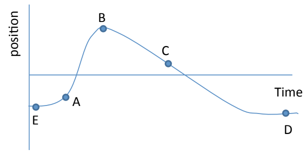
Class Review Topics
You choose

Priorities:
a) position / velocity
b) Force / acceleration
c) Conservation of energy / work

Priorities:
a) Conservation of energy / work
b) Bernoulli
c) Nuclear energy

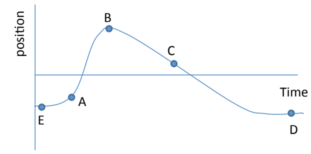
Priorities:
a) Light E/M radiation
b) Blackbody spectra
c) Static elect/ Voltage
d) circuits

Priorities:
a) More of the above
b) Sound
c) lasers



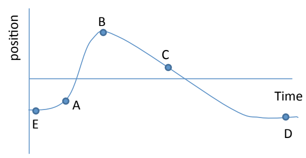
What is the person's velocity at A

a) Positive
b) Negative
c) Zero
d) Can't be determined



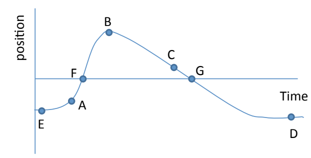
Name all points where the person is stationary

a) E, B and D
b) E and D
c) All points
d) E, C and D
e) B only



Name all the points where the person is accelerating

a) A, B and C
b) B only
c) All points
d) A and C
e) A and B



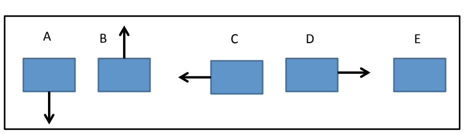
What is the person's average velocity between points F and G?

a) Something greater than zero (positive)
b) Something less than zero (Negative)
c) Zero
d) Can't determine from this graph

Net forces and acceleration

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

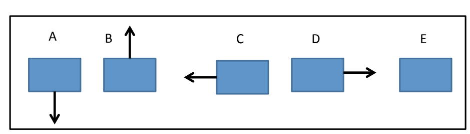
Which diagram shows the net force on a loaded box when it is at rest?



Net forces and acceleration

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

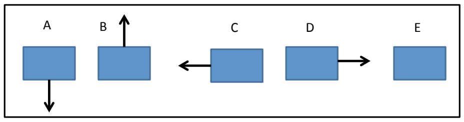
Which diagram shows the net force on a loaded box accelerating to the right at $2 m/s^2$?



Net forces and acceleration

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

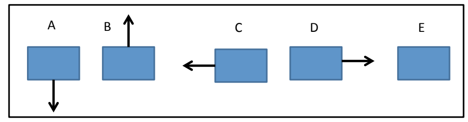
Which diagram shows the net force on a loaded box when it is being pushed to the right at a steady velocity ?



Net forces and acceleration

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

Which diagram shows the net force on a loaded box when it is decelerating to a stop ? (Prior to decelerating it was moving to the right at a steady velocity)



Net forces and acceleration

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

What is the magnitude of the horizontal force that I am applying to the box when it is sliding across the floor at a constant velocity?

a. 392 N
b. 117. 6 N
c. 1306.7 N
d. 2.9 N
e. None of the above

Net forces and acceleration

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

What is the magnitude of the horizontal force that I am applying to the box when it is accelerating across the floor at $1.5 m/s^2$?

a. 60 N
b. 57.6 N
c. 588.0 N
d. 177.6 N
e. None of the above

Springs

I have a spring which is labeled 'Spring constant = 8 N/m'. I assume that this is correct and use it to measure the mass of an apple. I attach the apple to the bottom of the spring and it stretches 12.5cm (or 0.125m) . What is the mass of the apple? (assume $g = 10 m/s^2$)

a) 0.1 kg b) 1kg c) 10kg d) 100kg e) Can't be determined.

Now I hang the same apple on a different spring and it stretches much less than 12.5cm. What is the spring constant of this spring?

a) Less than 8N/m
b) 8N/m
c) More than 8N/m
d) Can't determine from information given

Which spring exerted the bigger upwards force on the apple?

a) The weak spring which had a large extension
b) The stiffer spring (smaller extension)
c) They exerted the same upwards force
d) Can't tell from this information

Energy & Work

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

When the box is travelling at a constant velocity of 3m/s, what is its KE?

a. 360 J
b. 180 J
c. 60 J
d. 120 J
e. None of the above

Energy & Work

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg. The warehouse floor is made of concrete and there is a coefficient of sliding friction of 0.3 between the boxes and the floor.

If I suddenly let go and stop pushing the box when it is travelling at 3m/s across the floor, how far does the box travel before it comes to a stop?

a. 0m
b. 0.5 m
c. 1m
d. 1.5m
e. 2m

Energy & Work

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If I suddenly let go and stop pushing the box when it is travelling at 3m/s across the floor, how far does the box travel before it comes to a stop?

a. 0m
b. 0.5 m
c. 1m
d. 1.5m
e. 2m

$W_{ext} - |W_{friction}| = \Delta PE + \Delta KE$

Work done by friction = KE lost

$-|F_{friction}\, d| = KE_f - KE_i$

$-(0.3mg)(d) = 0 - ½ mv^2$

$(0.3g)(d) = ½ v^2$

$d = ½ v^2/(0.3g)$

$= (0.5*9) / (0.3*9.8)$

$= 1.5m$

Energy & Work

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg.

On the far side of the warehouse I load a box onto a light frictionless cart. I push the cart plus box up a loading ramp. The height of the ramp is 4m above the floor. The length of the ramp is 8m.

How much work do I do pushing the cart at a slow steady speed from the bottom of the ramp to the top?

a. 392 N
b. 392 J
c. 1568 J
d. 40 J
e. 39 N

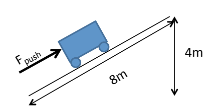
Energy & Work

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg.

On the far side of the warehouse I load a box onto a light frictionless cart. I push the cart plus box up a loading ramp. The height of the ramp is 4m above the floor. The length of the ramp is 8m.

What force do I have to apply (parallel to the surface of the ramp) to push the cart up the ramp?

a. 392 N
b. 196 N
c. 1568 N
d. 0 N
e. None of the above



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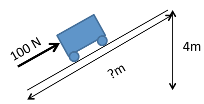
On the far side of the warehouse I load a box onto a light frictionless cart. I push the cart plus box up a loading ramp. The height of the ramp is 4m above the floor. The length of the ramp is 8m.

Suppose that I can only push with a maximum force of 100 N. What is the minimum length of ramp that I need to use?

a. 15. 7m
b. 8m
c. 19.3 m
d. 25.5 m
e. None of the above



Energy & Work

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On the far side of the warehouse I load a box onto a light frictionless cart. I push the cart plus box up a loading ramp. The height of the ramp is 4m above the floor. The length of the ramp is 8m.

At the top of the ramp I let the cart go. What is its speed when it reaches the bottom of the ramp?

a. 1568 J
b. 78.4 m/s
c. 8.9 m/s
d. 6.3 m/s
e. None of the above

Energy & Work

I'm working in a warehouse packing goods into boxes and moving them to the loading bay. Once loaded, each box has a mass of 40kg.

On the far side of the warehouse I load a box onto a light frictionless cart. I push the cart plus box up a loading ramp. The height of the ramp is 4m above the floor. The length of the ramp is 8m.

This time I take the box off the cart and let it slide down the ramp. There is a frictional force between the box and ramp of 100N. Assume that we are using the 8m ramp. What is the KE of the box at the bottom of the ramp?

a. 1568 J
b. 784 J
c. 496 J
d. 768 J
e. None of the above

Energy & Work

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On the far side of the warehouse I load a box onto a light frictionless cart. I push the cart plus box up a loading ramp. The height of the ramp is 4m above the floor. The length of the ramp is 8m.

This time I take the box off the cart and let it slide down the ramp. There is a frictional force between the box and ramp of 100N. Assume that we are using the 8m ramp. What is the speed of the box at the bottom of the ramp?

a. 6.2 m/s
b. 38.4 m/s
c. 2.7 m/s
d. 4.8 m/s
e. 0m/s

Bernoulli's equation

$$E_{tpv} = P + \tfrac{1}{2}\rho v^2 + \rho g h$$

PPE ↑ KE ↑ GPE ↖

Conservation of energy for a unit volume of an incompressible liquid (e.g. water)
Assumes: No pumps, no friction in system of interest

Method:
- Pick 2 points in system
  - One where we know everything
  - One where we want to calculate a quantity
- Write an expression for E_{tpv} at both points
- Equate expressions E_{tpv} at both points
- Solve equation to find unknown quantity

My house is on the side of a hill. The water at the faucet has a mains pressure of 30 psi (200,000 Pa) above atmospheric. (Set AP as the zero of pressure). I attach a hose to the faucet and let the hose run down the hill. The faucet is open but the valve at the outlet of the hose is closed.
If the outlet of the hose is 6m vertically below the faucet, what is the pressure (above atmospheric) behind the outlet valve?

$$E_{tpv} = P + \tfrac{1}{2}\rho v^2 + \rho g h$$

a. 200,000 Pa
b. 141,200 Pa
c. 258,000 Pa
d. 324, 400 Pa
e. None of the above

My house is on the side of a hill. The water at the faucet has a mains pressure of 30 psi (200,000 Pa) above atmospheric. I attach a hose to the faucet and let the hose run down the hill. The faucet is open but the valve at the outlet of the hose is closed.
The outlet valve is still closed and 6m below the house. I poke a small hole in the hose near the outlet valve. What is the velocity of the water leaving this hole?

$E_{tpv} = P + ½ \rho v^2 + \rho gh$

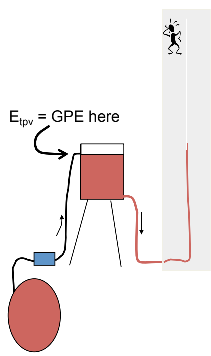
a. 22.8 m/s
b. 20.2 m/s
c. 15.4 m/s
d. 9.0 m/s
e. 4.6 m/s

My house is on the side of a hill. The water at the faucet has a mains pressure of 30 psi (200,000 Pa) above atmospheric. I attach a hose to the faucet.
If I run the hose up the hill instead and open the outlet valve, what is the maximum vertical height of the hose outlet above the faucet at which any water will come out?

$E_{tpv} = P + ½ \rho v^2 + \rho gh$

a. 30.5 m
b. 20.4 m
c. 14.7 m
d. 9.8 m
e. 0 m

Water distribution in skyscrapers

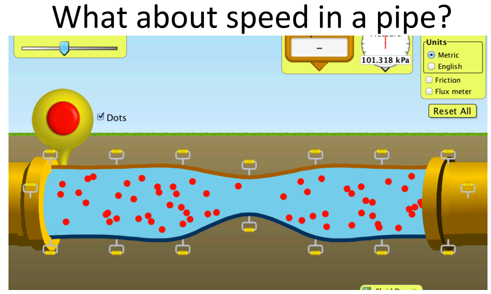


The skyscraper water problem:
- Less pressure on the higher floors,
- Water won't make it to the top floor….

How can you solve this problem?

- Put very high pressure pump at bottom (give water enough PPE at bottom)
- Use a series of pumps up the building
- Pump water to a tank on the roof, then you will always have pressure on the floors below.

What about speed in a pipe?



$P + ½ \rho v^2 + \rho gh = E_{total}/V$ ($E_{total\ per\ unit\ volume}$)

http://phet.colorado.edu/en/simulation/fluid-pressure-and-flow

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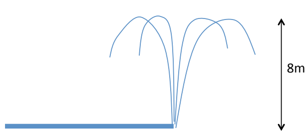


I'm designing a fountain for a city park. I want the water in the fountain to squirt 8m vertically in the air. What pressure will I need in the large pipe just before the nozzle? (Assume that friction can be ignored)

a. 8000 Pa
b. 80 Pa
c. 80,000 Pa
d. 12 000 Pa
e. More information required

$E_{tpv} = P + ½ \rho v^2 + \rho gh$

More Bernoulli!!

I have a tank of water that is 4m deep.
What is the pressure of water at the bottom on the tank?
(Set AP as the zero of pressure, ρ = 1000kg/m^3 for water)

More Bernoulli!!

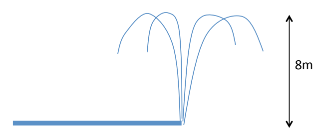
I have a tank of water that is 4m deep.
(Set AP as the zero of pressure)
I drill a small hole in the side of the tank 2m below the surface.
What is the velocity of water leaving the hole?

More Bernoulli!!

I have a water pump that produces water at pressure P_{pump} at the outlet. If I want to pump water to a height of 8m above the pump, what is the minimum pressure that the pump needs to produce?

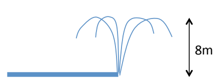
More Bernoulli!!

I have a water pump that produces water at pressure P_{pump} at the outlet. If I want the water to leave a small nozzle at the end of the pipe (8m above the pump) at a velocity of 2m/s, what pressure must the pump produce?



What is the speed of the water immediately after the nozzle?

a. ~15.3 m/s
b. ~12.5 m/s
c. ~8.7 m/s
d. ~ 4.3 m.s
e. Water does not come out



If the fountain squirts 2m³ of water in the air every second, what is the power produced by the pump that is supplying the pressurized water to the nozzle?

a. 78400 W
b. 2 W
c. 1000 W
d. 237,806 W
e. 156,800 W

Recipe- how to make an atom:

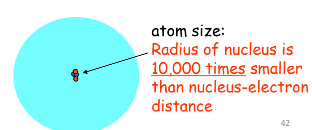
Ingredients: 1 teaspoon protons
1 teaspoon neutrons
1 cup of electrons

Proton (**positive charge**)
Neutron (**no charge**)

Electron
(**negative charge**)

1. Mix protons and neutrons thoroughly.
2. Bake at 100 million degrees until sticks together to form solid dense nucleus (about .0000001 s).
3. Frost with lightly with fluffy layer of negative electrons.

4. *Chill before serving!*



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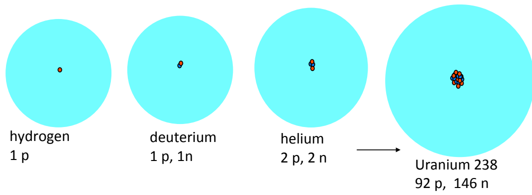
Each element has different number of protons.

Atom ingredients:

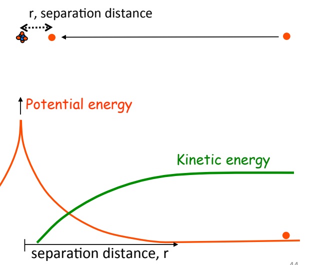
- Proton (positive charge) – charge = 1.6×10^{-19} Coulombs, mass = 1.66×10^{-27} kg.
- Neutron (no charge) – no charge, mass = 1.66×10^{-27} kg.
- Electron (**negative charge**) – charge = -1.6×10^{-19} Coulombs, mass = 9.10×10^{-31} kg



What if threw proton so starts out going towards nitrogen nucleus with a lot of speed (lots of kinetic energy)?

Starts with lots of kinetic energy →
Repelling force from nucleus slows down proton →
Proton's kinetic energy converted into electrostatic potential energy, as it gets closer to nucleus

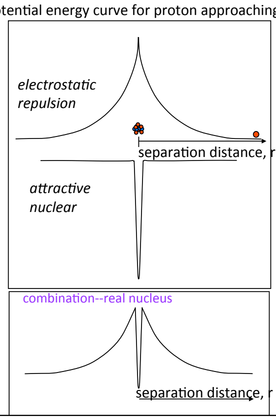
Potential energy curves- represent energy to bring particles together.



Gravity energy analogy.

if at center, want to roll down hill/fly apart … lots of electrostatic potential energy

Potential energy curve for proton approaching nucleus

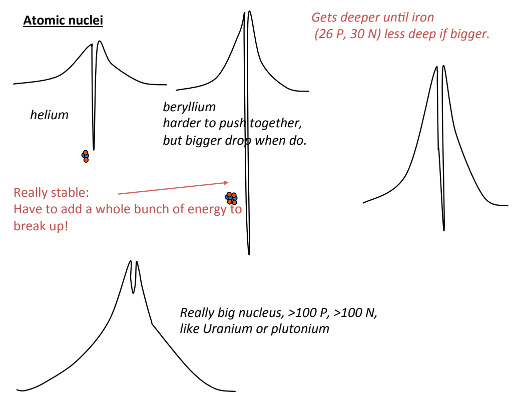


Energy scale gigantic compared to chemical energy.
Why? Simple coulomb's law.

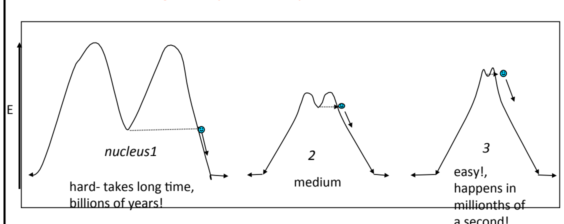
$F = \frac{k\,(\text{charge of \#1})(\text{charge of \#2})}{r^2}$

Chemistry- forces between electrons and protons on distance scale of atomic size (> 10^{-10} m).

Nuclear forces- forces between protons on distance scale 10-100,000 times smaller.
10,000 times closer means forces **100,000,000 times bigger** because of $1/r^2$. Lots more potential energy stored!!!

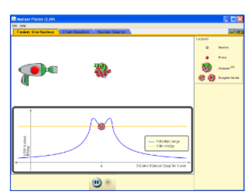


tunneling difficulty = width x depth of tunnel



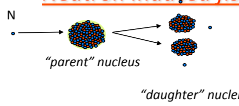
How much energy released?
a. 1 most, 2 second, 3 least
b. 2 most, 1, 3 least
c. 3 most, 2, 1 least
d. 3 most, 1, 2 least

Another Sim
(because this is hard to do at home)

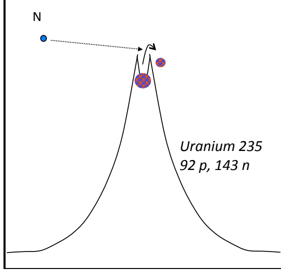


http://phet.colorado.edu/en/simulation/nuclear-fission

Neutron Induced fission- key to atomic bombs



- •two smaller nuclei
- •few extra free neutrons
- •**LOTS OF ENERGY!!**
- •(+sometimes other bad stuff)



Neutron absorbed →
Excites U235 nucleus up above potential barrier →
Splits into two smaller nuclei…
which zoom apart due to electrostatic repulsion!

simulation

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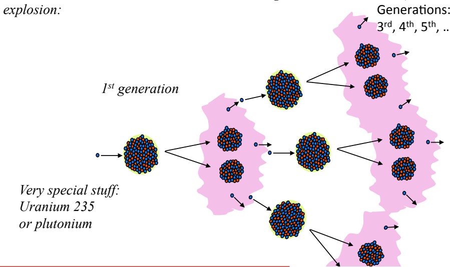
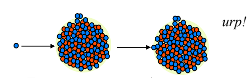
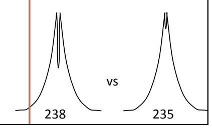
BACK TO CHAIN REACTION
Fission Nuclear explosion:
"atomic bomb"

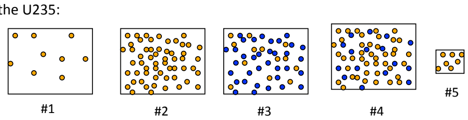


Why Ur 235 not 238? U 238 has 3 extra neutrons help hold it together. *Deeper crater in potential energy.*





U235 and U238 atoms are placed into a container, which are likely to result in a chain reaction (resulting in explosion) when a free neutron triggers fission of one of the U235:



a. #2 only
b. #1, #2, and #5
c. #2 and #4
d. #2, #3, and #4
e. #2, #4, and #5.

Lots of uranium in the ground… why not just blow up?

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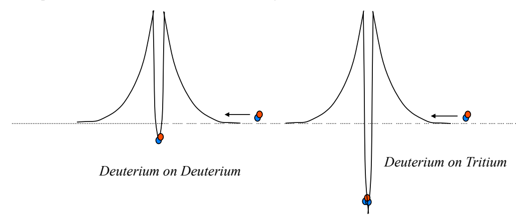
Fusion bomb or "hydrogen bomb"

Basic process like in sun. Stick small nuclei together.



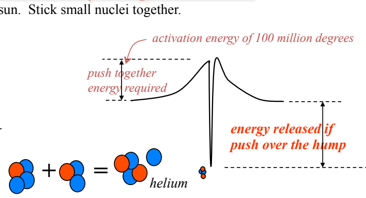
Which will release more energy during fusion?
a. Deuterium combining with deuterium
b. Deuterium combining with tritium

52

Fusion bomb or "hydrogen bomb"

Basic process like in sun. Stick small nuclei together.

Stick hydrogen isotopes together to make helium.



Simple if can push hard enough- just use sun or fission bomb.
More energy per atom than fission. Can use LOTS of hydrogen.

⇒*End up with GIGANTIC bombs*

1000 times bigger than first fission bombs

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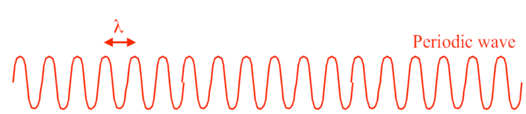
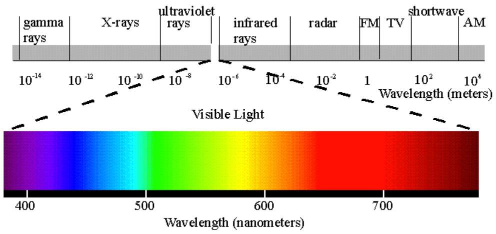
Wavelength

For *periodic* waves, we can identify a *wave length*, λ, by measuring the *distance* between unique points



Electromagnetic waves can have any wavelength
Scientific notation is useful!



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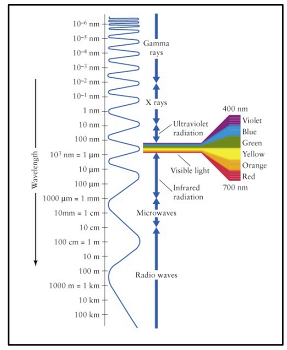
The electromagnetic spectrum



- All EM radiation is a periodic modulation of the electric field
- All EM radiation travels at speed $c = 3 \times 10^8$ m/s
- $c = \lambda \times f$
- Visible light is just one part of the electromagnetic spectrum with specific range of λ (and f)

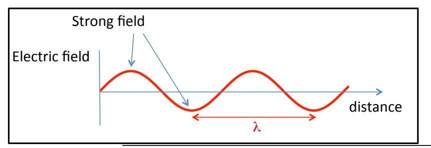
Purple light has a wavelength of 400 nm. What is its frequency?
(1 nm = 1×10^{-9} m)

a. 7.5×10^5 Hz
b. 7.5×10^{14} Hz
c. 1.3×10^{-6} Hz
d. 1333 Hz
e. 400×10^9 Hz

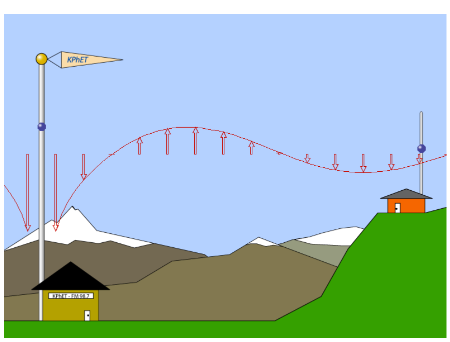
$f = c/\lambda$

What is Electric field?

- Light is periodic modulation of "electric field"



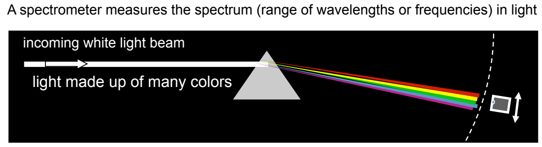
- Electric field exists everywhere in space
- Describes the force on a charged particle at each point in space
- Vector – has a magnitude and direction
- Units: Newtons/Coulomb
- Contains energy
- Created by charges (and created in other ways)
- Analogy: Like gravitational field describes the force on a particle with mass
- Balloon demo

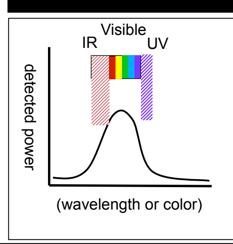


http://phet.colorado.edu/en/simulation/radio-waves

The spectrum of white light?

A spectrometer measures the spectrum (range of wavelengths or frequencies) in light





White light

- Defined as the spectrum of EM radiation emitted by the sun
- All visible λ present with roughly equal intensity

Blackbody spectrum and temperature

- Everything that has a non-zero temperature emits a spectrum of EM radiation
- The spectrum of EM radiation coming from a black object is called the "blackbody spectrum."
- Black object: Absorbs and emits all EM λ easily
- Go to the blackbody spectrum simulation
- BB spectrum determined by temperature only.
- The temperature of the object affects both
  - The total power of EM radiation emitted by the object
  - The range of wavelengths emitted (the spectrum)

Temperature and total emitted power (brightness)

Stefan-Boltzman law gives total electromagnetic power (energy/ second) out of a hot object at temperature T

Power $= e \times \sigma \times T^4 \times a$

Area of surface

Temperature of object (in Kelvin!)

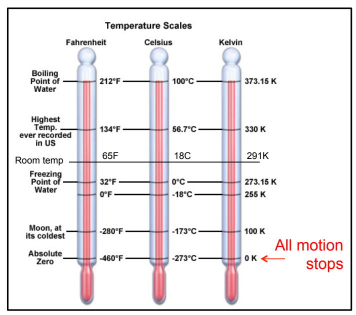
Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}$ J/(s m^2 K^4)

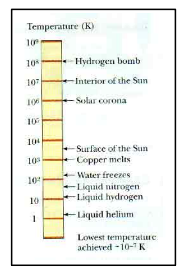
e = "emissivity"; how well the light gets out

What is 2400 degrees C in degrees K?

a. 2127 K
b. 2400 K
c. 8.8 K
d. 2673 K
e. None of the above

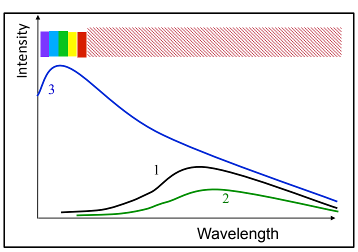
The Kelvin Temperature Scale: Links T to motion



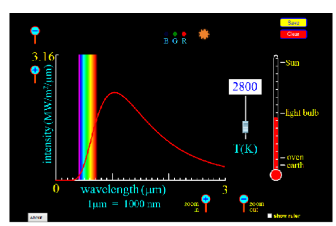


- 1 degree Kelvin = 1 degree Celsius = 9/5 degree Fahrenheit
- 0 degree Celsius = 273 K

Identify spectrum of radiation given off by person (37 C) and a block of barely frozen ice (0 C).



a. 2 is person, 1 is ice,
b. 1 is person, 2 is ice,
c. None, because ice gives off no thermal radiation,
d. 1 is both ice and person because they are almost identical
e. 3 is person, one of the others is ice.



The plot above shows the BB spectrum of an object at the temperature of a typical lightbulb. Why is the lightbulb <20% efficient?

a. Not all of the electrical power going into the lightbulb gets converted into EM power
b. Less than 20% of the electrical power in gets converted to IR power
c. All the electrical power going in gets converted to EM power but less than 20% is at visible wavelengths
d. Visible light is at shorter wavelengths and therefore doesn't contain EM energy
e. The surface area of the lightbulb filament is too small for an efficient conversion of electrical power to visible EM power.

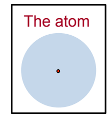
What type of EM radiation is emitted from the surface of the earth?

a. Primarily UV
b. Primarily visible
c. Primarily IR
d. IR and visible
e. All parts of the EM spectrum at roughly equal intensities

Source of electricity: Electric charges

Everything (earth, you, the table etc) made of tiny particles called atoms
Atoms are made up of 3 even tinier particles:
Electrons, neutrons and protons

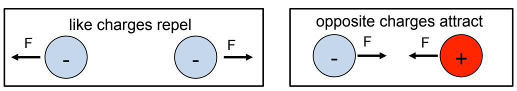
Particle	Charge	Mass
Electron	-e	9.11×10^{-31} kg
Proton	+e	1.67×10^{-27} kg
Neutron	0	1.67×10^{-27} kg



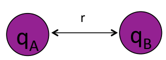
$e = 1.6 \times 10^{-19}$ Coulombs
Coulomb (C) is the unit of charge

Static electricity: What happens when charges are stationary
Electricity (and electric currents): What happens when charges (usually electrons) are moving

Putting this together: Electric Force



Consider 2 'point' charges, A and B. What force does charge A feel?



Observed behavior:
- Force depends on q_A and q_B : More charge, more force
- Force depends on distance between them (r) : less distance, more force

Coulomb's Law:
$Force_{of\ B\ on\ A} = \frac{kq_Aq_B}{r^2}$

- Describes the force between 2 point charges
- k is Coulomb constant = 8.99×10^9 N m^2/C^2
- q_A and q_B are amount of charge in coulombs (C)
- r is separation in m

1 Coulomb = 6×10^{18} electron charges!

Electric Hockey Simulation!

$Force_{of\ B\ on\ A} = \frac{kq_Aq_B}{r^2}$

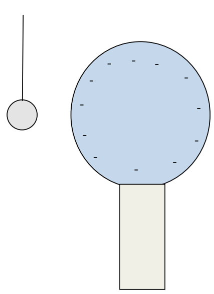
Place charge (B) 2cm from charged puck (A). See charged puck fly away

Now place charge (B) 1 cm away from charged puck (A).
Compared to previous situation force on A will be:
a. half as large, b. same size, c. twice as large, d. four times larger
e. something else.

Place charge (B) 1cm away from charged puck (A) as in previous Q.
Add a second charge to B, right on top of first.
Compared to previous question, force on A is:
a. ½, b. same, c. x 2, d. x 4, e. something else.

Bring uncharged metalized mylar balloon up to Van de Graaff.

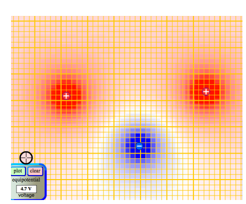
Predict what will happen:
1. Before it touches
2. After it touches



1. Before touching
   a. Not affected by VdG
   b. Attracted to it
   c. Repelled
2. After touching
   a. Not affected by VdG
   b. Attracted to it
   c. Repelled

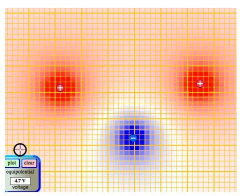
Voltage has to do with conditions of system

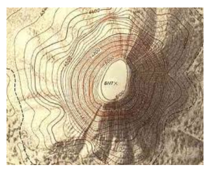
- Amount of charge
- Distance from that charge
- Like the electric force (related but different)



Voltage is like the height of mountain

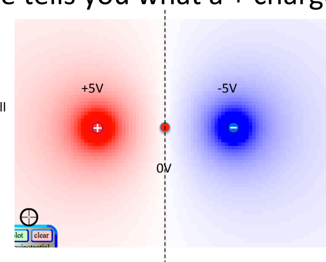
- Think Topographical maps





Voltage tells you what a + charge will do

+V is like top of hill
-V Is like valley



Where is 0 V?

What will a +q do at 0V:
a) Be attracted to higher voltage
b) Be attracted to lower voltage
c) Not be impacted

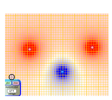
Voltage is like the height of mountain

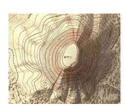
- Voltage
- Charge, q
- Electrical Potential Energy

EPE = q Δ V

- Height (and gravity)
- Mass, m
- Gravitational potential Energy

GPE = m g Δh





Two metal plates connected by a battery.
Battery maintains a voltage difference of V between the plates

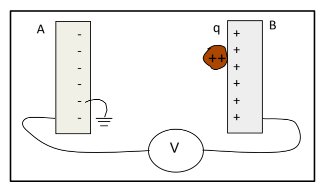
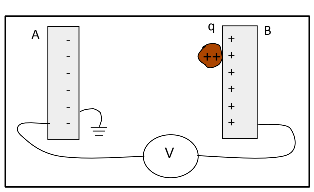


Plate A is grounded (set to zero V)
What is the voltage of plate B?

a) 0
b) +V
c) -V
d) Can't determine from information given



What will happen to the charge q if we let go of it (ignore gravity)?

a) Nothing
b) It will fly over to plate A
c) Sparks will fly
d) Something else

Electrostatic potential energy and voltage

New force: Electrostatic force between charges
New PE: Electric Potential Energy (EPE)

Forces and PE go in pairs - Remember gravitational force:
- Do work against gravitational force (mg) to raise an object's GPE (mgh)
- Similarly, do work against electric force to raise an object's EPE

EPE = q ΔV, where q = charge of object and ΔV is voltage difference
Like GPE with q ↔ m and ΔV ↔ Δh

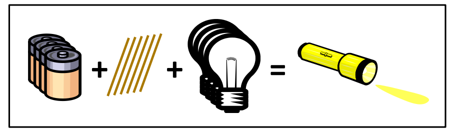
Voltage (V)
- tells you EPE of any charge at that location in space
- Tells you work required to bring a unit charge from V = 0 to that location
- Determined by surrounding charges.
  Closer you are to + charge the more + the voltage
- A grounded object is always at V = 0
- Usually most interested in ΔV: voltage difference between 2 locations

Best understood by doing practice questions!

Electrostatics Summary

- Positive and negative charge: Like charges repel, opposites attract
- Coulombs law for point charges: $F = k \frac{q_A q_B}{r^2}$
  Force acts along line joining particles
- Voltage: Determines EPE of charge at that location in space
  Close to + charges voltage is more + and vice versa
  Grounded object is at 0V
  (Also called Electric Potential)
- EPE: = $q\Delta V$
  New form of potential energy
  Lots of analogies to GPE ($\Delta V \leftrightarrow \Delta h$, $q \leftrightarrow m$)

Flashlights, circuits, batteries, and power



- Given batteries, light bulbs, and wire, how can we design a light bulb circuit
  a) that will burn brightest,
  b) that will last longer,
  c) that will be dim,
  d) that will turn on and off.
- How can you control and predict current and power in light bulbs?
- All this basic circuit stuff applies to home wiring, home electronics, heaters etc.
- Thursday lecture … help save lives … physics of dangers of electrocution.

Builds on electrostatics (like charges repel, opposite charges attract, voltage, EPE)
………but now electrons are moving…………………

………. **need to start thinking like an electron!**

Electric circuits: some important ideas

1. Current is conserved (electrons don't appear/disappear)
2. Change in V over circuit = V of battery, or energy source
3. $V = I R$ (Ohm's law)
   - useful for whole circuit (R_{total}, V_{total}, give I_{total})
   - or individual component (e.g. R_{bulb}, V_{bulb} give I_{bulb}),
   …….Don't mix and match.
4. $P = I V = I (IR) = I^2R$
   $= (V/R)V = V^2/R$ } power dissipated by resistance R
5. Resistors in series:
   Resistances add: $R_{tot} = R_1 + R_2$
   Current through all resistors is the same
6. Resistors in parallel:
   Voltage drop across parallel legs of circuit is same

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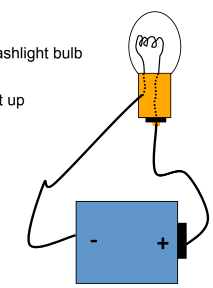
light bulb circuit: Wiring

What will happen when hook up battery to flashlight bulb with 2 wires as shown?

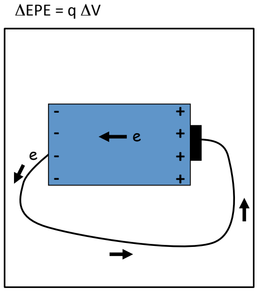
a. light up b. barely light up c. not light up



light bulb circuit: Battery

Voltage difference between ends of battery… 1.5 Volts, 9 Volts, 12 Volts

$\Delta EPE = q\,\Delta V$



What happens to EPE of electrons as they flow around the loop?
a) EPE is always the same.
b) EPE increases through battery; EPE decreases through circuit.
c) EPE decreases through battery EPE increases through circuit.

Circuit elements summary

Wires: Make complete circuit necessary for steady flow of electrons
Usually have negligible (zero) resistance

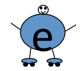
Battery: Has positive charges piled up at one terminal and negative charges at the other
Provides voltage difference ΔV around circuit
Provides each electron with $q\,\Delta V = eV$ of EPE to spend in circuit
Provides push for electrons around circuit (bigger V, bigger push)

Bulb: Filament is a high resistance wire in which electrons lose their energy as heat

Energy changes in circuit

Battery:
Chemical to EPE of electrons
In circuit wires:
EPE to KE of electrons
In bulb:
KE of electrons to thermal energy (random KE) of filament atoms
Filament surface:
Thermal energy of filament atoms to radiated energy (light)
In Battery:
heat and light

This is a task for Electron man!

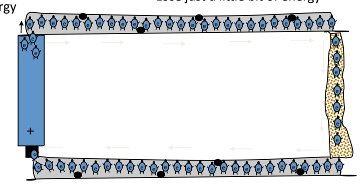


Circuits – Think like an electron

Useful tip:
In questions, assume connecting wires have zero R and e^- lose zero energy in them, unless told otherwise

1. Start: Lots of energy

2. Wires: Not much to bump into – Low R. Lose just a little bit of energy

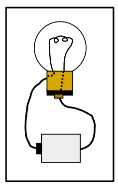


3. Filament
Lots to bump into
Higher R
(Like trudging through mudpit)
Lose lots of energy.

4. End: Exhausted! All energy used up getting through course.

- Same current through connecting wires and filament.
- $R_{filament} >> R_{wires}$
- Almost all energy lost in filament.

Circuit language



Resistance (R) of a circuit element is measure of how hard it is for electrons to pass through.
Units: Ohms (Ω)

Current (I) : charge per second flowing past a point in the circuit
(= # electrons per second × charge on electron)
Units : Amps (1 A = 1 C/s)

Voltage (difference) (ΔV)

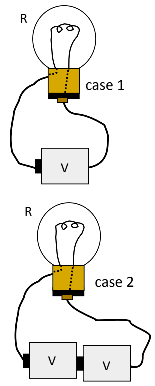
a) **Across battery:** Measure of EPE given to each e^- as it passes through battery. EPE given = eV. Related to pushing force on electrons in circuit
b) **Across a resistor (wire, filament etc):** Measure of EPE lost by each e^- as it passes through. EPE lost = eV.

Unless told otherwise voltage difference across connecting wire = 0.
Units: Volts (V)

Note: All quantities specific to one component.
Don't mix and match!

Ohm's Law: ΔV = IR
R – Resistance of component
I – Current through component
ΔV – Voltage dropped across component

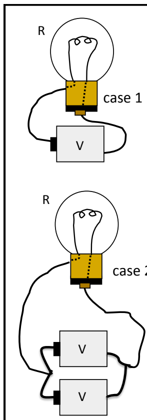
Batteries in series (nose to tail)



Compare the brightness of the bulbs in case 1 and case 2.
All bulbs and batteries are identical

a. Case 2 twice as bright as case 1
b. Case 2 same brightness but runs twice as long
c. Case 2 **more** than twice as bright as case 1
d. Case 2 produces no light

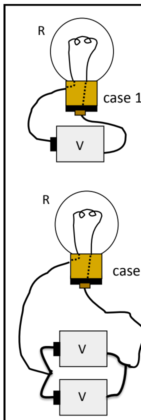
Batteries in parallel



Compare the brightness of the bulbs in case 1 and case 2.
All bulbs and batteries are identical

a. 2 twice as bright as 1
b. 2 same brightness
c. 2 more than twice as bright as 1
d. 2 produces no light

Batteries in parallel



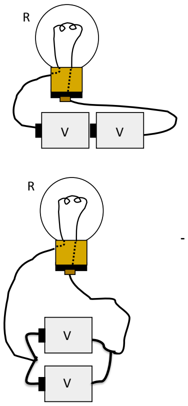
What is the difference then?

Each battery can produce a given amount of Current (electrons/ second) for a certain amount of time

Note: rating on batteries is in Amp-Hours!
(what is an amp-hour?)

Zoinks.. With two batteries I have a greater reservoir of electrons to draw from.

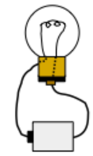
Case 2: last twice as a long!



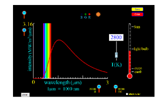
Summary:
- **Series:** more energy for each electron! (brighter)
  how you make a 9 V out of D-Cells, or AAAs
- **Parallel:** longer lasting
  difference between AAAs and D cells

How much power from bulb.

How much power in bulb
(or circuit):
ΔV = 12V (given)
R = 15 Ohms
I = ???



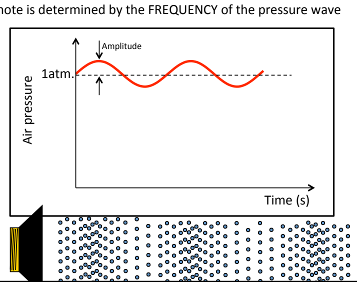
How much in visible?



10%-20%
~ 1 Watt!!

Sound so far

- Sound is a pressure or density wave carried by air molecules
- Sound wave is a very small fluctuation on the background pressure of 1atm or 100,000Pa
- Musical note: Regularly spaced series of high and low pressure regions.
- Volume of the note is determined by the AMPLITUDE of the pressure wave
- Pitch of the note is determined by the FREQUENCY of the pressure wave



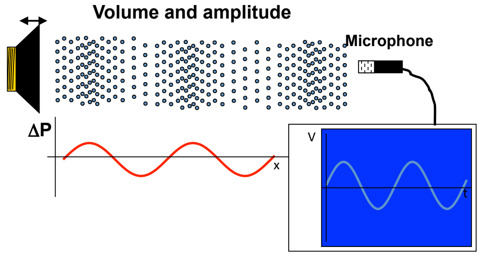
Thinking about waves:

Frequency (f)	**# of oscillations/sec**	**(Hz = 1/s)**
Wavelength (λ)	**Distance of one complete cycle** (e.g. distance between pressure maximums)	**(m)**
Period (T)	**Time for one complete oscillation**	**(s)**
Speed (v)	**Distance traveled per second**	**(m/s)**

Relationships among these variables:

$v = \lambda \times f$
Distance per second = distance per oscillation × # of oscillations per second
$f = 1/T$
oscillations per second = 1/time for one oscillation
$v = \lambda / T$

Volume and amplitude



Question: If I increase the volume, what will happen to the signal from the microphone?
a. **The peaks will go up and the valleys will go down.**
b. **The peaks will get closer together.**
c. **The whole signal will go up.**
d. **Both a and b.**
e. **Nothing will happen**

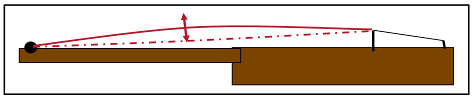
DO EXPERIMENT….

How to change the pitch (note) of the speaker?

To get a higher pitch sound, we need to adjust the speaker to:
a. vibrate back and forth more rapidly, taking a smaller amount of time for each cycle
b. vibrate back and forth at the same rate as before, but the range of it's back and forth motion is larger.
c. receive more power
d. vibrate back and forth more slowly, taking a longer amount of time for each cycle
e. vibrate back and forth at the same rate as before, but the range of it's back and forth motion is smaller.

How do we get notes of different pitch from a violin?

Get the strings to vibrate at different frequencies
⇒ Must control the vibrations or 'wave motion' of the strings



Remember, for ANY wave: $v = f \times \lambda$
$\Rightarrow f = v / \lambda$

Frequency (pitch) of violin note — Speed of wave (on string) — Wavelength of string motion

To change the pitch (frequency) of a note we can
a) Change v - the speed of waves on the string
- change thickness or tension of the string
b) Change λ - the wavelength
- change the length of the string

a) Changing pitch by **speed of waves** on a string

$$v_{string} \sim \frac{F_T}{m_L} \qquad f = \frac{v_{string}}{\lambda}$$

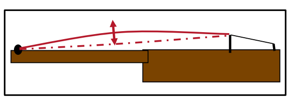
a) How do violinists tune their strings?
- Adjust the tension (F_T)
- Mass on spring tells us:
  → Increasing F_T like increasing the stiffness of the spring (same mass)
  → Bigger spring force ⇒ accelerates and oscillates more quickly

b) Why does the G string produce a lower note than the E string?
- G string is thick ⇒ large mass per length (m_L)
- E string is thin ⇒ small mass per length
- Mass on spring expts:
  → Thicker string like bigger mass (same spring)
  → More mass ⇒ accelerates and oscillates more slowly

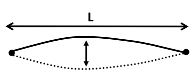
b) Change note by Wavelength of waves on a string

If we could only control the frequency of a violin string with thickness and tension, the violin would have 4 notes.....

But, $f = \frac{v_{string}}{\lambda}$ so we can also change the frequency by changing the wavelength



Simplest or fundamental oscillation of a violin string

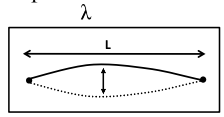


How much of a wavelength does this fundamental motion demonstrate?
a) 1 wavelength
b) 2 wavelengths
c) ¼ wavelength
d) ½ wavelength

Wavelength of waves on a string

If we could only control the frequency of a violin string with thickness and tension, the violin would have 4 notes.....

$f = \frac{v_{string}}{\lambda}$ So we can also change the frequency by changing the wavelength

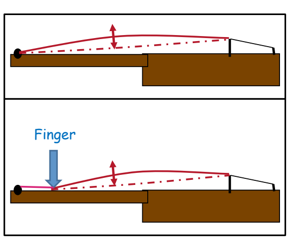


$L = ½ \lambda \Rightarrow \lambda = 2L$

$$\Rightarrow f_1 = \frac{v_{string}}{\lambda_1} = \frac{v_{string}}{2L}$$

- Fundamental wavelength and hence frequency directly related to length of string
- Can change fundamental frequency by shortening the string with fingers
- Fundamental frequency of string determines that pitch that we hear

$$f_1 = \frac{v_{string}}{\lambda_1} = \frac{v_{string}}{2L}$$



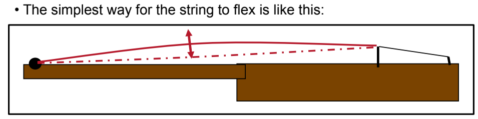
Longer string
Longer wavelength,
lower frequency

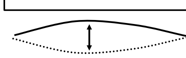
Shorter string
Shorter wavelength
Higher frequency

DEMO CAPO

Harmonics

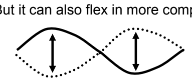
- String is tied down at each end.
- It oscillates back and forth.
- The simplest way for the string to flex is like this:



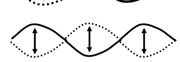


Fundamental frequency, 1st harmonic.
$f_1 = v_{string}/2L$

But it can also flex in more complicated ways and we call these higher harmonics



2nd harmonic:
half the wavelength, twice the frequency
$f_2 = 2f_1 = v_{string}/L$



3rd harmonic:
third the wavelength, three times the frequency,
$f_3 = 3f_1 = 3v_{string}/2L$

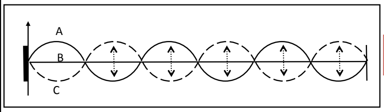
It is the mixture of harmonics that each instrument produces along with the fundamental that gives it its unique sound

DEMO STANDING WAVE

More questions on harmonics

A string is clamped at both ends and then plucked so that it vibrates in the mode shown below, between two extreme positions A and C. Which harmonic mode is this?

a. fundamental,
b. second harmonic,
c. third harmonic,
d. 6th harmonic

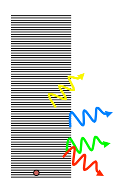


A, B and C are snapshots of the string at different times.

Harmonic demo

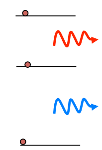
Review of atom discharge lamps-- neon signs.

Energy levels metal, bulb filament, or not stuck in atom (like sun). If hot, jump between all diff. levels. Wiggle around, all colors.

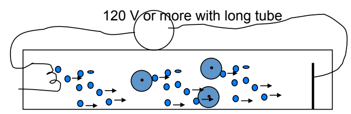


Energy levels in isolated atom.

kick up, only certain wavelengths when come down.



In discharge lamps, lots of electrons given bunch of energy (voltage). Bash into atoms. *("discharge tube")*



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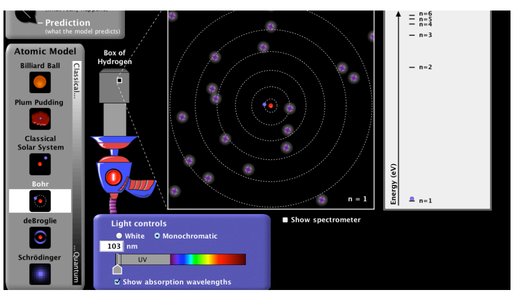
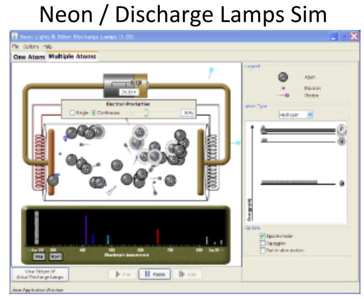
Atomic Models & Light



Neon / Discharge Lamps Sim



Note: different atoms have different energy levels (orbits for electrons), resulting in different energies of light (colors) coming out

http://phet.colorado.edu/en/simulation/discharge-lamps

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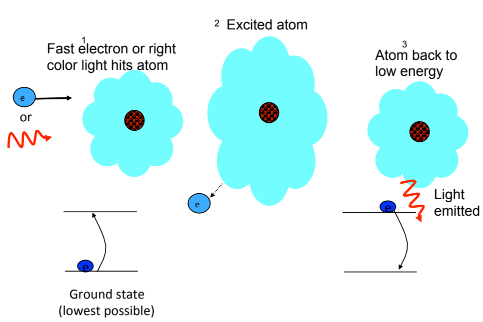
atoms lazy- always want to go back to lowest energy state.
Have to get rid of energy, send it off as light.



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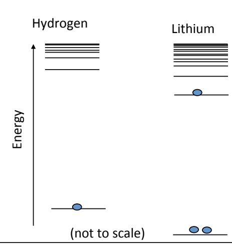
Important Ideas

1) Electrons in atoms only found in specific energy levels
2) Different set of energy levels for different atoms
3) 1 photon emitted per electron jump *down* between energy levels. Photon color determined by energy difference.
4) electron spends very little time (10^{-8} s) in excited state before hopping back down to lowest unfilled level.
5) If electron not stuck in atom, can have any energy.



Electron energy levels in 2 different atoms … Levels have different spacing.

Atoms with more than one electron … lower levels filled.

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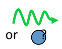
Laser-- Light Amplification by Stimulated Emission of Radiation

repeated cloning of photons to produce LOTS of identical photons of light.

Requirements: 1) stimulated emission (always have)
2) population inversion of bunch of atoms (hard)
3) optical feedback (mirror)



photon, little piece of wave,
we often draw as little ball because less work.

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photon, little piece of wave,
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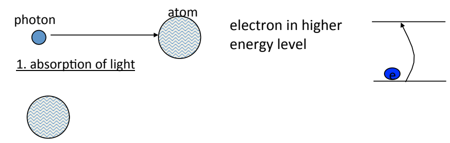
<u>Everything to know about interaction of light and atoms. 3 easy steps.</u>



<u>2. Spontaneous emission of light.</u> Electron jumps down from upper level, gives off light. Randomly in any direction.

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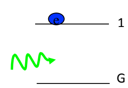
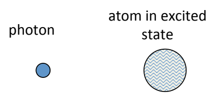
<u>"Stimulated emission" of light.</u> First realized by A. Einstein



Photon hits atom already in higher energy level.
original photon continues and atom emits second identical one



second identical photon comes out. Atom jumps down.
Cloning photon.

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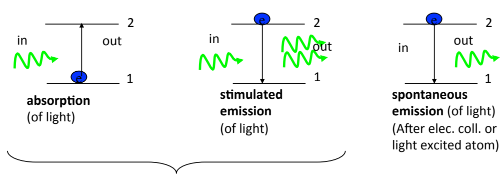
Three processes by which light interacts with atoms



Surprising fact. Chance of stimulated emission of excited atom **EXACTLY** the same as chance of absorption by lower state atom. Critical fact for making a laser.

Laser-- just use stimulated emission to clone photon many times (~10^{20} /sec)
Light **A**mplification by **S**timulated **E**mission of **R**adiation

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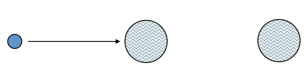
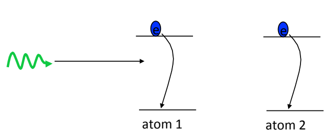


what will come out on the right? Think before you pick…
a. 1 photon, b. 2 photons, c. 3 photons, d. 4 photons, e. 8



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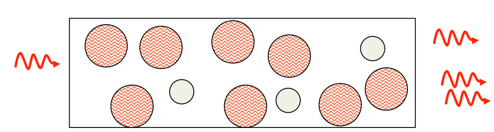
so now see how to get population inversion, will give amplification of red light. If enough atoms in upper, will lase.



PhET Simulation

But much easier if not let light all escape. Reuse.
mirror to reflect the light.

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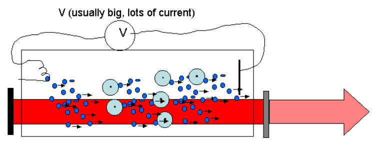
can get amplification, but to really build up to nice high power beam need feedback of mirrors.

Open laser He-Ne with exposed discharge tube and mirrors.



gas laser like Helium Neon.
Just like neon sign with with helium and neon mixture in it and mirrors on end.

Diode laser- same basic idea, but light produced like in light emitting diode at P-N diode junction.

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What have we learned in this section:

1) Lasers (pump up to population inversion, put mirrors around it, stimulated emission will take care of the rest)

2) For operation, lasers need at least 3 energy levels (ground state and 2 excited states). It helps if the middle level has a long lifetime ("metastable)

3) How glow in the dark toys work

4) Lots of cool demonstrations. Looked at emission spectra. Disassembled a working laser.

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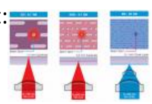
Many applications of lasers

- High energy small area:
  - Cutting: surgery, laser welding
  - "communication" (and weapons)

- Focus light into extremely small spot:
  - (diffraction limit, because in phase!)
  - CDs, DVDs, …



- Collimated beam
  - Tracking, leveling,
- Pure color
  - LIDAR….

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