**Measurement Disturbance (12.2)**

1) Make a Venn diagram of the equations that you can use for electrons, photons and both.

2) It is harder to see interference with buckyballs than electrons because buckyballs

a) are neutral and harder to accelerate b) are bigger and need bigger slits

c) have smaller wavelengths d) have bigger wavelengths

3) Suppose you want to show your wave-like nature with diffraction as you walk through the doorway. How slowly would you need to move?

a) 1035 m/s b) 1015 m/s c) 10-15 m/s d) 10 -35 m/s

4) Three types of particles with the same momentum – electrons, protons, neutrons - were sent toward double-slits and then detectors. Which showed the greatest spacing between nodes?

a) electrons b) protons c) neutrons d) they were all the same

5) Why have interference effects with tennis balls not been observed?

a) The de Broglie wavelength equation, ****= h/p is only for sub-microscopic objects.

b) The experiment has not been done yet.

c) The de Broglie wavelength for a tennis ball will be much smaller than for an atom.

d) The de Broglie wavelength for a tennis ball will be larger than for an atom.

6) The experiment demonstrating interference of buckminsterfullerene, C60, had the molecules moving at 210 m/s. Each molecule has an atomic mass of 720 atomic units and a diameter of 1 nm. The molecules passed through the slits with widths of 50 nm and separations of 100 nm. After the slits, the molecules travelled 1.25 m before being detected.

a) What is the mass of one molecule?

b) What is the momentum?

c) What is its wavelength?

d) How does this wavelength compare with the size of the molecule?

e) How does this wavelength compare with the size of the slits?

f) What would the distance between fringe maxima be if the screen was 5.0 m from the slits?

**Watch the video Challenge of Quantum Reality from 16:48 – 19:16**

7) If we do measurements to determine which slit an electron went through, we find that

1. half of the electron goes through each slit. b) the whole electron goes through both slits.
2. the whole electron goes through one or the other slit. d) the interference pattern disappears

8) The Tubingen experiment which detected which slit the electron passed through was very subtle. The electrons that passed near one of the two detectors generated a tiny current in that detector. The detectors were at the bottom of the image. Why is the interference pattern visible at the top but not the bottom? ****

**Watch the video from 19:18 – 23:10**

3) For electrons in a double-slit experiment, physicists know

1. where an electron will hit the screen. b) which slit they went through

c) that the electron went through both slits. d) that all interpretations give the same predictions

4) There are competing ideas about what is happening between the source and the detector in the double-slit experiment. In which of the interpretations does an electron go through one and only one slit?

1. Pilot Wave and Collapse b) Pilot Wave and Many Worlds
2. Collapse and Many Worlds d) all three

5) The double-slit experiment is hard to understand because

a) the math is so difficult b) the theory is still new and not fully tested

c) you need to study it in university d) nature does not make sense

6) Wave-particle duality will be better understood

a) after more experiments have been done b) after a better theory is devised

c) it never will be understood d) it never will be understood

**Watch the video from 23:10 – 27: 37**

7) An electron microscope can produce clearer images of significantly smaller objects than a light microscope can because the electrons have a

a) larger frequency b) smaller size. c) slower speed. d) shorter wavelength.

8) Which quantum application has had the greatest effect on your life?

a) solar panels b) transistors c) lasers d) other

9) Quantum physics was needed for the development of

a) computers, electron microscopes b) maglev trains, particle accelerators

c) nuclear energy and bombs d) LED’s, lasers

**Textbook:** p. 659 # 5-7, 16-17, p. 661 # 2, 7, 11, 12, 34, 35

 **Assignment**: How do transmission, scanning and tunneling electron microscopes differ?