Announcements

1. Tuesday: 5/6/03 2PM Final exam

   Bring: $\leq$ 5 equation sheets (must turn these in)

   calculator

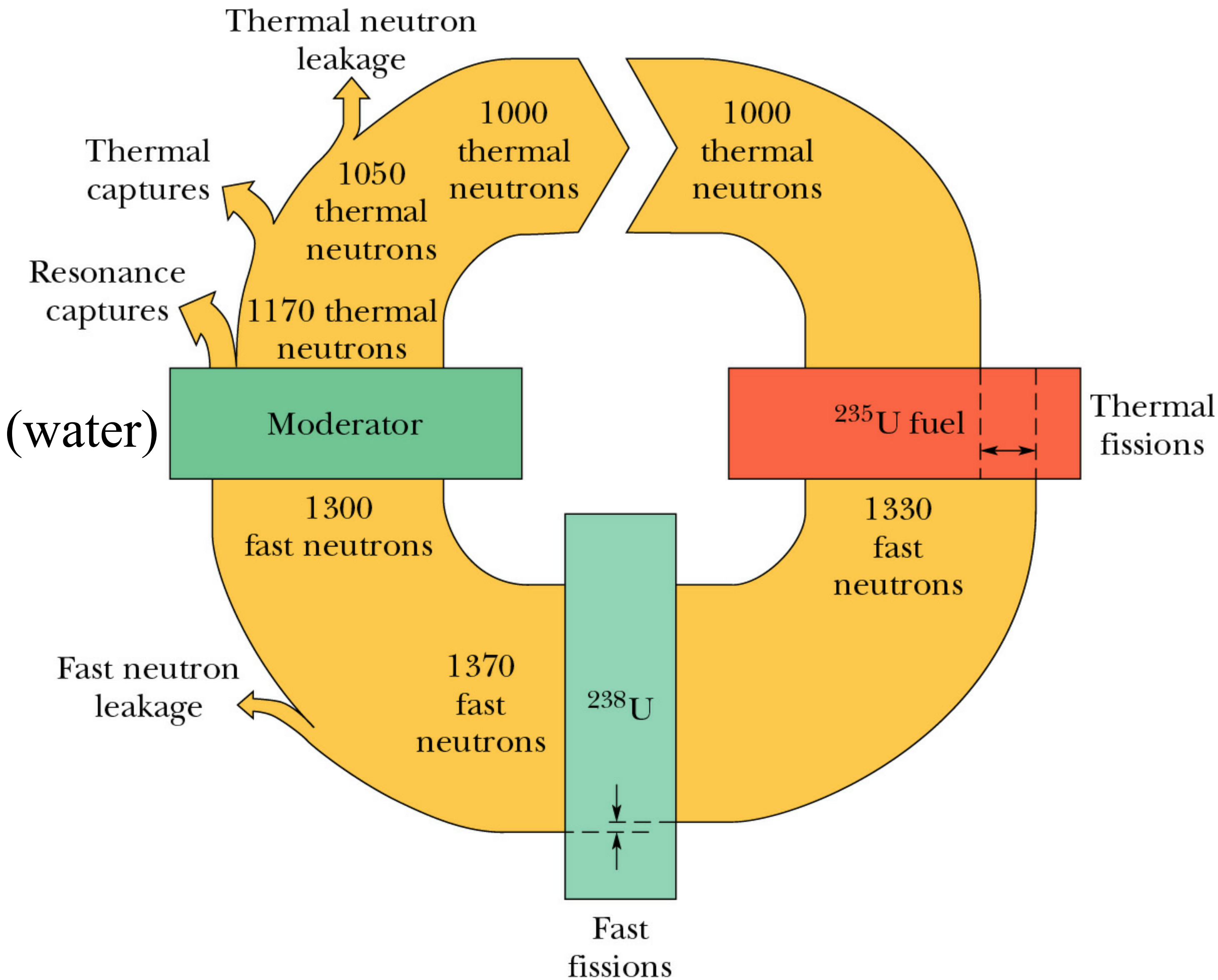
   pencil or pen

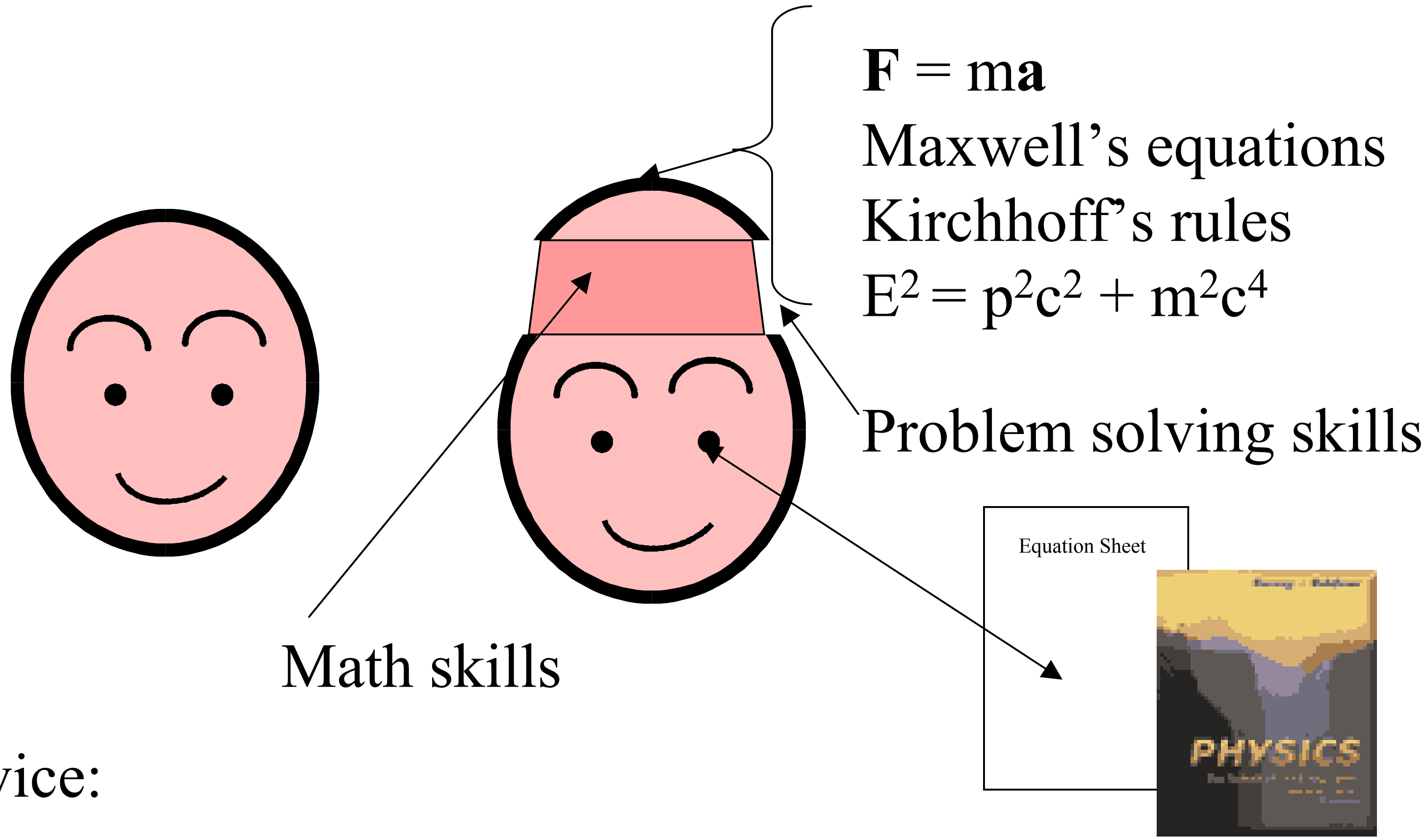
   clear head

   textbook ?? (must remove all extra pages)

2. Advice for studying
3. Example problems

Comment on nuclear reactors: Model for nuclear reactor –





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.

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 34-45 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
- Basic ideas of quantum physics -- $E=hf$ for photons, $p=h/\lambda$
- Nuclear physics – radioactive decay, radiation dose, reactions

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

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

How much energy is released with each decay?

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

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

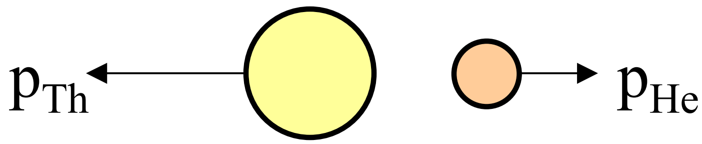
If you have a sample of 10^{23} $^{238}_{92}U$ atoms, what is its radio-activity?

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

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

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

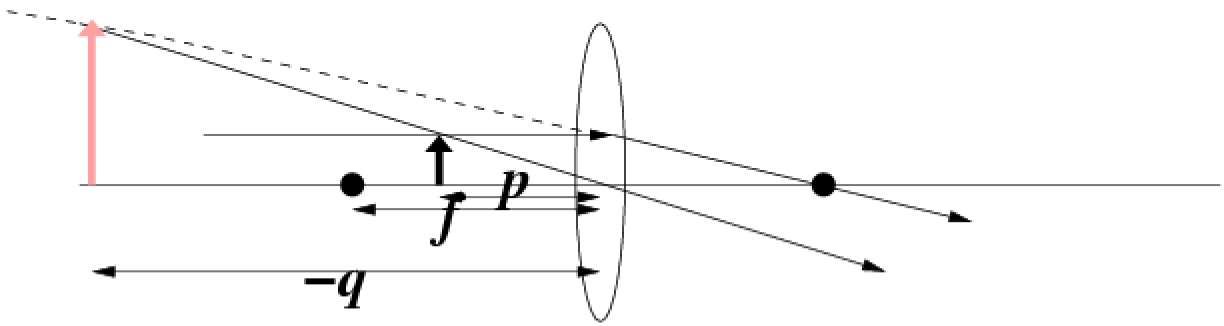
energy absorbed = number of decays · K_{He}

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

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 $f'=5\text{x}10^{14}$cycles/s, knowing that this spectral feature would have a frequency of $f=7.5\text{x}10^{14}$cycles/s in the rest frame of the star. What can you conclude about the velocity of the star relative to the Earth?

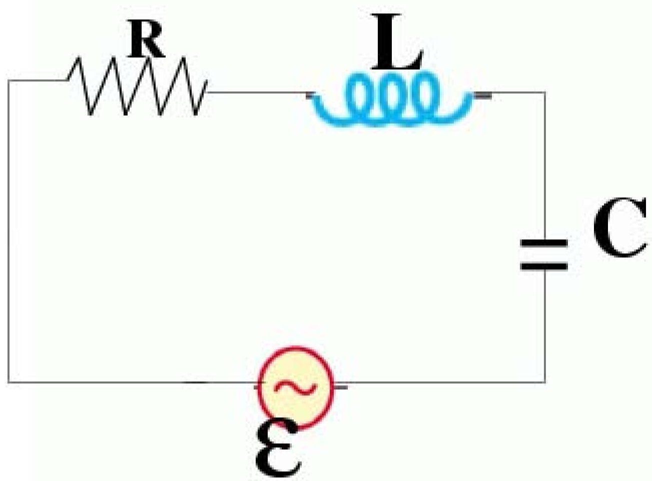
since $f' < f$ → star moving away from Earth

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

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

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

6.



In the circuit diagram shown on the left, the AC emf takes the form $\mathcal{E}(t) = \mathcal{E}_{\max}\cos(\omega t)$, with $\mathcal{E}_{\max} = 300$ V and $\omega = 700$ rad/s. The circuit elements have the values: $R = 0.1\Omega$, $L = 0.006$ H, and $C = 1 \times 10^{-5}$ F.

(a) Write down Kirchhoff's equation(s) for this circuit.

(b) Find an expression for the current $I(t)$ as a function of time, evaluating all of the terms except for the time.

(c) Find an expression for the charge $q(t)$ as a function of time, evaluating all of the terms except for the time.

(d) Substitute your expressions for current and charge into Kirchhoff's equations and verify that the solutions do satisfy these equations.

6. (a)

$$-RI - L\frac{dI}{dt} - \frac{q}{C} + \mathcal{E} = 0.$$

(b)

$$I(t) = \frac{\mathcal{E}_{max}}{Z}\cos(\omega t - \phi).$$

In our case, $Z = \sqrt{(100)^2 + (700 \cdot 0.006 - 1/(700 \cdot 1 \times 10^{-5}))^2} = 170.96\Omega$
$\phi = \tan^{-1}\left(700 \cdot 0.006 - 1/(700 \cdot 1 \times 10^{-5})\right)/100 = -0.94598$ rad.

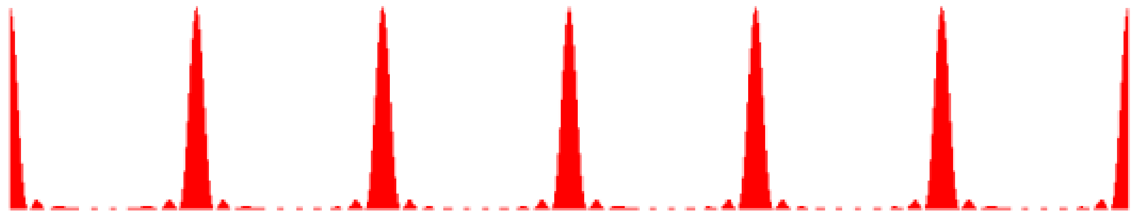
$$I(t) = 1.7548A\cos(700t + 0.94598).$$

(c)

$$q(t) = \frac{1.7548A}{700rad/s}\sin(700t + 0.94598) = 0.002507C\sin(700t + 0.94598).$$

Identify the slit configurations which produce the following diffraction patterns:

1.



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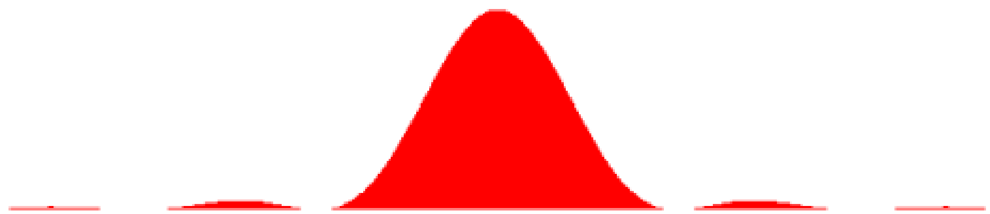

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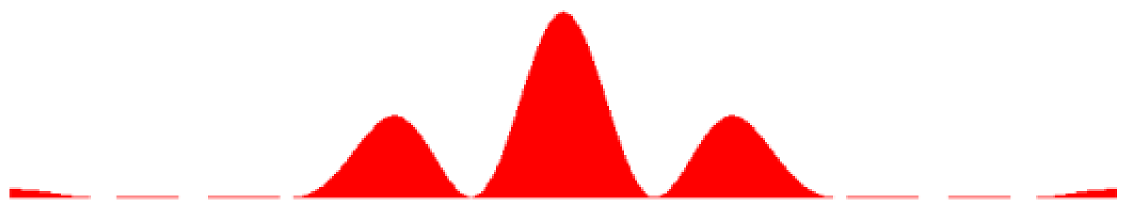

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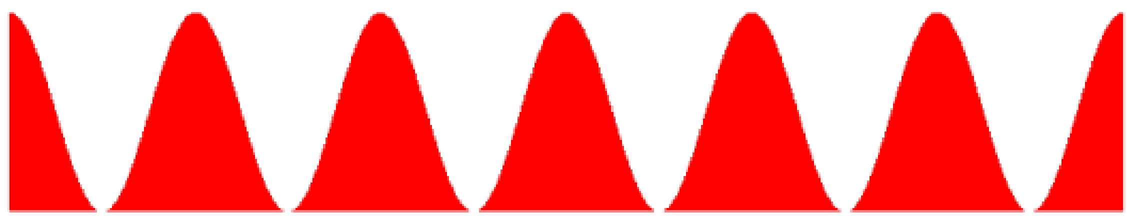
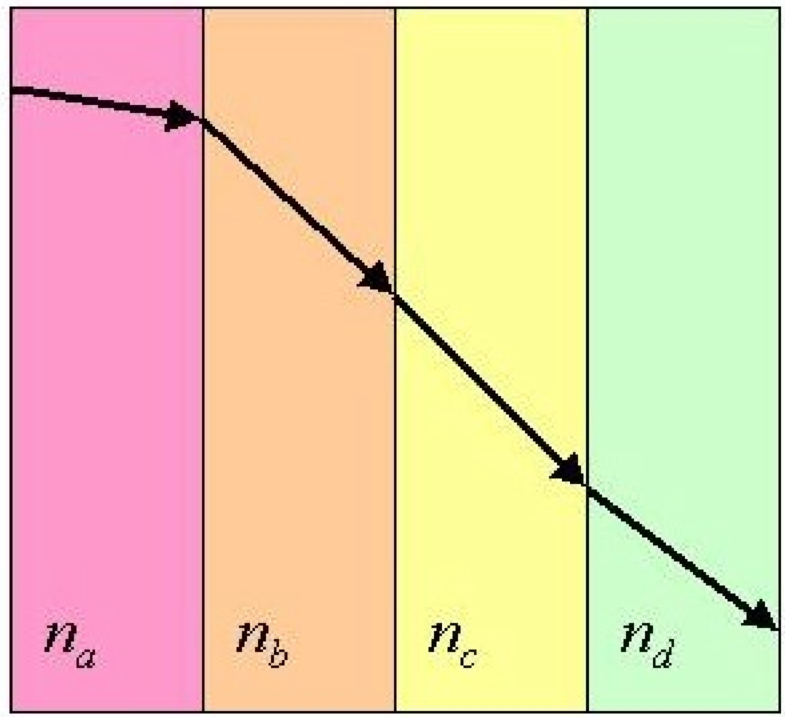


The diagram below represents a ray diagram in various media:



What can you say about the relationship between the various refractive indices?