

Review

Announcements:

- First midterm is 7:30pm tomorrow in this room.
- Formula sheet has been posted and will be on the exam.
- Old exams and solutions are on CULearn
- Next weeks homework has been posted and is due Wednesday as usual. It is extra credit but it covers material that will be on the test.



Comments on last homework

It was a difficult assignment (average of 36 out of 50)...

More and more of your physics assignments will be like that.

Most of the Physics 1110 and 1120 problems could be done with plugging numbers into a formula or perhaps 2 lines of algebra before plugging numbers in.

The new physics problems will often have multiple line derivations with messy algebra in between.

Check your units! This is a quick and easy way to check if you messed up some algebra. You can't add energy and velocity!

If you start over a problem, please cross out or erase the incorrect work. This helps out the graders (and maybe keeps you from getting confused too).

Exam details

9 problems but several are multiple parts for a total of 22 parts.

Of the 22 parts:

- 4 are multiple choice like

- 2 are very short answer (one or two sentences)

- the rest require getting a result

You don't have to show your work on multiple choice questions but if you do, it will be considered.

All other problems you must show work to receive full credit. Partial credit will be given when it is earned.

Exam is at 7:30pm tomorrow in G125 (this room). Please bring a pen/pencil and a calculator.

Special Relativity – Chapter 1

Postulates of relativity:

1. All physical laws are the same in all inertial reference frames
2. The speed of light is the same in all inertial reference frames

Relativity of simultaneity: events which are simultaneous in one frame may not be in another; even the order may be switched.

Proper time Δt_0 between two events is the time measured in the frame in which both events occur at the same location.

Proper length L_0 of an object is the length measured in the rest frame of the object.

Time dilation (moving clocks run slower): $\Delta t = \gamma \Delta t_0$

Length contraction (moving objects are shorter in the direction they are traveling): $L = L_0 / \gamma$

In the twin paradox, Carol took a trip to Sirius and then returned while Vicki stayed home. Which statement is true:

- A. The proper time for this trip is the time measured by Vicki.
- B. The proper time for this trip is the time measured by Carol.
- C. There is no proper time for this trip due to multiple inertial reference frames.
- D. The proper time for this trip depends on which length is used.
- E. The proper time for this trip is kept by someone on Sirius.

Proper time Δt_0 between two events is the time measured in the frame in which both events occur at the same location.

For this trip there are actually **three** events (leaving Earth, arriving at Sirius, arriving at Earth). Carol's frame is the only one in which all three events occur at the same location.

Special Relativity – Chapter 1 (continued)

Lorentz transformations are used to transform coordinates (position and time) from a rest frame S to a moving frame S' .

$$x' = \gamma(x - vt) \quad y' = y \quad z' = z \quad t' = \gamma(t - vx/c^2)$$

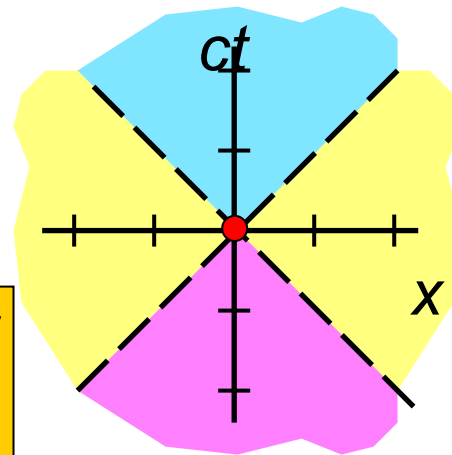
The *inverse* Lorentz transformations go the other way (S' to S) and can be obtained by swapping primes and signs.

Velocity addition formula is also different than the Galilean velocity addition formula: $u' = \frac{u - v}{1 - uv/c^2}$

Spacetime diagrams can be used to understand where & when events occur and how they are related in the space-time continuum.

Relativistic Doppler shift for observer and source approaching at β .

$$f_{obs} = f_{source} \sqrt{\frac{1 + \beta}{1 - \beta}}$$



Future
(forward
light cone)

Elsewhere

Past
(backward
light cone)

Clicker question 2

Set frequency to DA

Two events take place 90 m apart with an intervening time interval of $0.60 \mu\text{s}$ in reference frame S. What is the speed of the reference frame S' which measures the proper time between the two events?

- A. 0
 - B. $0.25c$
 - C. $0.50c$
 - D. $0.90c$
 - E. c
- $x' = \gamma(x - vt)$
 $y' = y$
 $z' = z$
 $t' = \gamma\left(t - \frac{v}{c^2}x\right)$

Proper time Δt_0 between two events is the time measured in the frame in which both events occur at the same location.

So in the S' frame, both events must occur at point 0. That is, $x' = 0$ when $x = 90 \text{ m}$ and $t = 0.60 \mu\text{s}$.

To get $x' = \gamma(x - vt) = 0$

requires $x - vt = 0$, i.e. $x = vt$.

Solving for v :
$$v = \frac{x}{t} = \frac{90 \text{ m}}{.6 \mu\text{s}} = 150 \text{ m}/\mu\text{s} = 0.5c$$

Special Relativity – Chapter 2

Conservation of momentum and energy continues to hold for isolated systems if we redefine momentum and energy as:

$$\begin{aligned} p &= \gamma_u mu \\ E &= \gamma_u mc^2 \end{aligned} \quad \text{for mass } m \text{ with velocity } u \text{ and } \gamma_u = 1 / \sqrt{1 - u^2 / c^2}$$

This gives a rest energy of $E_{\text{rest}} = mc^2$

Define kinetic energy: $KE = E - E_{\text{rest}} = \gamma_u mc^2 - mc^2 = (\gamma_u - 1)mc^2$

Energy-momentum relationship: $E^2 = (pc)^2 + (mc^2)^2$

For a massless particle like a photon, this reduces to $E = |pc|$

One other equation is $\beta = pc / E$

This is it for equations in Chapter 2. Usually use conservation of energy and conservation of momentum to solve problems.

A Λ particle with mass $1116 \text{ MeV}/c^2$ decays at rest to a proton with mass $938 \text{ MeV}/c^2$ and a pion with mass $140 \text{ MeV}/c^2$. What can we say about the proton and pion momentum and energy?

- A. The proton and pion have the same magnitude momentum and energy.
- B. The proton and pion have the same energy but the proton has more momentum.
- C. The proton and pion have the same momentum but the proton has more energy.
- D. The proton and pion have equal and opposite momenta and the proton has more energy.
- E. We cannot make a determination based on information given.

Conservation of momentum requires the proton and pion momentum add to 0 so must be equal and opposite. Since $E^2 = (pc)^2 + (mc^2)^2$, the proton has more energy due to larger mass.

Atoms and discoveries – Chapter 3

Atoms have a nucleus (with nucleons) which is surrounded by electrons.

Atomic number **Z**: # of protons (also # of electrons for neutral atom).

Atomic mass number **A**: number of **nucleons** (protons + neutrons).

Protons & electrons have the same magnitude charge: $1.6 \times 10^{-19} \text{ C}$

Three important experiments led to this knowledge:

Thomson discovered the electron in 1897 and measured e/m .

Sent electrons through crossed E and B fields.

Millikan measured electron charge with oil drop experiment in 1911.

Measured charges and masses (indirectly) of oil drops to get e .

Rutherford found the nucleus by observing how α particles scatter in thin metal foils. Most scatter very little, but some bounce back indicating very high electric field (nucleus).

Clicker question 4

Set frequency to DA

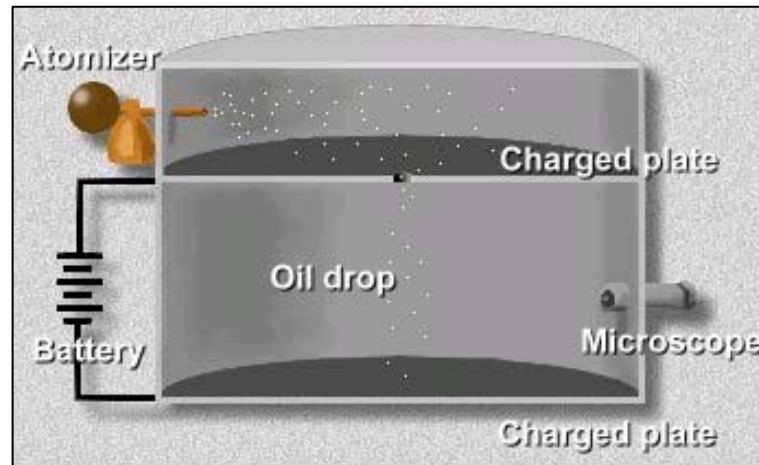
The Millikan oil drop experiment was performed on ionized oil drops which could be manipulated by changing the magnitude of the electric field in which the oil drops were located.

Can one obtain the charge on the drop by measuring just the electric field when the drop is stationary?

A. Yes

B. No

C. Some other answer



When it is suspended by the electric field, we have:

$$F_{net} = q_{drop}E - m_{drop}g = 0$$

so $q_{drop} = m_{drop}g / E$ Need to determine the mass.

Can let the drop fall and measure terminal velocity to get mass.

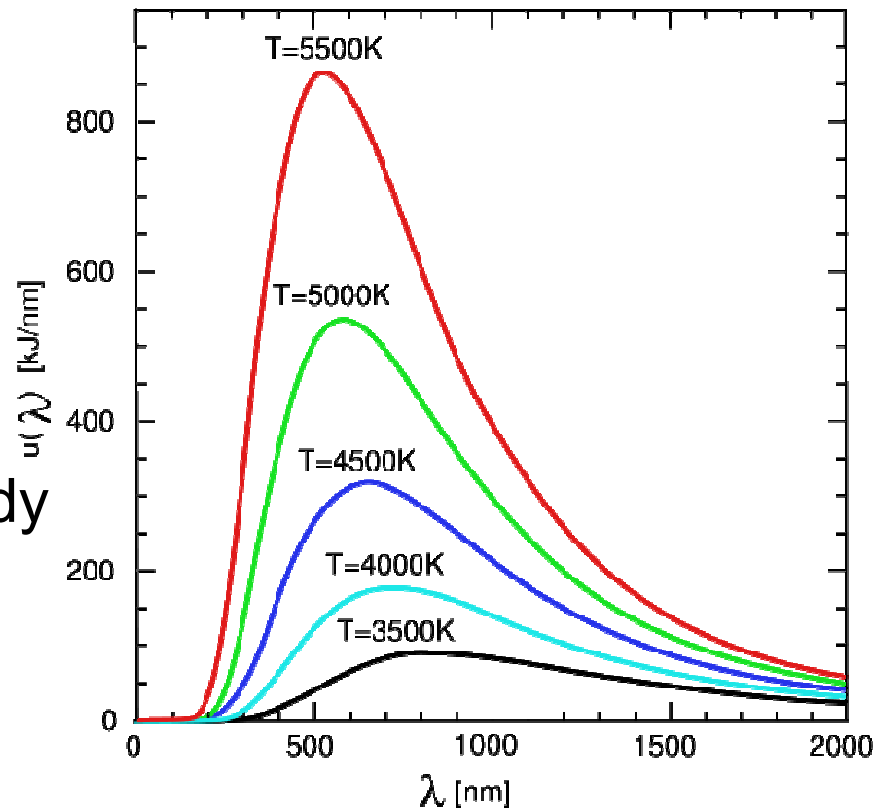
EM waves and blackbody radiation

Electromagnetic waves transfer power based on *just* the amplitude of the E and B fields.

$$\text{Intensity} = \frac{\text{Power}}{\text{area}} = \frac{\text{energy/time}}{\text{area}} \propto E_{\text{avg}}^2 \propto E_{\text{max}}^2$$

Blackbody radiation is due to the temperature of the object which is radiating. Higher temperature shifts the frequency up *and* increases the total intensity as shown.

1900: Max Planck explained blackbody radiation, but needed to assume that only certain quanta of light can be emitted by the blackbody: $E=nhf$

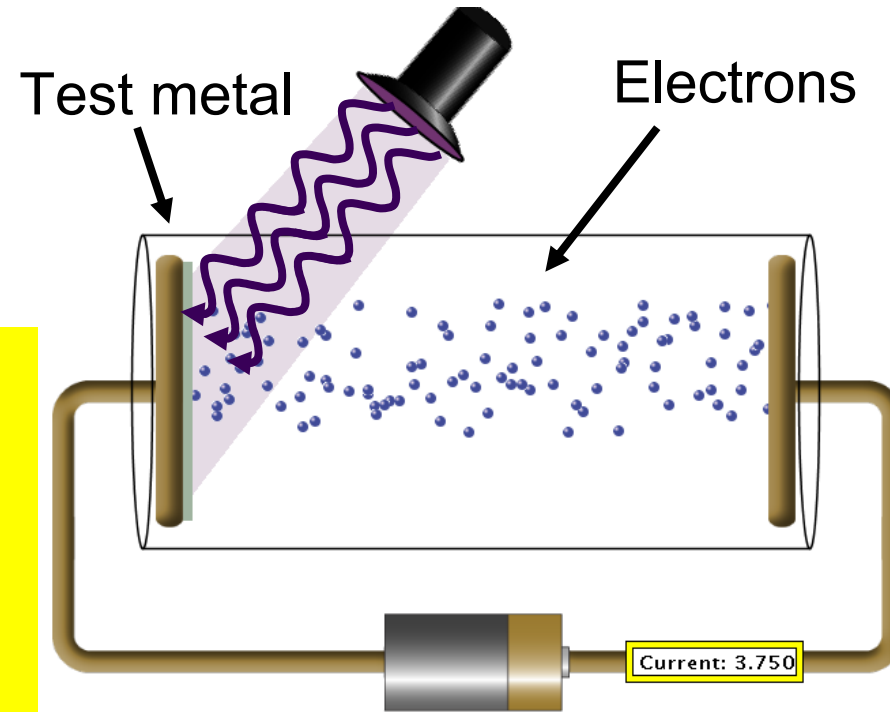


Photoelectric effect

Two metal plates in vacuum, adjustable voltage between them, shine light on one plate. Measure current between plates.

Observations didn't match theory:

1. Minimum frequency needed to get current no matter the intensity
2. Current depended on frequency as well as intensity.



1905: Einstein's solution: photons have energy hf and only one photon can interact with electron at a time. Minimum frequency leads to minimum energy to eject the electron from the metal (overcome work function). Energy above minimum goes into electron KE.

Conservation of energy: $E_{\text{photon}} = E \text{ to escape metal} + \text{electron KE}$

$$KE_{\text{max}} = hf - \phi$$

Calcium has a work function of 2.9 eV. What is the longest wavelength light that can eject electrons from calcium?

A. 230 nm

B. 400 nm

C. 430 nm

D. 620 nm

E. Impossible to tell

$$E = hf = 6.626 \cdot 10^{-34} \text{ J}\cdot\text{s} \cdot f = 4.14 \cdot 10^{-15} \text{ eV}\cdot\text{s} \cdot f$$

$$E = hc/\lambda = 1.99 \cdot 10^{-25} \text{ J}\cdot\text{m} / \lambda = 1240 \text{ eV}\cdot\text{nm} / \lambda$$

The longest wavelength is the lowest energy so it would leave the electron with zero kinetic energy. That is, the photon energy would just be equal to the work function.

Using the above equation we find: $2.9 \text{ eV} = 1240 \text{ eV}\cdot\text{nm} / \lambda$

$$\text{Solving for } \lambda \text{ gives: } \lambda = \frac{1240 \text{ eV}\cdot\text{nm}}{2.9 \text{ eV}} = 430 \text{ nm}$$