Announcements

1. Final exam -- take-home version won class vote

   Some details

2. Advice for studying
3. Thanks
4. List of topics
5. Examples

Final exam

- **Purpose: Incentive to review and to practice the physics you learned this semester**
- **Preparation –**

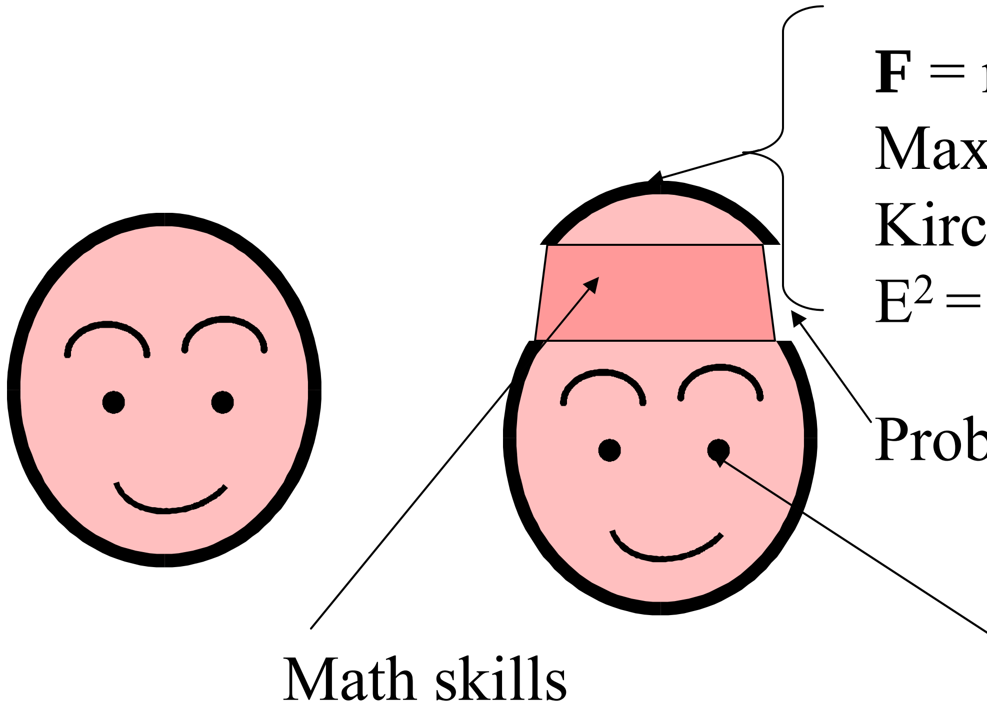
  Review the material in Chapters 22-44, lecture notes, previous exams, homework, etc. Formulate questions and get them answered.

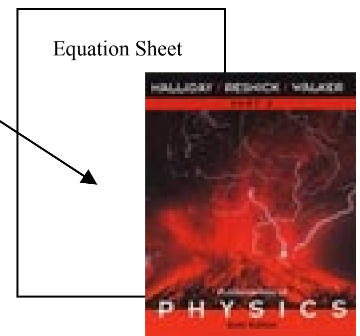
- **Exam itself:**

  Once you open the exam packet, under the conditions of the honor code you must not discuss physics with anyone other than me. Keep all of your materials – the exam, your scratch work, etc. in the packet except when you are working on it.

More details about exam:

- **Exam will be due at 9 AM on Tuesday 5/3/05.**
- **Exam will (hopefully) be available on Friday. (You will receive an email from me; after which you can pick it up any time.)**
- **In working the exam you may use:**
  - **Your notes**
  - **Your text**
  - **The internet**
- **In working exam, you may NOT use:**
  - **Consultation with ANYONE other than me.**
  - **Extra credit will be gladly offered for catching any errors in the test. (Information will be emailed to class.)**





Advice:

1. Keep basic concepts and equations at the top of your head.
2. Practice problem solving and math skills.
3. Develop an equation sheet that you can consult.
4. Know where to find important constants in your text book.
5. Formulate questions and get them answered.

Problem solving steps

1. Visualize problem – labeling variables
2. Determine which basic physical principle(s) apply
3. Write down the appropriate equations using the variables defined in step 1.
4. Check whether you have the correct amount of information to solve the problem (same number of knowns and unknowns).
5. Solve the equations.
6. Check whether your answer makes sense (units, order of magnitude, etc.).

Topics covered in final exam:

Material from Chapters 22-44 in your text book

Especially material covered in lectures and/or in homework

Tools

Vectors – addition, subtraction, dot product, cross product – especially wrt to **E** and **B** fields and their associated forces

Analysis of circuits using Kirchhoff's rules (direct current and alternating current)

Ray diagrams and interference phenomena for electromagnetic waves

Trigonometry and trig identities

Simple algebra and calculus

See Appendix E of your text

List of (some) of the topics covered:

- Basic ideas of quantum physics -- $E=hf$ for photons, $p=h/\lambda$ for particles and photons; quantum tunneling
- Nuclear physics – radioactive decay, radiation dose, reactions
- Special theory of relativity
- Interference phenomena in EM waves
- Geometric optics
- Reflection and refraction of EM waves
- AC circuits
- DC circuits
- Lorentz force law
- Maxwell's equations; Coulomb's law, Biot-Savart law

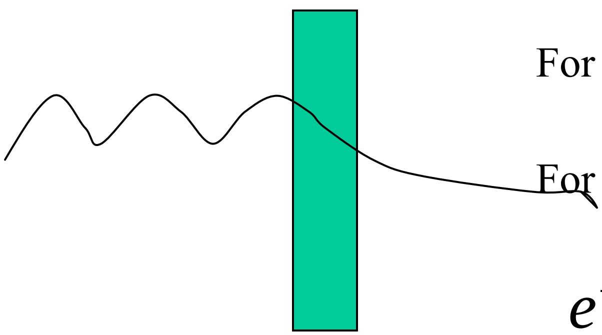
4. [HRW6 39.P.082.] (a) Suppose a beam of 5.0 eV protons strikes a potential energy barrier of height 6.0 eV and thickness 0.70 nm, at a rate equivalent to a current of 1000 A. How long would you have to wait-- on average-- for one proton to be transmitted? (WARNING: this is an EXTREMELY large number!)

(No Response) [4.41e+111] s

(b) How long would you have to wait if the particle was an electron rather than a proton?

(No Response) [2.08e-19] s

$$T = e^{-2kL} \qquad k \equiv \frac{2\pi}{h}\sqrt{2m(U_0 - E)}$$



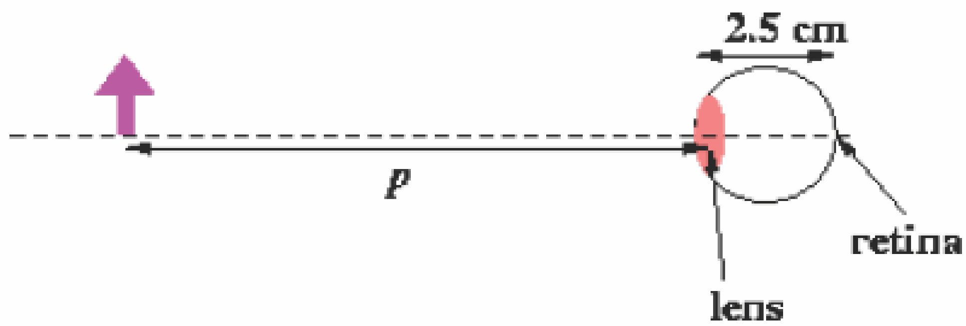
$$\text{For proton}: \quad 2kL = \frac{4\pi \cdot 0.7\times10^{-9}}{6.6\times10^{-34}}\sqrt{2\cdot1.67\times10^{-27}(6-5)\cdot1.6\times10^{-19}} = 308.2$$

$$\text{For electron}: \quad 2kL = \frac{4\pi \cdot 0.7\times10^{-9}}{6.6\times10^{-34}}\sqrt{2\cdot9.11\times10^{-31}(6-5)\cdot1.6\times10^{-19}} = 7.2$$

$$e^{-308.2} = 10^{-\log_{10}(e)308.2} = 10^{-133.84956} = 0.14138\times10^{-133}$$

$$I\Delta t T = 1.6\times10^{-19}\,C$$

$$\Delta t = \frac{1.6\times10^{-19}\,C}{1000C/sT}$$



1.

The figure above shows an idealized diagram of a human eye with a variable focus lens located 2.5 cm in front of the retina. The following questions concern the relationships between the object distance p, the focal length of the lens f, and the image distance i, assumed to be on the retina. To receive full credit for this problem, draw at least one appropriate ray diagram and answer questions (a), (b), and *either (c)* or (d).

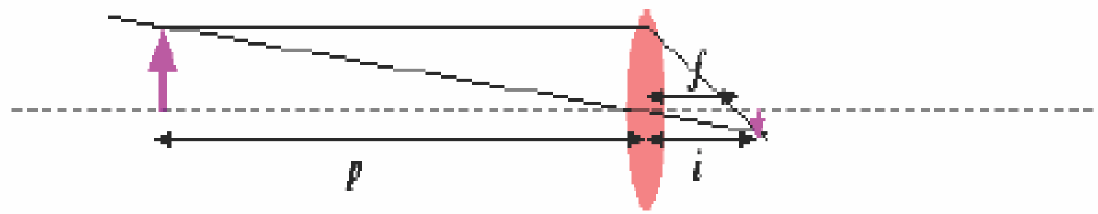
(a) What is the effective focal length of the eye lens for seeing an object 80 cm in front of the eye?

(b) What is the effective focal length of the eye lens for seeing an object 8 cm in front of the eye?

(c) Suppose that the maximum focal length of your eye is 2.3 cm. Using as much quantitative detail as you can, explain how an eyeglass lens placed 1 cm from the eye lens can bring the object at a distance of 80 cm into focus on your retina.

(d) Suppose that the minimum focal length of your eye is 2.0 cm. Using as much quantitative detail as you can, explain how an eyeglass lens placed 1 cm from the eye lens can bring the object at a distance of 8 cm into focus on your retina.

1.



(a) This problem makes use of the thin lens equation

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}. \tag{1}$$

$$\frac{1}{80} + \frac{1}{2.5} = \frac{1}{f} \quad \Rightarrow f = 2.42424\ cm. \tag{2}$$

(b)

$$\frac{1}{8} + \frac{1}{2.5} = \frac{1}{f} \quad \Rightarrow f = 1.90476\ cm. \tag{3}$$

(c) In this case, the focal length should be 2.42424 cm as found above, but can only be 2.3 cm. The lens equation tells us that the focussed image would then be place at 2.368 cm which is to the left of the retina. In order to move the focussed image on to the retina, we need to use a diverging lens. Denote by p_l the position of an object that will be correctly focussed.

$$\frac{1}{p_l} + \frac{1}{2.5} = \frac{1}{2.3} \quad \Rightarrow p_l = 28.75\ cm. \tag{4}$$

We need for the lens to make a virtual image at $-i_l = 28.75 - 1 = 27.75$ cm of the object at 80-1=79 cm.

$$\frac{1}{79} - \frac{1}{27.75} = \frac{1}{f_l} \quad \Rightarrow f_l = -42.776\ cm. \tag{5}$$

(d) In this case, the focal length should be 1.90476 cm as found above, but can be no smaller than 2.0 cm. The lens equation tells us that the focussed image would then be place at 2.6667 cm which is to the right of the retina. In order to move the focussed image on to the retina, we need to use a converging lens. Denote by p_l the position of an object that will be correctly focussed.

$$\frac{1}{p_l} + \frac{1}{2.5} = \frac{1}{2.0} \quad \Rightarrow p_l = 10\ cm. \tag{6}$$

We need for the lens to make a virtual image at $-i_l = 10 - 1 = 9$ cm of the object at 8-1=7 cm.

$$\frac{1}{7} - \frac{1}{9} = \frac{1}{f_l} \quad \Rightarrow f_l = 31.5\ cm. \tag{7}$$

Example: Consider the decay of ${}^{238}_{92}U$:

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th \quad + \quad {}^{4}_{2}He$$

How much energy is released with each decay?

$$Q=(M({}^{238}_{92}U) - M({}^{234}_{90}Th) - M({}^{4}_{2}He))c^2$$
$$=(238.05079 - 234.04363 - 4.00260)\ u\ c^2$$

$$=0.00456\ u\cdot 931.494\ MeV/u = 4.25\ MeV$$

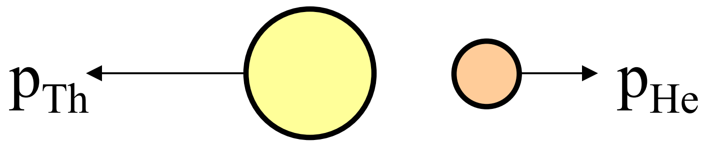
If you have a sample of 10^{23} ${}^{238}_{92}U$ atoms, what is its radio-activity?

$$\left|\frac{dN}{dt}\right| = \lambda N = \frac{\ln 2}{T_{1/2}} N \qquad T_{1/2} = 4.47 \times 10^9\ yr$$

$$\left|\frac{dN}{dt}\right| = \frac{\ln 2}{1.4106 \times 10^{17}\,s} \cdot 10^{23} = 7.09 \times 10^5 \text{ decays/s}$$

Continued: $^{238}_{92}U \rightarrow \; ^{234}_{90}Th + \; ^{4}_{2}He$

How much kinetic energy is carried by the $^{4}_{2}He$ particle?



Relativistic form: $$K = \sqrt{p^2c^2 + m^2c^4} - mc^2$$

Non-relativistic form: $$K = \frac{p^2}{2m}$$

$$p_{Th} = -p_{He}$$

Non-relativistic form: $$Q = \frac{p_{Th}^2}{2m_{Th}} + \frac{p_{He}^2}{2m_{He}} = K_{He}\left(\frac{m_{He}}{m_{Th}} + 1\right)$$

$$K_{He} = \frac{Q}{\frac{m_{He}}{m_{Th}} + 1} = \frac{4.25\ \text{MeV}}{\frac{4.00260}{234.043593} + 1} = 4.18\ \text{MeV}$$

Continued: ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$

If the ${}^{4}_{2}He$ are completely absorbed by a 1 kg mass, what is the radiation dose after 1 year of exposure?

dose = energy absorbed/kg

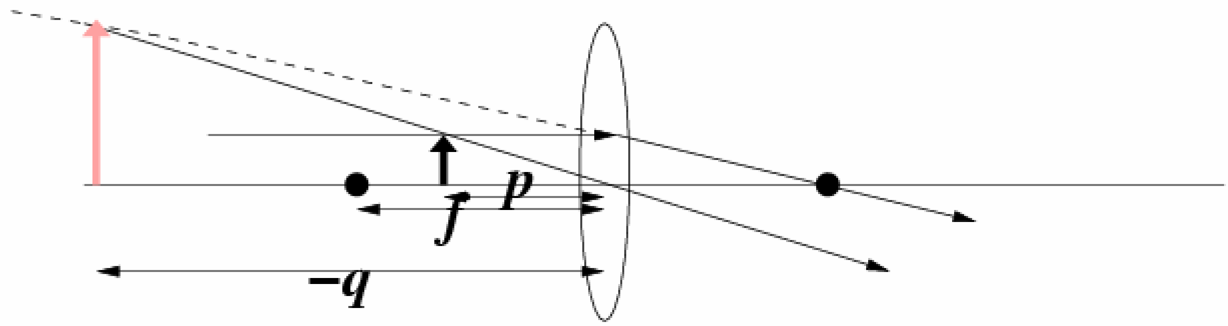
energy absorbed = number of decays · K_{He}

$$N_0\left(1-\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}\right) \approx N_0 \frac{\ln 2}{T_{1/2}} t = 10^{23} \frac{\ln 2}{4.47\times 10^9\, yr} 1yr = 1.55\times 10^{13}$$

dose = $1.55\text{x}10^{13} \cdot 4.18 \text{ x } 10^{6}$ eV $\cdot$ $1.602 \text{ x } 10^{-19}$ J/eV/kg

= 10.4 J/kg

3. The figure above shows Sherlock Holmes looking through a converging lens at a piece of evidence. Assume that the focal length of his lens is $f = 10$ cm. If he adjusts the distance p of the lens relative to the object appropriately, he is able to see the image magnified by 3 times its original size. In the space below, draw the ray diagram for this case, and determine the object and image distances p and q. Indicate whether the image is real or virtual.



3.

The ray diagram is shown above. The image is virtual

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}.$$

$$M = \frac{-q}{p} \quad \Rightarrow q = -Mp.$$

$$\frac{1}{p}\left(1 - \frac{1}{M}\right) = \frac{1}{f}.$$

Solving this expression for p:

$$p = \frac{2}{3}f = 6.67cm.$$

$$q = -3p = -20\ cm$$

Example:

Consider the following observation. Suppose you make an astronomical observation of a star, observing a spectral feature at f'=5x10^{14}cycles/s, knowing that this spectral feature would have a frequency of f=7.5x10^{14}cycles/s in the rest frame of the star. What can you conclude about the velocity of the star relative to the Earth?

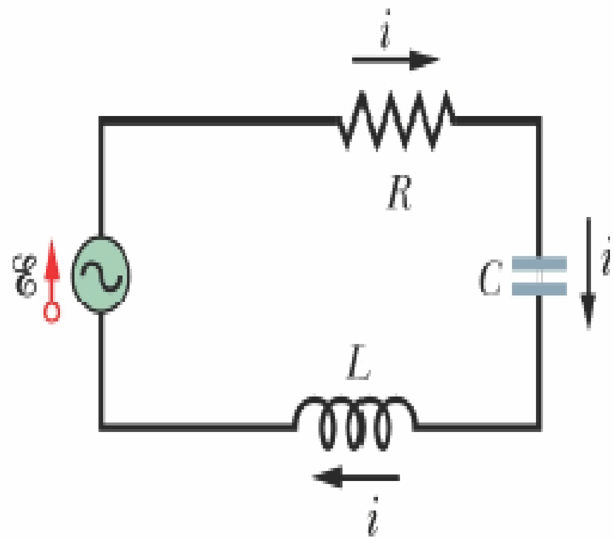
since $f' < f$ → star moving away from Earth

$$\text{Electromagnetic Doppler effect}: \quad f' = f\sqrt{\frac{1-v/c}{1+v/c}}$$

$$v = c\left(\frac{1-\left(f'/f\right)^2}{1+\left(f'/f\right)^2}\right) = 3\times10^8\,m/s\left(\frac{1-\left(5/7.5\right)^2}{1+\left(5/7.5\right)^2}\right) = 1.15\times10^8\,m/s$$

Note: $\lambda = 400$ nm $\quad \lambda' = 600$ nm → "red" shift

1.



The figure on the left shows a series circuit with a resistor $R = 15\Omega$, a capacitor $C = 3.2 \times 10^{-6}$ F, an inductor $L = 4$ H, and an emf $\mathcal{E} = \mathcal{E}_{\max}\cos(\omega_1 t)$, with $\mathcal{E}_{\max} = 75$ V and $\omega_1 = 280$ rad/s. Assume that the circuit has been in operation long enough so that all transient currents are negligible.

(a) What is the maximum current in the resistor?

(b) What is the maximum charge on the capacitor?

(c) What is the maximum voltage through the inductor?

(d) What is rate of power dissipation through the circuit?

1. (a)

$$I_{\max} = \frac{\mathcal{E}_{\max}}{Z}.$$

$$Z = \sqrt{R^2 + \left(\omega_1 L - \frac{1}{\omega_1 C}\right)^2} = 15.506\Omega.$$

$$I_{\max} = \frac{75}{15.506} = 4.8369A.$$

(b)

$$i(t) = I_{\max}\cos(\omega_1 t - \phi) = \frac{dq}{dt}.$$

It then follows that

$$q(t) = \frac{I_{\max}}{\omega_1}\sin(\omega_1 t - \phi) = Q_{\max}\sin(\omega_1 t - \phi).$$

$$Q_{\max} = \frac{I_{\max}}{\omega_1} = 0.01727C.$$

(c)

$$\mathcal{E}_L = -L\frac{dI}{dt} = L\omega_1 I_{\max}\cos(\omega_1 t - \phi).$$

$$\mathcal{E}_L\rfloor_{\max} = L\omega_1 I_{\max} = 5417.33.$$

(d)

$$P = \frac{1}{2}I_{\max}^2 R = \frac{1}{2}(4.8369)^2 \cdot 15W = 175.47W.$$