NAME ______________________ DATE ____________ CLASS ____________

Atomic Physics

Problem D

DE BROGLIE WAVES

PROBLEM

In 1974, the most massive elementary particle known was the ψ' particle, which has a mass of about four times the mass of a proton. If the de Broglie wavelength is 3.615×10^{-11} m when it has a speed of 2.80×10^3 m/s, what is the particle's mass?

SOLUTION

Given: $\lambda = 3.615 \times 10^{-11}$ m $\quad v = 2.80 \times 10^3$ m/s

$h = 6.63 \times 10^{-34}$ J•s

Unknown: $m = ?$

Use the equation for the de Broglie wavelength.

$$m = \frac{h}{\lambda v} = \frac{(6.63 \times 10^{-34}\ \text{J•s})}{(3.615 \times 10^{-11}\ \text{m})(2.80 \times 10^3\ \text{m/s})} = \boxed{6.55 \times 10^{-27}\ \text{Kg}}$$

ADDITIONAL PRACTICE

1. The world's smallest watch, made in Switzerland, has a fifteen-jewel mechanism and is less than 5 mm wide. When this watch has a speed of 3.2 m/s, its de Broglie wavelength is 3.0×10^{-32} m. What is the mass of the watch?
2. Discovered in 1983, Z° was still the most massive particle known in 1995. If the de Broglie wavelength of the Z° particle is 6.4×10^{-11} m when the particle has a speed of 64 m/s, what is the particle's mass?
3. Although beryllium, Be, is toxic, the Be^{2+} ion is harmless. When a Be^{2+} ion is accelerated through a potential difference of 240 V, the ion's de Broglie wavelength is 4.4×10^{-13} m. What is the mass of the Be^{2+} ion?
4. In 1972, a powder with a particle size of 2.5 nm was produced. At what speed should a neutron move to have a de Broglie wavelength of 2.5 nm?
5. The graviton is a hypothetical particle that is believed to be responsible for gravitational interactions. Although its existence has not been proven, cosmological observations and theories indicate that its mass, which is theoretically zero, has an upper limit of 7.65×10^{-70} kg. What speed must a graviton have for its de Broglie wavelength to be 5.0×10^{32} m? (Gravitons are predicted to have a speed equal to that of light.)
6. The average mass of the bee hummingbird is about 1.6 g. What is the de Broglie wavelength of this variety of hummingbird if it is flying at 3.8 m/s?
7. In 1990, Dale Lyons ran 42 195 m, in 3 h, 47 min, while carrying a spoon with an egg in it. What was Lyons' average speed during the run? If the egg's mass was 0.080 kg, what was its de Broglie wavelength?

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Additional Practice D

1. $v = 3.2$ m/s

$\lambda = 3.0 \times 10^{-32}$ m

$h = 6.63 \times 10^{-34}$ J•s

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(3.0 \times 10^{-32}\ \text{m})(3.2\ \text{m/s})} = \boxed{6.9 \times 10^{-3}\ \text{kg}}$$

2. $\lambda = 6.4 \times 10^{-11}$ m

$v = 64$ m/s

$h = 6.63 \times 10^{-34}$ J•s

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

$$m = \frac{h}{\lambda v}$$

$$m = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(6.4 \times 10^{-11}\ \text{m})(64\ \text{m/s})}$$

$$m = \boxed{1.6 \times 10^{-25}\ \text{kg}}$$

3. $q = (2)(1.60 \times 10^{-19}\ \text{C}) = 3.20 \times 10^{-19}$ C

$\Delta V = 240$ V

$h = 6.63 \times 10^{-34}$ J•s

$\lambda = 4.4 \times 10^{-13}$ m

$$KE = q\Delta V = \tfrac{1}{2}mv^2$$

$$m = \frac{2q\Delta V}{V^2}$$

$$v = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(4.4 \times 10^{-13}\ \text{m})(1.5 \times 10^{-26}\ \text{kg})} = 1.0 \times 10^{5}\ \text{m/s}$$

$$m = \frac{2(3.20 \times 10^{-19}\ \text{C})(240\ \text{V})}{(1.0 \times 10^{5}\ \text{m/s})^2}$$

$$m = \boxed{1.5 \times 10^{-26}\ \text{kg}}$$

Givens	*Solutions*
4. $\lambda = 2.5\text{ nm} = 2.5 \times 10^{-9}\text{ m}$ $m_n = 1.675 \times 10^{-27}\text{ kg}$ $h = 6.63 \times 10^{-34}\text{ J•s}$	$mv = \frac{h}{\lambda}$ $v = \frac{h}{\lambda m_n}$ $v = \frac{6.63 \times 10^{-34}\text{ J•s}}{(2.5 \times 10^{-9}\text{ m})(1.675 \times 10^{-27}\text{ kg})}$ $v = \boxed{1.6 \times 10^{2}\text{ m/s}}$
5. $m = 7.65 \times 10^{-70}\text{ kg}$ $\lambda = 5.0 \times 10^{32}\text{ m}$ $h = 6.63 \times 10^{-34}\text{ J•s}$	$mv = \frac{h}{\lambda}$ $v = \frac{h}{\lambda m}$ $v = \frac{6.63 \times 10^{-34}\text{ J•s}}{(5.0 \times 10^{32}\text{ m})(7.65 \times 10^{-70}\text{ kg})}$ $v = \boxed{1.7 \times 10^{3}\text{ m/s}}$
6. $m = 1.6\text{ g} = 1.6 \times 10^{-3}\text{ kg}$ $v = 3.8\text{ m/s}$ $h = 6.63 \times 10^{-34}\text{ J•s}$	$mv = \frac{h}{\lambda}$ $\lambda = \frac{h}{mv}$ $\lambda = \frac{6.63 \times 10^{-34}\text{ J•s}}{(1.6 \times 10^{-3}\text{ kg})(3.8\text{ m/s})}$ $\lambda = \boxed{1.1 \times 10^{-31}\text{ m}}$
7. $\Delta x = 42\ 195\text{ m}$ $\Delta t = 3\text{ h }47\text{ min} = 227\text{ min}$ $m = 0.080\text{ kg}$ $h = 6.63 \times 10^{-34}\text{ J•s}$	$v = \frac{\Delta x}{\Delta t} = \frac{42\ 195\text{ m}}{(227\text{ min})\left(\frac{60\text{ s}}{1\text{ min}}\right)} = \boxed{3.10\text{ m/s}}$ $\frac{h}{\lambda} = mv$ $\lambda = \frac{h}{mv}$ $\lambda = \frac{6.63 \times 10^{-34}\text{ J•s}}{(0.080\text{ kg})(3.10\text{ m/s})}$ $\lambda = \boxed{2.7 \times 10^{-33}\text{ m}}$

II