Physics 122, sections 502-4 and 8101 **Extra problems Solutions**
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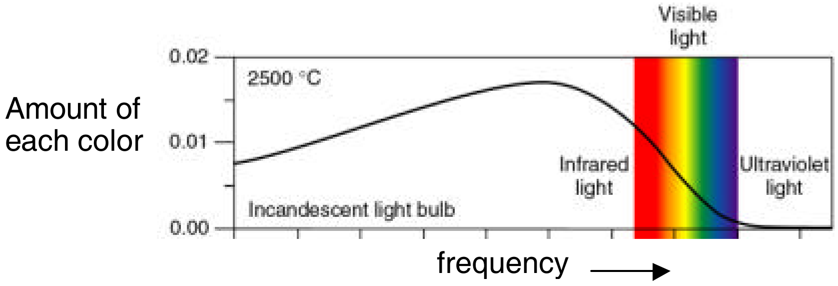
1) (optional. You won't be tested on this material, but it is useful to understand the colors and frequencies stuff.) When a light bulb is on,the filament gets very hot. Hot things emit light (because objects contain charges and when charges wiggle they emit light), and the hotter the object he higher the frequencies the object emits (hotter = faster wiggling.) (People are warm objects and emit light, but mostly in the infrared, too low a frequency to be visible.)

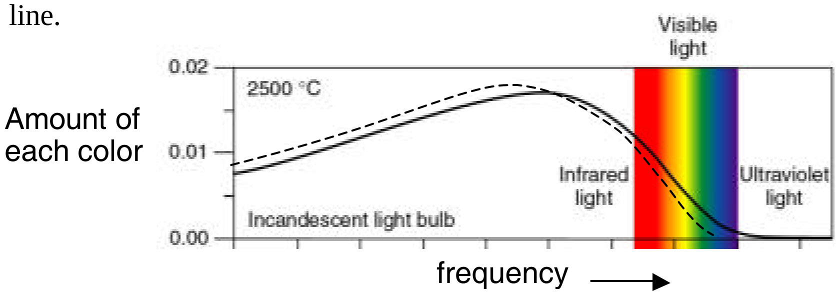
a) For a regular light bulb, the amount of light varies by frequency according to this graph.



What percentage, roughly, of the light is wasted (not useful for lighting things up so you can see them)?

It looks to me like about 10-15 % of the light shown on this graph is useful, visible light. That's the percentage of the area under the line that is visible light. I think more light is emitted at lower frequencies (the line doesn't got to zero in the part of the graph shown), so I'd say less than 10% of the total light emitted is useful.

b) A long-life bulb actually burns a little cooler and has a slightly longer filament. Running the filament cooler makes the filament last longer because filaments "burn out" by slowly evaporating away. (That's why a used bulb gets darker inside. It's the evaporated tungsten from the filament depositing on the inside of the glass.) The graph of colors for the cooler filament looks like the dotted line.



Is the percentage of useful light larger or smaller than for the regular bulb? And why do you need a longer filament?

The percentage of visible light is definitely reduced. The relative area under the dotted line is less in the higher frequencies and more in the lower, infrared frequencies. That's why you need a longer filament. To get the same amount of visible light you need more filament because each little bit is putting out less visible light than before.

c) Two students are talking about the bulbs.

Amy: The regular bulb must use more energy and be less "efficient" because it burns out quicker.
Bonnie: No, the regular bulb is more efficient because it wastes less light. It uses less energy over the same amount of time as the long-life bulb.

With whom do you agree and why?

Bonnie's right. The regular bulb is more efficient because it uses less energy in a given time (uses less power) to get the same amount of visible light. So, to compensate for the convenience of having to change the bulb less often, you are paying a higher electricity bill for the same amount of light. This extra electricity cost turns out to be much higher than the amount of money you might save in buying bulbs if the long-lasting ones cost the same amount of money. But usually they cost even more so you lose out twice!

Other implications of this physics is that when you use a dimmer switch, you are sending less electricity through each bulb, making the filament run cooler and the light dimmer (since you aren't compensating for it by adding a longer filament.) Thus you get less visible light. If you look at the lights while they are dimming, you'll also notice that the lights get more orange as they dim. This is because you are removing more and more of the blue light and leaving only the reds and yellows.

The most efficient light bulbs are the fluourescent bulbs, which convert all of the energy into light. They don't heat up a filament but rather ionize a gas, which emits a single frequency. Usually this is an ultraviolet frequency, and the coatings on the inside of the bulb change the color to visible, but still don't produce infrared or other invisible colors.

2) Suppose you have a light bulb and a concave parabolic mirror.

a) Where should you put the bulb if you want a real image the exact same size as the bulb?
I gave this problem since I want you to practice using the thin lens formula. First though, you should figure out how the image and object distance relate. $d_i/h_i=d_o/h_o$, so if the image and object heights are the same, the image and object distances must also be the same.

To find the image location, try the thin mirror formula. $1/d_i+1/d_o=1/f$, but $d_i=d$ in this case, $1/d_i+1/d_i=1/f$ and $d_i=2f$. This is where the bulb was for that demo where it made a deceptive real image.

b) If the focal length is 10 cm and you put the bulb 3 cm from the mirror, what is the image distance? Where is the image? How big is it and is it real or virtual? $1/d_i+1/d_o=1/f$, means $1/d_i+1/(3\text{ cm})=1/(10\text{ cm})$ gives $d_i=-\ 4.3$ cm. The negative sign means that the image is behind the mirror rather than in front, since the equation assumes the image is in front of the mirror. Make sure you can draw the rays to find the image in the mirror and convince yourself this must be right. $d_i/h_i=d_o/h_o$. From this you see that $h_i/h_o=d_i/d_o$, so the image height is -4.3cm/3cm times the object height. The image is magnified. It's -1.43 times taller than the original bulb. The negative sign means the image is right side up, since the formula we used assumed the image was upside down. Notice that if you didn't have a drawing AND a good understanding of what the formula means and how we got it, you wouldn't be able to interpret these negative signs.

3) In class I explained how a neutron can decay to a proton, since the mass energy of the proton (which is lighter) is less than the mass energy of the neutron. But, we talked about two reasons why there has to be at least one more particle produced in the decay. For practice, explain what those two reasons are and what they would predict about the properties an extra particle or set of particles must have.
Since charge is conserved still, there must be some other negative particle produced. Also, you need a second particle to conserve energy and momentum since the extra energy has to go somewhere and you can't have net zero momentum but net positive kinetic energy with only one particle. An obvious choice, which turned out to be true, was the electron, whose mass is much less than the difference between the neutron and proton masses.

PLUS, it was found experimentally that not all the mass energy was going into the kinetic energies of the proton and electron, so there had to be another particle. This type of decay is called beta-decay. $n \rightarrow p + e + \nu$.

4) The radioactive nucleus we talked about in class was ^{238}U, which has a half-life of 4.5 billion years. . This is the main component of "depleted uranium," natural uranium with most of the ^{235}U removed for use in nuclear reactors and weapons. Natural uranium is found in uranium ore, but it isn't that dangerous to us because it is usually deep underground (it must be mined) and because it doesn't have that much uranium in it (it's not that concentrated.) Once extracted and then depleted, depleted uranium (DU) is very concentrated and also often contaminated with plutonium and other things and thus must be treated as nuclear waste, meaning it must be carefully (and expensively) stored away in shielded containers.

However, rather than spend money storing the DU, the US government and the energy companies have come up with an ingenious plan - use it for weapons so we can get rid of the DU in wars or sell the weapons to other countries (for much profit.) DU is plentiful and 1.7 times more dense than lead and thus easily cuts through armour and buildings. In Iraq, Afghanistan, and Serbia, we used more than 1000 tons of DU.

a) Many human rights organizations have complained about the use of DU. One argument that you might hear (although not from them) is that DU has a 4.5 billion year half-life and as such is a huge radioactive danger. Others argue that it is precisely this long half-life that makes it safe. Evaluate these arguments from what you know about radioactive decay and half-lives.
The decay rate of a substance goes as $\Delta N/Dt=(N_0/t)e-t/\tau$. Since τ is 0.69 times the half-life $\tau_{1/2}$, the fact that there is a $1/\tau$ factor on the decay rate means that DU decays much more slowly than other radioactive materials with shorter half –lives. That means the radioactive hazard due to, say, a gram of DU is much less per second than for a gram of another material that produced equally damaging radiation with a shorter half-life. However, if it is dangerous even at this slow decay rate, the long half-life means it will continue to be dangerous for billions of years – that is, you can't just wait a while and have it be safe.

b) In class we discussed how different types of particles are more dangerous than others because they have different energies and different masses and different charges. ^{238}U emits a series of alphas, betas, and gammas of differing energies. The effect of radiation in humans is measured in "rem" and the effective dose rate is given in rem/hour. This number includes how many particles are being absorbed by the person in an hour, multiplied by how dangerous each particle is. If the air contained tiny particles of DU, the dose rate an average human breathing at an average rate would get would be 11 rem/hour for every gram of DU in each cubic meter of air.

When a Lockheed Martin Bunker Buster bomb, which contains over 1000 kg of DU, explodes, the bits of DU spontaneously ignite. (DU is pyrophoric, which means it spontaneously combusts when hot). The oxidized particles go airborne. If you assume that 70% (a reasonable estimate according to experts) of the DU becomes airborne and takes several days to settle, estimate what total dose (in rem) will the people living near the impact point receive?

According to some estimates I found, weather will spread the DU into about a 200 m radius, and I guessed, conservatively that it would spread upwards as much as 300 m. Probably it will spread upwards less because it is so heavy, but that's a good place to start, I think. So the concentration of the DU will be $1000\text{kg}(0.7)/[\pi(200\text{m})^2 300\text{m}] = 0.018\ \text{g/m}^3$. Thus the dose rate is $0.018\ \text{g/m}^3(11\text{rem/hour per g/m}^3) = 0.2\ \text{rem/hour}$. In three days this means 0.2rem/h(72 hours)=14 rem, 140 times the maximum recommended dose for the general public in a year.

c) The maximum recommended dose of radiation for the general public is 0.1 rem per year. How do these numbers compare?

So we saw, just from breathing for 3 days the dose is 140 times the recommended dose. But then the dust also settles and gets into the food and water supply.

Iraq's cancer rate is up many-fold since the first gulf war. Much of this is accountable for by poor nutrition and weakened immune systems and poor health care under the sanctions. However, breast cancer in girls as young as 12 is tough to explain otherwise. Unfortunately, the radioactive hazards, are even less than the other hazards of DU. It's a heavy metal and leads to heavy metal poisoning and the plutonium contaminants are even more poisonous.