Workshop Tutorials for Introductory Physics

QI1: **Photons**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
radiation, reflect, discrete, wave, spectrum, electromagnetic, photons, energy, mass, frequency, same, kinetic, 3×10^8, mass, duality, waves

Light, photons and the electromagnetic spectrum

In the 18th and 19th centuries it was believed that light was a _____. Many experiments provided evidence for the wave model of light since they showed that light could refract, _____ and interfere. However, there were other experiments that couldn't be explained by the wave model of light. In 1900 Max Planck proposed that when light was absorbed or emitted it only came in _____ amounts. The particles of light in this model became known as _____.

These photons have no _____, and no charge, but they do have _____. In fact they can have a huge range of energies, and the light that we can see is only a very small part of the _____. Photons are made up of a combination of an electric field and magnetic field which travel around together, and so we call the entire range the _____ spectrum. Photons are the "particles" associated with electromagnetic _____.

One of the interesting things about photons of a given wavelength is that they always travel at the _____ speed in a given medium, e.g. air. Other particles, like electrons, travel faster or slower depending on how much _____ energy they have, but photons always travel at the speed of light, c = _____ms^{-1} in vacuum or in air.

Even though light behaves like particles, it still behaves like _____! When you do some experiments, the light behaves like particles, while during other experiments it behaves like waves. This is a great mystery. Other particles with _____ like electrons and protons, and even whole atoms, also behave like waves. This is called wave-particle _____, and is one of the biggest mysteries of modern physics. For any wave, there is a relationship between the speed, _____ and wavelength given by $c = \lambda \times f$. Usually you need to know two of these to find the third. However, with light, because the speed is always the same, knowing the frequency will tell you the wavelength and vice versa.

Discussion questions
Give an example of an experiment that shows the particle nature of light. Explain why the experiment shows light to be behaving like a particle.
Give an example of an experiment that shows the wave nature of light. Explain why the experiment shows light to be behaving like a wave.

B. Activity Questions:

1. Wave and particle nature of light 1- interference pattern

Observe the interference pattern produced by the laser light passing through the slits.
Does this experiment show the wave nature or particle nature of light? Explain your answer.

2. Wave and particle nature of light 2- emission spectra

Use the spectroscope to examine the spectral lines of the hydrogen lamp.
Which model of light does this experiment support? Explain your answer.

C. Qualitative Questions:

1. Light is commonly described in terms of brightness and colour. Copy and complete the following table by filling in the quantities in the wave and particle models of light which relate to colour and brightness.

	Wave Model	Particle Model
Brightness		
Colour		

2. Humans only see a small part of the electromagnetic spectrum, the visible region. Some insects, such as bees, can also see in ultraviolet and infrared. Humans can only see from blue (around 400 nm wavelength) to red (around 700 nm).

a. Which have the higher energy, red or blue photons?

b. Which have the higher frequency, radiowaves or X-rays?

c. Why are X-rays used to see inside people, rather than visible light?

A major environmental issue at the moment is the release of gases which destroy the ozone layer in the upper atmosphere. A hole regularly forms over Antarctica and the layer is thinning elsewhere.

d. Why is the depletion of the ozone layer a concern?

e. Why is ultraviolet light much more dangerous than infrared of the same intensity?

D. Quantitative Question:

An enzyme called luciferase is used by many animals that produce light, for example fireflies. Fireflies produce a yellow light (with wavelength ~500 nm), while many marine organisms produce a green or blue light.

a. What is the photon energy of the light produced by fireflies? Is it greater or less than that produced by jellyfish?

b. If 10 fireflies are radiating light at a combined power of 0.1mW, how many photons per second is each firefly producing?

c. How is the light produced by 10 fireflies different to the light produced by 1 firefly?

d. How would the light be different if a firefly produced higher energy photons?