**Quiz 1**
**Phy 341**
**Spring 2007**

**Problem #1:** Consider an opaque barrier with 8 slits. The illuminating light has a frequency of $5 \times 10^{13}$ seconds$^{-1}$, and the slits are 0.3 mm apart. The screen on which the light shines is 10 meters away. Number the slits 1 through 8, with 1 at the top and 8 at the bottom. (a) What is the wavelength of the illuminating light? [5 points] (b) When only one slit is open the intensity on the screen is $I_0$. How bright is the midpoint on the screen when all the slits are open? [5 points] (c) Draw the intensity pattern when all the slits are open? [5 points] (d) Draw the configuration of the phasors at EACH of the dark spots on the screen between the central bright spot and the next location up the screen that is equally as bright. Label each phasor with its slit number, and identify what the angle, $\phi$, is between the phasors. [25 points] (e) What are the locations (in centimeters) of these dark spots on the screen? [10 points] (f) What is the brightness at EACH dark spot if the odd numbered slits are covered? ... if the even numbered slits are covered? [10 points] (g) What is the brightness of EACH dark spot if slits 2, 3, 6, and 7 are covered? [10 points] (h) Describe what change you need to make to the wavelength of the illuminating light if you want each dark spot to be twice as far from the midpoint? [5 points] (i) Describe what change you need to make to the distance between the slits if you want each dark spot to be twice as far from the midpoint? [5 points] TOTAL: 80 POINTS.

**Solution:**

(a) The wavelength and frequency have the following relationship, $\lambda f = c$. So the wavelength is,

$$\lambda = \frac{c}{f} = \frac{(3 \times 10^8 \text{ m/s})}{(5 \times 10^{13} \text{ /s})} = 6 \times 10^{-6} \text{ m}.$$  

(b) The brightness at the midpoint is the number of slits squared times the brightness of just one slit. Therefore, with 8 slits, the brightness at the midpoint is $64 I_0$.

(c) The qualitative plot of the intensity pattern with all slits open is,

(d) From the plot above we see there are 7 dark spots between two consecutive maximum bright spots. Remember the phasors fan out like a Chinese fan as you move up the screen from the midpoint.

1st dark spot:
From the plot above we see there are 7 dark spots between two consecutive maximum bright spots.

1st dark spot:

\[ \phi = \frac{\pi}{4} \]

2nd dark spot:

\[ \phi = \frac{2\pi}{4} = \frac{\pi}{2} \]

3rd dark spot:

\[ \phi = \frac{3\pi}{4} \]

4th dark spot:

\[ \phi = \frac{4\pi}{4} = \pi \]

5th dark spot:

\[ \phi = \frac{5\pi}{4} \]

6th dark spot:

\[ \phi = \frac{6\pi}{4} = \frac{3\pi}{2} \]
7th dark spot:

\[ \phi = \frac{7\pi}{4} \]

(e) The locations of the first 7 dark spots up the screen are found by solving \( \phi = \frac{2\pi x \lambda}{\lambda D} \) for \( x \), for each dark spot and angle above. The locations are:

\[ x = \{2.5 \text{ cm}, 5.0 \text{ cm}, 7.5 \text{ cm}, 10.0 \text{ cm}, 12.5 \text{ cm}, 15.0 \text{ cm}, 17.5 \text{ cm}\} \]

(f) From the phasor configurations in part (d) we see that if we cover up either the even slits or the odd slits, all the locations of the dark spots remain dark except for the location of the 4th dark spot. The location on the screen where the 4th dark spot was, now has an intensity of \( 16d_0 \).

(g) Again from the phasor configurations in part (d) if we cover up slits 2, 3, 6, 7, then all the locations of the dark spots remain dark except for the location of the 2nd and 6th dark spots. For these two locations we add up the remaining phasors and get a right triangle with a hypotenuse of \( \sqrt{8} \) A. Therefore, the intensity at the locations on the screen where the 2nd and 6th dark spot were, are now \( 8d_0 \).

(h) From our slit expression, we solve for \( x \), \( x = \frac{\phi \lambda D}{2\pi w} \). The angle between successive phasors does not change if we want the dark spots to be twice as far from the midpoint. Given that \( w \) and \( D \) remain the same, then we need to use an illuminating light source that has twice the wavelength as before. In this case, it means we need \( \lambda = 12 \times 10^{-6} \text{ m} \).

(i) Again from the slit expression, we have that \( x = \frac{\phi \lambda D}{2\pi w} \). Again the angle between phasors at the dark spots remains the same, and \( D \) remain constant. Therefore, if we want the dark spots to be twice as far from the midpoint we need to make the distance between the slits half as much, or \( w = 0.15 \text{ mm} \).

**Problem #2**: There is this "thing ?" called likelihood. An example of likelihood would be whether or not I will die rich. Can it really be called a thing? What does that mean? (5 points) Can it be measured? What does that mean? (10 points) Assuming it can be measured, define a standard and a protocol for comparing likelihoods. (10 points) In your system, if you have two independent events do the likelihoods add? Independent events are ones whose realization does not effect each other. (10 points) TOTAL: 35 POINTS

**Solution**: The issue is whether or not we can get likelihoods into an objectively established ordered set. Can we designate a likelihood and see if it is greater, less than, or equal to the designated likelihood? Many likelihoods are like the example in the problem -- the likelihood that I will die rich. It is inferential and not as objective as it should be. My kids always thought that I was already rich and likely to die that way. My wife was sure that I wasn't rich and didn't think I would be doing any better when I died. In this sense, this likelihood is not objective and thus would not serve as a physics "thing". There are likelihoods that can be agreed upon. The likelihood of dying in an auto accident on a per passenger mile basis on a type of highway and compared with the likelihood of dying in a plane crash on a per passenger mile basis. These can be made objective because you can draw on an experiential base. In fact, you could get a whole range of activities and rank the death likelihood. Working with an experiential base you can apply a quantitative measure expressed as a fraction between zero and one, the probability. You can even get an addition like rule. Two in fact. If the two activities are independent the probability of the joint event is the product of the probabilities. If the two events are independent and alternatives their probability adds.

**Problem #3**: A fluid that pours with difficulty is called viscous. There is a measure of the viscosity called simply the coefficient of viscosity and is measured by the placing the fluid between two parallel plates, one fixed and one free to move.
With a constant force in the direction perpendicular to the plane of the plates on the movable plate sets the movable plate in motion. When it settles down to a uniform velocity, the coefficient of viscosity is defined as the ratio of the force on the plane to the area of the moving plate divided by the ratio of the speed of the movable plate to the separation distance between the plates. In terms of mass, length and time what is the dimensional content of the coefficient of viscosity. (10 points) Blood is a viscous fluid which means that its flow is determined by the viscosity. A blood vessel with a pressure change per unit length of \( P \) has a certain a certain volume of flow per unit time. What is the dimensional content of \( P \) and its units in the MKS system? (10 points) A friend of mine had a heart exam and the physician said that there was a blockage that was reducing its rate of blood flow by 50%. How much of the cross sectional area of the vessel was obstructed. (10 points) Assuming the blockage was spread uniformly around the inside of the vessel, how much was the radius reduced? (5 points) How much blood does your heart pump in a year? (10 points) How much water is pumped by the city of Austin in a year? (10 points) TOTAL: 55 POINTS

\[ \text{Solution: } \text{The coefficient of viscosity is the ratio of a force over an area divided by the ratio of a velocity over a length.} \]

The units of the coefficient of viscosity, \( \nu \), follows from \( \frac{F}{L} \) or \( \frac{m\cdot m/s}{m^2/s} \) or \( \frac{m^2/s}{m^2/s} \). \( P \) is the pressure per unit length. Since pressure is force per unit area \( P \) is force per area or \( P = \frac{F}{A} = \frac{m}{L\cdot T} \). We want a flow or a volume per unit time \( \frac{L^3}{T} \) which is has as its variables \( v \), \( P \) and the area of the blood vessel. Since the flow has no mass units, the general form for the flow must be \( F = (\frac{P}{\nu}) A^b \frac{d}{T} (\frac{1}{L^2})^a \) \( L^2 \) \( V \) \( L \) \( T \). Thus \( a=1 \) and \( b=2 \). Thus the flow scales as the area of the vessel squared. A flow reduction of 50% comes from a reduction of area by 40%. If the blockage is spread around the vessel and the issue is the radius, a reduction of flow by 50% comes from a reduction of the radius by \( \frac{r}{r_0} \) \( \frac{1}{2} \) or \( \frac{r}{r_0} = (1 - \frac{1}{2}) \approx 1 - \frac{1}{8} = \frac{7}{8} \) reduction.

Problem #4: There is this long canyon with steep impenetrable walls. For our purposes infinitely long. The bottom of the canyon is very fertile with an abundance of wildlife including bears. The bears are distributed along the canyon. Each bear has a range. The range is sum of the two half distance between a bear and his neighbors on each side. Basically each bear sits at the center of his range. When a bear has his range reduced he gets hungry and therefore aggressive. Any bear will give up range to a more aggressive bear. Let's make this into a field theory. There are two fields. What are they? (10 points) What is the equilibrium configuration of these fields? (10 points) A new bear is inserted into the canyon between two bears. What happens to the fields? (10 points) Is the effect a local dynamic? Explain. (10 points) What do you need to make a complete quantitative field theory with a local dynamic? (10 points)

TOTAL: 50 POINTS

\[ \text{Solution: In this problem, the most straight forward field theory has the two fields as the range of each bear and the aggression of the bear. The equilibrium configuration of the fields is an equal distribution of range and aggression. If a new bear is introduced, the nearby bears have their range reduced by } \frac{1}{2} \text{ and thus have a new range of } \frac{1}{2} \text{ \( r_0 \) and have an aggression that is greater than their neightobors on the other side from the new bear and will start to take range from them. The new bear has only a range of } \frac{1}{2} \text{ \( r_0 \) and is thus more aggressive than his neighbors on both sides and will take range from them. Thus the initial condition for the fields following the insertion is} \]
We have articulated our dynamic at least partially. In each field, \( A(x,t) \) and \( R(x,t) \), the difference from neighbors drive the other field. In other words, the change in range is proportional to the difference in aggression and conversely the change in aggression is proportional to the difference in range. There is also a length scale in the problem, the range at equilibrium, \( r_0 \).

The missing ingredient is a time scale. A dynamic needs a time scale. The reaction time of the bears. With a time scale and equation like

\[
\frac{\Delta A}{\Delta t} = -\frac{r_0}{\tau} \left\{ \frac{R(x+\Delta x, t) - R(x, t)}{\Delta x} + \frac{R(x-\Delta x, t) - R(x, t)}{\Delta x} \right\}
\]

\[
\frac{\Delta R}{\Delta t} = -\frac{r_0}{\tau} \left\{ \frac{A(x+\Delta x, t) - A(x, t)}{\Delta x} + \frac{A(x-\Delta x, t) - A(x, t)}{\Delta x} \right\}
\]