Q1: What is the wavelength of an electron with kinetic energy $E = 10^4$ eV?

Hint: $M_e = 10^{-30}$ kg, $e = 1.6 \times 10^{-19}$ Coulombs

$$\frac{1}{2}mv^2 = \frac{p^2}{2m} \quad \lambda = \frac{h}{p} \quad p^2/2m = E \quad p = \sqrt{2meE} \quad \lambda = \frac{h}{\sqrt{2meE}}$$

$A_1 = eV = (1.6 \times 10^{-19})(10^4) = 1.6 \times 10^{-15}$ eV/J

$P = \sqrt{2meE}$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meE}} = 6.6 \times 10^{-34} \sqrt{2 \times 10^{-30} \times 1.6 \times 10^{-19} \times 10^4}$$

$$\approx 1.2 \times 10^{-11} \text{ m}$$
Q2: At what angle $\theta_{\text{min}}$ will the electrons from the two slits destructively interfere?

\[ A: \quad d \sin \theta_{\text{min}} = \frac{1}{2} \lambda \]

\[ \sin \theta_{\text{min}} = \frac{1}{2} \frac{\lambda}{d} = \frac{1}{2} \frac{1.2 \times 10^{-4} \text{m}}{10^{-4} \text{m}} = 0.06 \]

\[ \theta_{\text{min}} \approx 3.5^\circ \]

Q3: How many electrons hit $P_{\text{min}}$ per second, with both slits open?

Q4: If I close one slit, letting no electrons through it, do I get fewer electrons at $P$?

\[ A3: \text{None} \]

\[ A4: \text{No, blocking one slit yields more electrons at } P. \]

How can this be?

- Electrons are weird
- This happens even when one electron at a time!
- Each electron goes partly through both slits. Amplitudes cancel.
- Electron diffraction off surfaces really happens

$\sim$ Multiple "Antenna" Sources
Atoms on Surface

DEMO: Electron Diffraction
Q5: Why don't we notice people diffracting? What is \( \lambda \) for a 50 kg physicist jogging at \( v = 2 \text{ m/s} \)?

\[
\lambda = \frac{\hbar}{mv} = \frac{6.6 \times 10^{-34} \text{ kg m}^2/\text{s}}{(50 \text{ kg})(2 \text{ m/s})} = 6.6 \times 10^{-36} \text{ m}
\]

Heavy particles \( \Rightarrow \) short wavelengths
Slits need to be \( \sim \) wavelength to see diffraction
Light passing through windows \( \Rightarrow \) nearly straight
Physicists passing through doors \( \Rightarrow \) no diffraction

Interference effects in light hard to see except for thin slits & light \( \ll \) size of door

Interference effects in sound easy to observe, \( \times \) sound \( \ll \) door size

[LEAVE ROOM] Shout THROUGH DOOR

"That's why it's easy to hear someone even when you can't see me - sound diffracts around edges of doors."

Interference of physicists very hard to observe, because \( \lambda \) physicist is so small.
If electrons and light come in lumps, how can they interfere and diffract?

How come more electrons at \( P_{\text{min}} \) when fewer holes to pass through?

Wave equations \( \Rightarrow \) intensity \( I(y) \) at screen.

\( I(y) \) gives the probability that an electron or photon will hit near \( y \).

For photons, electric fields \( E(y) \) add:
when \( E_L(P_{\text{min}}) + E_R(P_{\text{min}}) = 0 \) no photons.

For electrons, wave functions \( \psi(y) \) add

\[ \psi(x) = "\text{psi} (x)" \]

\[ |\psi(x)|^2 \] is probability that electron is near \( x \)

\( \mathcal{F} \), \( \psi_R(P_{\text{min}}) = -\psi_L(P_{\text{min}}) \), when both slits are open no electrons will hit at \( P_{\text{min}} \).