NAME ______________________ DATE ______________ CLASS ______________

Atomic Physics

Problem D

DE BROGLIE WAVES

PROBLEM

A grain of sand blows along a seashore at a velocity of 5.2 m/s. If it has a de Broglie wavelength of 5.8×10^{-29} m, what is the mass of the sand grain?

SOLUTION

Given: $v = 5.2$ m/s $\qquad \lambda = 5.8 \times 10^{-32}$ m

Unknown: $m = ?$

Choose the equation(s) or situation: Use the equation for the de Broglie wavelength, given on page 849.

$$\lambda = \frac{h}{mv}$$

Rearrange the equation(s) to isolate the unknown(s): Rearrange the equation relating wavelength, mass, and velocity to solve for mass.

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34}\ \mathrm{J \cdot s}}{(5.2\ \mathrm{m/s})(5.8 \times 10^{-29}\ \mathrm{m})} = \boxed{2.2 \times 10^{-6}\ \mathrm{kg}}$$

ADDITIONAL PRACTICE

1. A cheetah can run as fast as 28 m/s. If the cheetah has a de Broglie wavelength of 8.97×10^{-37} m, what is the cheetah's mass?
2. A Boeing 747 jet airliner has a maximum airspeed of 7.1×10^{2} m/s. If the airliner has a de Broglie wavelength of 5.8×10^{-42} m, what is the mass of the jet?
3. The smallest known virus is a potato spindle. Suppose a potato spindle moves across a Petri dish at 5.6×10^{-6} m/s and has a de Broglie wavelength of 2.96×10^{-8} m. What is the mass of a potato spindle?
4. Suppose a raindrop falls from the sky at a velocity of 12 m/s and has a de Broglie wavelength of 2.6×10^{-29} m. What is the mass of the raindrop?
5. Calculate the de Broglie wavelength of an electron orbiting the hydrogen atom at a velocity of 2.19×10^{6} m/s.
6. The ship *Queen Elizabeth* has a mass of 7.6×10^{7} kg. Calculate the de Broglie wavelength if this ship sails at 35 m/s.
7. Earth has a mass of 5.94×10^{24} kg and orbits the sun at a velocity of 3.0×10^{4} m/s. Calculate Earth's de Broglie wavelength.
8. Our solar system is within the Milky Way galaxy. Astronomers estimate that our galaxy has a mass of 4.0×10^{41} kg. Calculate the de Broglie wavelength of our galaxy if it were to move at a velocity of 1.7×10^{4} m/s.
9. What is the speed of an electron with a de Broglie wavelength of 9.87×10^{-14} m?
10. What is the speed of a neutron with a de Broglie wavelength of 5.6×10^{-14} m?

Givens	*Solutions*
8. $E_{initial} = E_2 = -2.77$ eV $E_{final} = E_1 = -5.80$ eV	$E = E_{initial} - E_{final} = E_2 - E_1$ $E = -2.77 \text{ eV} - (-5.80 \text{ eV}) = \boxed{3.03 \text{ eV}}$ $E = hf$ $c = f\lambda$ $\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{3.03 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$ $\lambda = \boxed{4.10 \times 10^{-7} \text{ m} = 4.10 \times 10^2 \text{ nm}}$
9. $E_{initial} = E_3 = -1.29$ eV $E_{final} = E_1 = -5.80$ eV	$E = E_{initial} - E_{final} = E_3 - E_1$ $E = -1.29 \text{ eV} - (-5.80 \text{ eV}) = \boxed{4.51 \text{ eV}}$
10. $E_{initial} = E_3 = -1.29$ eV $E_{final} = E_1 = -5.80$ eV	$E = E_{initial} - E_{final} = E_3 - E_1 = 4.51$ eV $\lambda = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{4.51 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$ $\lambda = \boxed{2.76 \times 10^{-7} \text{ m} = 276 \text{ nm}}$

Additional Practice D

1. $v = 28$ m/s $\lambda = 8.97 \times 10^{-37}$ m	$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(8.97 \times 10^{-37} \text{ m})(28 \text{ m/s})} = \boxed{26 \text{ kg}}$
2. $v = 7.1 \times 10^2$ m/s $\lambda = 5.8 \times 10^{-42}$ m	$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(5.8 \times 10^{-42} \text{ m})(7.1 \times 10^2 \text{ m/s})} = \boxed{1.6 \times 10^5 \text{ kg}}$
3. $v = 5.6 \times 10^{-6}$ m/s $\lambda = 2.96 \times 10^{-8}$ m	$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(2.96 \times 10^{-8} \text{ m})(5.6 \times 10^{-6} \text{ m/s})} = \boxed{4.0 \times 10^{-21} \text{ kg}}$
4. $v = 12$ m/s $\lambda = 2.6 \times 10^{-29}$ m	$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(2.6 \times 10^{-29} \text{ m})(12 \text{ m/s})} = \boxed{2.1 \times 10^{-6} \text{ kg}}$
5. $m_e = 9.109 \times 10^{-31}$ kg $v = 2.19 \times 10^6$ m/s	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(9.109 \times 10^{-31} \text{ kg})(2.19 \times 10^6 \text{ m/s})} = \boxed{3.3 \times 10^{-10} \text{ m}}$
6. $m = 7.6 \times 10^7$ kg $v = 35$ m/s	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(7.6 \times 10^7 \text{ kg})(35 \text{ m/s})} = \boxed{2.5 \times 10^{-43} \text{ m}}$
7. $m = 5.94 \times 10^{24}$ kg $v = 3.0 \times 10^4$ m/s	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(5.94 \times 10^{24} \text{ kg})(3.0 \times 10^4 \text{ m/s})} = \boxed{3.7 \times 10^{-63} \text{ m}}$

Givens	*Solutions*
8. $m = 4.0 \times 10^{41}$ kg $v = 1.7 \times 10^{4}$ m/s	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(4.0 \times 10^{41} \text{ kg})(1.7 \times 10^{4} \text{ m/s})} = \boxed{9.7 \times 10^{-80} \text{ m}}$
9. $m_e = 9.109 \times 10^{-31}$ kg $\lambda = 9.87 \times 10^{-14}$ m	$v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(9.109 \times 10^{-31} \text{ kg})(9.87 \times 10^{-14} \text{ m})} = \boxed{7.37 \times 10^{9} \text{ m/s}}$
10. $m_n = 1.675 \times 10^{-27}$ kg $\lambda = 5.6 \times 10^{-14}$ m	$v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(1.675 \times 10^{-27} \text{ kg})(5.6 \times 10^{-14} \text{ m})} = \boxed{7.1 \times 10^{6} \text{ m/s}}$