PHYSICS 1020

Homework set 13

3 March 1997

[**13.2**] How can the photoelectric effect be used to open a door when somebody approaches?
Answer:
A light beam crosses the path leading to the door. The light hits a photovoltaic cell, causing a current to flow which keeps the door-opening device in the "off" position. When the beam is interrupted by a person approaching the door, the current stops, and the door-opener switches to the "on" position.

[**13.5**] Explain why,in terms of photons, ultraviolet light can damage cells in your skin but visible light cannot.
Answer:
Ultraviolet photons have more energy, enough to disrupt the chemical processes in the cells of your skin. Remember that the energy carried by a photon is

$$E = hf$$

where f is the frequency and h is Planck's constant.

[**13.6**] Which has greater energy, a microwave photon or a visible photon? About how many times greater?
(consult Fig. 9.7)
Answer:
Microwave radiation has a much longer wavelength, i.e. lower frequency ($\approx 10^{11}$Hz, than visible light $\approx 10^{15}$Hz ; since the energy carried by a photon is proportional to its frequency, a visible photon carries more (about 10000 times) energy than a microwave photon.

[**13.9**] Making estimates: About 10 visible photons are needed to cause a single photosynthesis reaction in living plants. About how much energy is carried by these 10 photons?
Answer:
Since the frequency of visible light is $\approx 10^{15}$Hz, the energy carried by a visible photon is

$$E = hf = (6.6 \times 10^{-34}\mathrm{Js}) \cdot (10^{15}\mathrm{Hz}) = 6.6 \times 10^{-19}\mathrm{J}$$

The energy carried by 10 photons is then 6.6×10^{-18}J.

[**13.12**] If electrons behaved only like particles and not like waves, what pattern would you observe in the double-slit experiment?
Answer:
If electrons behaved like particles rather than waves, they would not show interference, and the pattern observed would be the pattern corresponding to the sum of the single slit patterns, i.e. non-interfering, as shown in Fig. 13.13(a).

[**13.14**] Which has the longer wavelength, an electron or a proton moving at the same speed?
Answer:
The de Broglie wavelength of a particle is inversely proportional to its momentum $p = mv$; since a proton is about 1800 times more massive than an electron, its momentum at the same speed is 1800 times that of an electron, and therefore its wavelength 1800 times smaller. The electron has the longer wavelength.

[**13.16**] If a proton microscope" could be devised, how would you expect its wavelength to compare with the wavelength of an electron microscope?
Answer:
As mentioned in the answer to the previous question, if the protons were moving at the same speed as the electrons, the protons would have a shorter wavelength. If they were moving with the same momentum, they would have the same wavelength.

[**13.20**] What is the percentage probability of getting two heads in a row in fair coin tosses? Of getting five heads in a row? how would you experimentally test your prediction about getting five heads in a row?
Answer:
To make it clearer and less ambiguous, the question should really be worded slightly differently, as follows:
In fair coin tosses, what is the probability of getting two heads when tossing two coins? And what is the probability of getting five heads when tossing five coins? (this is what the book's author really meant).
The answer is:
The probability of getting head with one unbiased ("fair") coin is = 1/2 = 50%. Since the coins are independent, the probabilities multiply; the probability of getting two heads with two coins = the square of the probability of getting head with one coin =

$$(\frac{1}{2})^2 = \frac{1}{4} = 0.25 = 25\%$$

The probability of getting five heads when tossing five coins

$$(\frac{1}{2})^5 = \frac{1}{32} = 0.03125 = 3.125\%$$

To verify this prediction experimentally, you would have to perform many tosses of five coins – at least one hundred. For 100 tosses of five coins, you should observe about three all-heads outcomes. But of course there would be a certain (small) probability that you would get none or six or more!

[**13.25**] Suppose that two electrons travel separately thorough a double-slit apparatus such as shown in Fig.13.19. The first electron hits at the upper end of the interference pattern, and the other hits at the lower end. Is it correct to say that the first electron came through slit A and the second came through slit B? Explain.
Answer:
It would not be correct to say that one electron came through one slit, while the other went through the other; due to the interference between the electron waves, in some sense both electrons go through both slits.