

# Questions and Problems for HW 1

## Assignment

### You only do a subset of these!!

The images below are of questions and problems. I am asking you to do a subset of these and this list is in a separate assignment document.

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#### Questions

1. Write down an equation defining the angular momentum of a particle with position  $\mathbf{r}$  and momentum  $\mathbf{p}$ .
2. Which physical effect or experiment shows that light has a wave nature?
3. Express the kinetic energy  $KE$  of a particle in terms of its momentum  $p$ .
4. What would be the wavelength of a wave described by the function  $u(x, t) = A \sin(2x/\text{cm} - 10t/\text{s})$ ?
5. What would be the frequency of a wave described by the function  $u(x, t) = A \sin(2x/\text{cm} - 10t/\text{s})$ ?
6. What would be the phase velocity of a wave described by the function,  $u(x, t) = A \sin(2x/\text{cm} - 10t/\text{s})$ ?
7. Write down the exponential function corresponding to a traveling wave with a wavelength of 10 cm and a frequency of 10 Hz.
8. Write down a trigonometric function describing a stationary wave with a wavelength of 10 cm.
9. What condition must be satisfied by the difference of the two path lengths for constructive interference to occur for the two-slit interference experiment?
10. How would the interference pattern of a two slit interference experiment change if the distance between the two slits were to increase?
11. Which forms of electromagnetic radiation have a wavelength shorter than visible light?
12. Calculate the frequency of electromagnetic radiation having a wavelength of 10 nm.
13. Write down a formula expressing the energy of a photon in terms of the frequency of light.
14. Write down a formula expressing the energy of a photon in terms of the wavelength of light.
15. What is the energy of the photons for light with a wavelength of 0.1 nm?
16. Suppose that it were possible to increase the charge of an atomic nucleus without increasing the number of electrons. How would the probability cloud around the nucleus change as the charge of the nucleus increased?
17. How long does it generally take for an atom to make a transition?
18. Under what circumstance would an  $\alpha$ -particles be scattered directly backward in Rutherford's experiment?
19. Use the fact that the proton is composed of two up-quarks and a down-quark and the neutron is composed of two down-quarks and an up-quark to find the charge of the up- and down-quarks.
20. In what sense are protons and neutrons composite particles?

## Problems

1. Calculate the frequency of light having a wavelength  $\lambda = 500$  nm.
2. Calculate the energy of the photons for light having a wavelength  $\lambda = 500$  nm.
3. Suppose that a beam of light consists of photons having an energy of 5.4 eV. What is the wavelength of the light?
4. The sinusoidal functions  $\sin nkx$  appearing in Eq. (I.19) may be shown to satisfy the identity

$$\int_0^L \sin mkx \sin nkx dx = \frac{L}{2} \delta_{n,m},$$

where  $\delta_{n,m}$  is the Kronecker delta function defined to be equal to one if  $n$  and  $m$  are equal and zero if  $n$  and  $m$  are not equal. Using this identity, multiply Eq. (I.19) from the left with  $\sin mkx$  and integrate from 0 to  $L$ , to obtain

$$\int_0^L \sin mkx f(x) dx = \frac{L}{2} S_m.$$

This last equation is equivalent to Eq. (I.20).

5. From an experiment in which  $x$ -rays are scattered from a crystal, one finds that the wavelength of the radiation is 1.2 Å. What is the energy of the  $x$ -ray photons?
6. A wave is described by the function

$$\psi(x) = Ae^{i(\alpha x + \beta t)}.$$

What are the wavelength and frequency of the wave in terms of the constants  $\alpha$  and  $\beta$ ?

7. Find the length of the smallest standing wave that can be formed with light having a frequency of 600 THz. Recall that 1 THz =  $10^{12}$  Hz.
8. Suppose an atom makes a transition from a state in which it has an energy  $E_2$  to a state having an energy  $E_1$  where  $E_2 > E_1$ . What is the energy of the quantum of light emitted by the atom? Derive an expression for the wavelength of the emitted light.
9. Consider a light wave with wavelength 400 nm incident on a double slit with distance  $h = 1.2$  μm between the slits. What is the angle of the first two diffraction maxima (beyond the central maximum at  $0^\circ$ )?
10. Using Euler's identity Eq. (I.24) show that adding two waves given by  $y_1 = Ae^{i(kx - \omega t)}$  and  $y_2 = Ae^{i(kx + \omega t)}$  gives a new wave with time-dependent amplitude  $2A \cos(\omega t)$  and position dependence  $e^{ikx}$ .
11. A very sensitive detector measures the energy of a single photon from starlight at 2.5 eV and at the same time measures its wavelength at 495 nm. What is the value of Planck's constant at that far-away star?
12. Write a MATLAB program to plot the function  $y = \sqrt{30}x(1 - x)$  between  $x = 0$  and  $x = 1$ .
13. Using the plotting capability of MATLAB, show that the addition of two waves,  $y_1 = \sin \theta \cos 3\theta$  and  $y_2 = \sin 3\theta \cos \theta$  gives the expected result from the trigonometric identity Eq. (I.17).
14. Following the MATLAB example in the text, plot the first three components of the Fourier series for a square wave together on the same figure. Label each line appropriately.
15. Following the MATLAB example in the text, plot the result of adding together the first three components of the Fourier series for a square wave.