**1 2.1 Wave-Particle Duality**

Watch the **Challenge of Quantum Reality** from 3:00 to 6:14[**http://www.youtube.com/watch?v=wihrAjFXg3o**](http://www.youtube.com/watch?v=wihrAjFXg3o)Use the following diagram for the next five questions.

1. . b) c) d)
2. A **water wave** passes through two slits. Which pattern matches the amplitude of the resulting wave?

2) **Sound** is directed toward two slits. Which pattern matches the loudness of the sound after the slits?

1. A beam of **tennis balls** are being fired through two slits and then at a wall. Sketch what it will look like if the balls leave a mark on the wall. Which pattern above can represent the density of marks?
2. A beam of **light** passes through two slits and then at a wall. Sketch what it will look like. Which pattern above can represent the brightness?

 5) A beam of **electrons** passes through two slits and then hit a detector. Sketch what the distribution of electrons will look like. Which pattern above can represent this?

6) Particles are different from waves because particles are

a) spread out and generate an interference pattern in the double-slit experiment.

b) localized and generate an interference pattern in the double-slit experiment.

c) localized and generate a distribution that is the sum of each single-slit distribution.

d) spread out and generate a distribution that is the sum of each single-slit distribution.

Watch the **Challenge of Quantum Reality** from 7:50 -13:51 [**http://www.youtube.com/watch?v=wihrAjFXg3o**](http://www.youtube.com/watch?v=wihrAjFXg3o)7) The double-slit experiment shows that electrons

a) behave like waves and behave like particles. b) behave like waves, but are particles

c) behave like particles, but are waves. d) are both waves and particles**.**

8) What is the equation for the wavelength of an electron?

9) It is easier to see an interference pattern if the electrons

a) travel slower b) travel faster c) speed has no effect on the pattern

10) The photo below shows the interference pattern produced by an electron double-slit experiment. The electrons were sent through a double-slit apparatus with slit separation of 200 nm. The detector screen was 79.0 cm from the double slits. The image has been magnified by a factor of 100.



1. Calculate the wavelength of the electrons using the pattern.

b) Calculate the momentum and velocity of the electrons using the wavelength.

Watch the **Challenge of Quantum Reality** from 14:05-15:23
11) Sketch a light interference pattern. Sketch what it looks like if the intensity is really, really low.

12) The video shows light behaving like a particle. What behaviours show that light behaves like a wave and not like a particle?
a) refraction, interference, polarization b) reflection, interference, polarization
c) reflection, refraction, polarization d) reflection, refraction, interference

Watch the **Challenge of Quantum Reality** from 15:23-16:48

13) The experiment demonstrating the interference of buckminsterfullerene or buckyballs - 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.

(Another experiment by the same group using phthalocyanine - C32 H18 N8 - can be viewed as **Single Molecules in a Quantum Movie** <http://www.youtube.com/watch?v=vCiOMQIRU7I&feature=player_embedded> )

1. What is the mass of one buckyball? (1 amu = 1.660538922 x 10-27 kg.)
2. What is the momentum?
3. What is its wavelength?

d) Draw a scale diagram of the buckyball, its wavelength and the slit widths and separations.

14) 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

15) 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.

16) 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.

**Textbook: 12.2** p. 614 # 1, 6, p. 620 # 1, 2