Assignment 8

1. In the 19th century it was believed that light waves travelled through a medium called the ether. This medium had peculiar properties that it existed in outer space but did not exert any drag on the Earth's motion about the sun. The existence of the ether was tested using a Michelson interferometer shown below. For simplicity, assume the distance d from the beamsplitter B to mirror M1 is the same as from B to M2.
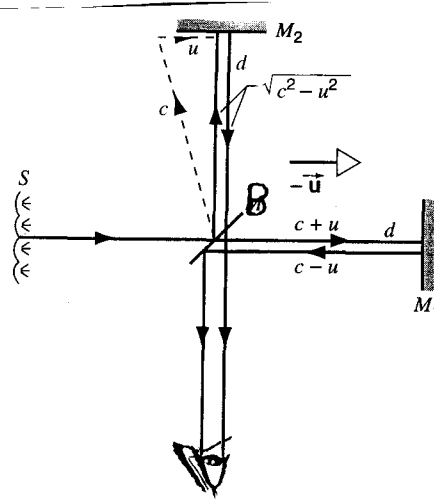

FIGURE 41-21. The "ether" streaming with velocity $-\vec{u}$ through Michelson's interferometer. The speeds shown are based on the (incorrect) ether hypothesis.

a) Suppose the velocity of the Earth around the sun is in the horizontal direction. Hence, an observer on the Earth sees the ether traveling in the opposite direction. Show the times taken for the light signal to travel from

   i) B to M1 and back to B is $t_1 = \dfrac{2d}{c} \dfrac{1}{1 - (u/c)^2}$

   ii) B to M2 and back to B is $t_2 = \dfrac{2d}{c} \dfrac{1}{\sqrt{1 - (u/c)^2}}$

b) If the interferometer is rotated by $90°$, then the time difference Δt between the portions of the detected light travelling in the two arms of the interferometer is reversed. The change in time difference $2\Delta t$ changes the phase which shifts the interference fringes. Show the number of shifted fringes is given by

   $$\Delta N = \dfrac{2d}{\lambda} \left(\dfrac{u}{c}\right)^2$$

c) Find ΔN if $d = 11$ meters and the experiment uses yellow light.

d) The experiment could detect shifts of 0.01 fringes and observed no change at all! What does this tell you about the existence of the ether?

2. A tunable laser is passed through a cavity consisting of two mirrors. The detector measures the following signal.
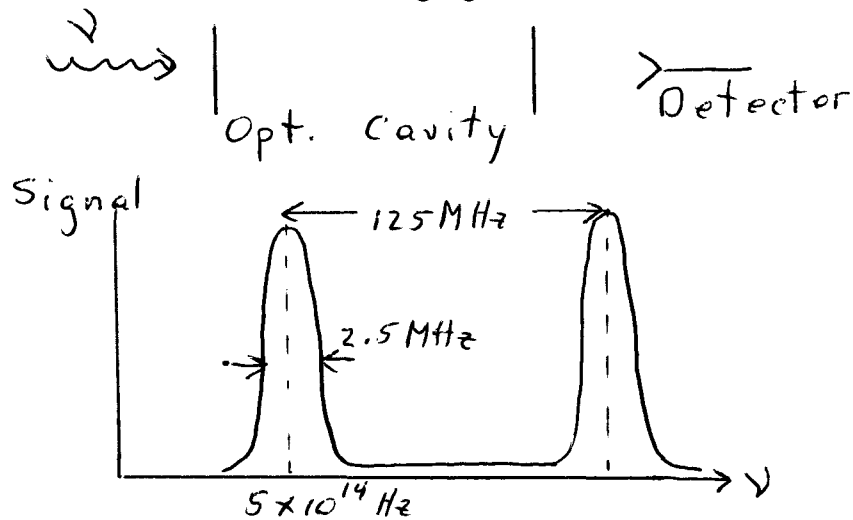
a) What is the wavelength of the laser?

b) How long is the cavity?

c) What is the cavity finesse?

d) What is the Q Factor?

e) If both mirrors have the same reflectivity R, what is R?

3. Light is incident on a pair of slits separated by 0.5 mm. The diffraction signal is observed on a screen 2 meters from the slits. Find the wavelength of light if adjacent maxima of the diffraction signal are 2.5 mm apart.

4. What are the wavelengths of light generated when infrared light generated by a YAG laser when its frequency is a) doubled and b) tripled in a nonlinear crystal?

5. Select one laser (YAG, Ar+, ArF, Diode, Dye etc.) and find the following.

a) Diagram of energy levels involved in generating the laser radiation

b) Diagram of laser components

c) Relevant characteristics
   i. CW or pulsed
   ii. Power or Pulse Energy & duration
   iii. Wavelength

d) Give an example of an application where the laser is used.