PhET's Quantum Wave Interference Simulation

http://phet.colorado.edu/en/simulation/quantum-wave-interference
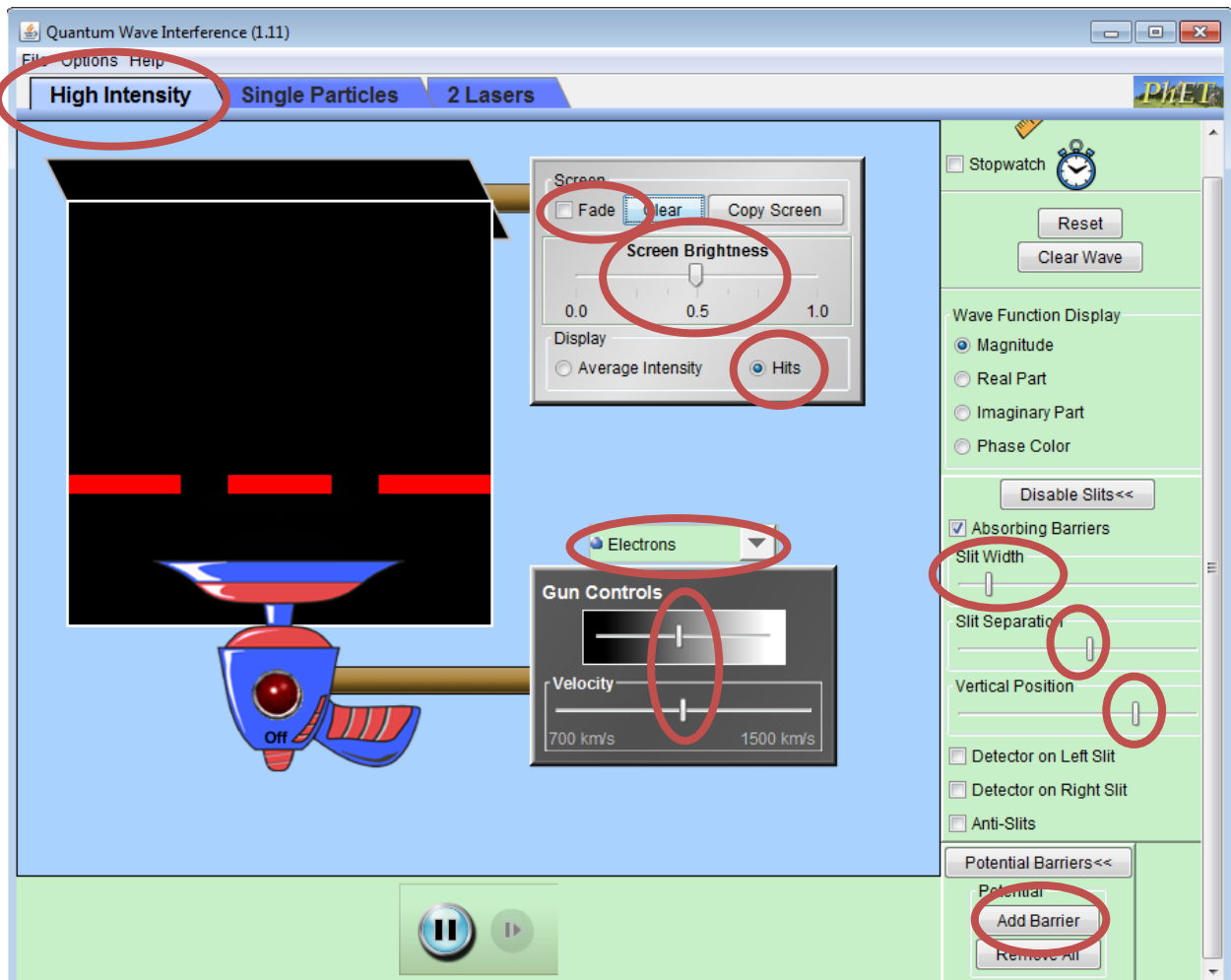
Select settings as follows:

Hit the **Run Now** button. Set up the simulation (using controls from top to bottom):
- high intensity
- screen: hits, medium brightness, no fade
- particles: electrons
- slits: 1/10 width, ½ separation, ¾ vertical (this produces three clear maxima)
- add a potential barrier to block the right slit
- gun: ½ intensity (middle of slider), ½ velocity (default)

An electron gun is set to fire a couple hundred electrons per second. The screen at the back detects the electrons that make it through the slit(s).

1) The right slit is blocked off. If the gun is fired for two seconds you will see about 200 electrons spread over
   a) in a narrow region opposite the slit
   b) mostly on the left half of the screen
   c) only on the left half of the screen
   d) spread evenly over the whole screen

   Prediction and Reason: ……………………………………………………..

   Sketch the Result:

2) If the experiment is repeated the screen will look
   a) exactly the same
   b) almost the same
   c) very different

   Prediction and Reason: ……………………………………………………..

   Sketch the Result:

3) The right slit is opened and the left slit is blocked. Sketch the pattern that will form.

   How does this pattern compare to the previous one?

4) Both slits are uncovered. The screen will show about 400 electrons that hit
   a) evenly across the screen
   b) in one concentrated region fading to the edges
   c) in two concentrated regions. The middle will have few hits.
   d) in three concentrated regions. The middle will have many hits.

   Prediction and Reason: ……………………………………………………..

   Sketch the Result:

   How does this pattern compare to the two single slit patterns?

5) The intensity is reduced so that there will only be one electron going through the slits at a time. The next electron will land
   a) anywhere on the screen
   b) almost anywhere but most likely in the middle third
   c) most likely in the middle or near 0.6 nm or 3.6 nm
   d) most likely near 1.2 nm or 3.0 nm

Prediction and Reason: ………………………………………………………..

Result: …

6) When the intensity of the gun is altered so that only one electron is travelling at a time. What will the pattern look like? You will see
   a) one spread out region that is the sum of the two spread out regions from each slit
   b) three spread out regions because an individual electron acts like a wave
   c) three spread out regions because the electrons ricochet off the slit edges

Prediction and Reason: ………………………………………………………..

Result: ……………………………………………………………………………….

7) A detector is added to the left slit. This will be able to detect whether the electrons went through the left side or the right slit. It will not block the electrons.
   Sketch the Result:

   How does this pattern compare to the two single slit patterns?

8) If you turn the detector off then electron goes through
   a) the left slit
   b) the right slit
   c) either the left or right, but we can't know which
   d) both slits
   e) neither slit

Prediction and Reason: ………………………………………………………..

Result:

9) The wavelength of an electron is given by $\lambda = h/mv$. If the electrons move faster, then the
   a) pattern will get brighter
   b) pattern will get fainter
   c) bright spots will move closer together
   d) bright spots will move further apart

Prediction and Reason: …………………………………………………………..

Result:

10) How will the pattern for just a single slit change as the slit width is decreased? It will become
   a) fainter all over but the same size
   b) fainter all over and narrower
   c) fainter directly opposite the slit
   d) fainter where it diffracts around the slit

Prediction and Reason: …………………………………………………………..

Result:

11) You can't detect a person's wavelength because
   a) people are not waves, that's only for sub microscopic particles
   b) the wavelength is ridiculously big
   c) the wavelength is ridiculously small

Prediction and Reason: ………………………………………………………………….

12) A person's mass is on the order of 100 kg. Typical human speeds are on the order of 10^0 m/s and h is on the order of 10^{-33} Js. A human's wavelength is similar to the size of a
   a) cell   b) atom   c) nucleus   d) proton   e) something else

Prediction and Reason: …………………………………………………………………..

13) Go to the simulation at
http://phet.colorado.edu/new/simulations/sims.php?sim=Quantum_Wave_Interference. Select helium atoms as your particle. On the screen settings choose 'hits', not average intensity and disable the fade option. Add double slits.
   a) At the default settings, how far is the first maximum from the center? Use the ruler.

   b) What are the slit separations and speed of the helium at this setting?

   c) What is the wavelength of helium at this speed?

   d) Calculate how far the slits must be from the screen?

   e) Alter the settings until you get the clearest pattern of central three maxima. Describe in detail what you must do and why to achieve this.

14) The real electron experiment was preformed by A Tonomura in 1989. The electrons were accelerated by a potential difference of 5 x 10^4 m/s V. Do the following calculations non-relativistically. (Details can be found at http://www.hqrd.hitachi.co.jp/em/doubleslit.cfm.)

    a) How fast were these electrons moving?

    b) How fast is that compared to the speed of light? 42 %.

    c) How long would they take to cross the 1 m apparatus?

    d) What was the wavelength of these electrons?

    e) Should relativistic equations be used?

    f) How was the slit set-up in this experiment different from the simulation?

15) 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 slits with widths of 50 nm and separations of 100 nm. After the slits, the molecules travelled 1.25 m before being detected. (More details can be found at http://www.quantum.univie.ac.at/research/matterwave/c60/index.html.)

    a) What is the mass of one molecule?

    b) What is the momentum?

    c) What is its wavelength?

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

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

    f) How far apart would the slits be for the interference of light with a ratio like this?

    g) How far apart would the fringes be separated if the screen was 5 m from the slits?

    h) How far from the center would the first maximum be?

    i) How was the slit set-up different from the simulated experiment?

16) The two-slit experiment illustrated several fundamental concepts in quantum mechanics. Explain what each of these is and how they are demonstrated in the experiments:

    a) Intrinsic Randomness
    b) Measurements Affect Reality
    c) Superposition
    d) Heisenberg's Uncertainty Principle

17) Google "Dr. Quantum double slit". This should take you to a very popular and well-animated version of the electron two-slit experiment. Unfortunately it has the physics seriously wrong in a few places. Describe these.