16 pts.

The Hydrogen Atom

Sol.

1).

$$E_n = \frac{-13.6\,eV}{n^2}$$

$$\Delta E = E_4 - E_1 = \frac{-13.6\,eV}{4^2} - \left(\frac{-13.6\,eV}{1^2}\right) = \boxed{12.8\,eV}$$

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2)

$$E_n = \frac{-13.6\,eV}{n^2}$$, ground state → $n = 1$

$$E_1 = -13.6\,eV$$

$$E_{Final} = -13.6\,eV + 12.1\,eV = -1.5\,eV$$

- We are now looking for which energy level as the energy of $-1.5\,eV$.

$$E_2 = \frac{-13.6\,eV}{2^2} = -3.4\,eV$$

$$E_3 = \frac{-13.6\,eV}{3^2} = \boxed{-1.5\,eV} \quad \boxed{n = 3}$$

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3). Remove electron = ionize

ground state: $E_1 = \frac{-13.6\,eV}{1^2} = -13.6\,eV$

$$\Delta E = 0 - (-13.6\,eV) = \boxed{13.6\,eV}$$

Final state, ionized: $E_\infty = \frac{-13.6\,eV}{\infty^2} \to 0$

4. Same method as Q:3 but this time the initial energy level is $n = 2$.

$$E_2 = \frac{-13.6\,eV}{2^2} \qquad E_\infty = \frac{-13.6\,eV}{\infty} \rightarrow 0$$

$$\Delta E = 0 - \left(\frac{-13.6\,eV}{2^2}\right) = \boxed{3.4\,eV}$$

Matter Waves.

1).

$$p = \frac{h}{\lambda} \rightarrow \lambda = \frac{h}{p}, \quad p = mv$$

$1.32 \times 10^{-34}\,m$

$$\lambda = \frac{h}{m\,v} = \frac{6.6 \times 10^{-34}\,J\cdot s}{(0.50\,kg)(10\,m/s)} = \boxed{\cancel{2.6 \times 10^{-36}}\,m}$$

The reason that we don't see the basketball diffract is that its wave length is much smaller than the hoop. For diffraction to occur $\lambda \approx a$ where a is the diameter of the hoop.

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2).

$$\lambda = \frac{h}{p} = \frac{6.6 \times 10^{-34}\,J\cdot s}{(10^{-4}\,kg)(2 \times 10^{-3}\,m/s)} = \boxed{3.3 \times 10^{-27}\,m}$$

$3.3 \times 10^{-27}\,m$ is 10^{-12} smaller than a proton

3). a. Using the de Broglie relation, $P = \frac{h}{\lambda}$

Explanation
→ we need to find the speed (v) of the student such that diffraction will occur. Assume we need the ~~wavelength~~ wave length of the student to be roughly the same size of the doorway (width).

$$p = \frac{h}{\lambda} \rightarrow mv = \frac{h}{\lambda} \rightarrow v = \frac{h}{m\lambda}$$

$$\lambda \approx 81\,cm = 81 \times 10^{-2}\,m = 8.1 \times 10^{-1}\,m$$

$$m = 81\,kg$$

$$v = \frac{6.6 \times 10^{-34}\,J \cdot s}{(81\,kg) \cdot (8.1 \times 10^{-1}\,m)} = \boxed{1 \times 10^{-35}\,m/s}$$

b). using the speed (v) found above,

$$v = d/t \Rightarrow t = \frac{d}{v}, \quad d = 12\,cm = 12 \times 10^{-2}\,m$$

$$t = \frac{12 \times 10^{-2}\,m}{1 \times 10^{-35}\,m/s} = \boxed{1.2 \times 10^{34}\,s}$$ → a very long time

Just to compare: Age of the universe is $\boxed{4.1 \times 10^{17}\,s}$ ≈ 13 billion yrs.

4). using $p = \frac{h}{\lambda}$

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

1). $E = 1.0\,eV$, $E = \frac{p^2}{2m}$

need to convert to Joules 1st

$$\frac{1.0\,eV \mid 1.6\times10^{-19}\,J}{\mid eV} = 1.6\times10^{-19}\,J$$

$$p^2 = 2mE \rightarrow p = \sqrt{2mE} = \sqrt{2(9.0\times10^{-31}\,kg)(1.6\times10^{-19}\,J)}$$

$$p = 5.4\times10^{-25}\,kg\cdot m/s$$

$$\lambda = \frac{h}{p} = \frac{6.6\times10^{-34}\,J\cdot s}{5.4\times10^{-25}\,kg\,\frac{m}{s}} = 1.2\times10^{-9}\,m$$

$$\boxed{\lambda = 1.2\,nm}$$

1). $E = 1.0\,keV = 1.0\times10^{3}\,eV = 1.6\times10^{-16}\,J$

$$p = \sqrt{2\cdot(9.0\times10^{-31}\,kg)(1.6\times10^{-16}\,J)} = 1.7\times10^{-23}\,kg\,\frac{m}{s}$$

$$\lambda = \frac{6.6\times10^{-34}\,J\cdot s}{1.7\times10^{-23}\,kg\,m/s} = 3.9\times10^{-11}\,m = 39\,pm$$