HOMEWORK 10

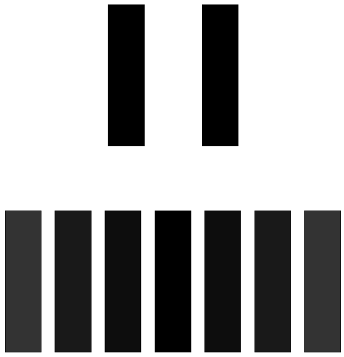
QUANTUM MECHANICS 1

For **Questions 1-6**, state whether the statements about the properties of particles and waves are **True** or **False**.

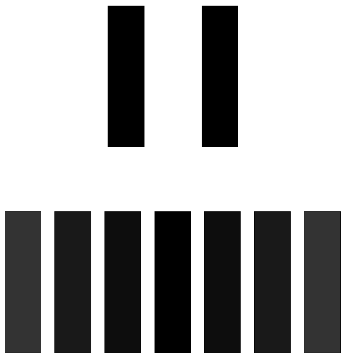
1. Particles are **discrete** (individually separate and distinct).
2. If a particle is too large, its position cannot be well defined.
3. Colliding particles bounce off each other.
4. A wave with a **long wavelength** will also have **high frequency**.
5. Colliding waves interfere with each other.
6. Waves do not have a well defined position.

Questions 7-11 are in reference to an experiment where scientists pass various objects (marbles, light, electron beam) through a **double slit**.

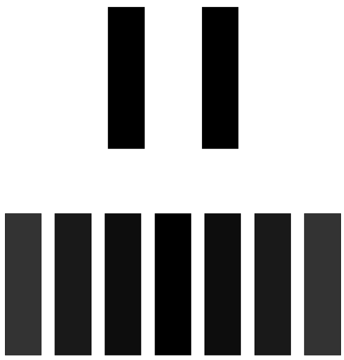
7. Which of the following shows the pattern created by the **marbles** after they pass through the double slit?



8. Which of the following shows the pattern created by the **light** after it passes through the double slit?



9. Which of the following shows the pattern created by the **electrons** after they pass through the double slit?



10. Which property of **light** results in the pattern seen in the double slit experiment?
    a) Energy carried by waves
    b) Continuous frequency spectrum of waves
    c) Uncertainty of wavelength
    d) Constructive and destructive interference of waves

11. Which of the following statements **best** summarizes the conclusion of the double slit experiment with the electron beam?
    a) Electrons have negative charge.
    b) Electrons exhibit particle behavior.
    c) Electrons exhibit the wave property of interference.
    d) Electrons follow the Pauli exclusion principle.

In quantum mechanics, there is a link between the momentum of a particle, and the wavelength of its wavefunction. The *de Broglie equation* describes this connection:

$$\lambda = \frac{h}{p} \tag{10.1}$$

where λ is the wavelength of the wavefunction, p is the momentum of the particle and $h = 6.63 \times 10^{-34}$ kg·m^2/s is Planck's constant. Analyzing the de Broglie wavelength of particles in various systems is key to understanding whether or not it will exhibit quantum mechanical properties. Use Eq 10.1 to answer **Questions 12-16**.

12. A cricket ball has a momentum of 2.5 kg·m/s after being hit by the batter. What is the de Broglie wavelength of the cricket ball?
    a) 2.5 m
    b) 2.65 km
    c) 2.65×10^{-34} m
    d) $2.65 \times 10^{+34}$ m

13. An electron has a momentum of 5.4×10^{-25} kg·m/s. What is the de Broglie wavelength of the electron?
    (a) 1.2 m
    (b) 1.2×10^{-9} m
    (c) 1.2×10^{-34} m
    (d) $1.2 \times 10^{+10}$ m

14. Which of the following statements **best** describes why wave-like behavior is commonly observed in electrons but not for the cricket ball.

    a) The de Broglie wavelength of an electron is much larger than that of the cricket ball.
    b) The de Broglie wavelength of the cricket ball is too large to observe.
    c) The energy of the electron is much higher than the energy of the cricket ball.
    d) Electrons are special and can behave as waves but other particles cannot.

An interesting consequence of the de Broglie wavelength equation is that it can also be applied to light. Because of this, we can assign a momentum to a particle of light, despite the fact that light has no mass. Solve for p in Eq 10.1, and use the result to find the momentum of light in **Questions 15-16**.

15. Red light (in the visible spectrum) has a wavelength of approximately 650 nm (or 6.5×10^{-7} m). What is the momentum (p) of a photon of red light?

    a) 1.02×10^{-27} kg $\cdot$ m/s
    b) 1.02 kg $\cdot$ m/s
    c) 5.72×10^{-23} kg $\cdot$ m/s
    d) 3.84×10^{-15} kg $\cdot$ m/s

16. Carrier waves which carry WiFi internet have a frequency of 5 GHz, and wavelegnth of about 6 cm (6×10^{-2} m). What is the momentum (p) of photons in a WiFi carrier wave?

    a) 6.3×10^{26} kg $\cdot$ m/s
    b) 1.1×10^{-32} kg $\cdot$ m/s
    c) 4.3×10^{-24} kg $\cdot$ m/s
    d) 9.0×10^{-30} kg $\cdot$ m/s