Solutions to psheet 9

(1) $\Delta x \Delta p_x \geq \frac{\hbar}{2}$

$\Delta p_x = m \Delta v_x$

$$\Delta v_x \geq \frac{\hbar}{2m\Delta x} = \frac{6.63e-34}{2(1e-3)(1e-2)2\pi}$$

$$= 5.28e-30 \text{ m/s}$$

not measurable

b/c takes 10^{20} s to move 1 atomic dist.

$\cancel{\frac{5.28e-30}{1e-2}(4.7 \times 10^{16})} =$

$$= (5.28e-30)(1e2)(4.7e16) \text{ cm/lifetimes.}$$

$$= 2.48e-10 \text{ cm/lifetime}$$

(2) $\Delta p \Delta x \geq \frac{\hbar}{2}$ $\qquad \lambda = \frac{h}{p}$ de Broglie $\Rightarrow \Delta p = \frac{h}{\Delta\lambda}$

$$\frac{\Delta\lambda}{\lambda} = 10^{-6} \Rightarrow \Delta\lambda = (6e-7)(1e-6)$$

$$= 6e-13 \text{ m}$$

$$\Delta p \Delta x \geq \frac{\hbar}{2}$$

$$\Delta x \geq \frac{\hbar}{2\Delta p}$$

$$\geq \frac{\hbar}{2h}\Delta\lambda$$

$$\geq \frac{\Delta\lambda}{4\pi}$$

$$\geq \frac{6e-13}{4\pi}$$

$$\geq 4.8e-14 \text{ m.}$$

(2)

(3) $h = 2\pi \Rightarrow \hbar = 1 \qquad \Delta x \, \Delta p_x \geq 1/2$

(a) $m \Delta v \, \Delta x \geq \frac{1}{2} \qquad \Delta x = 1\text{m} \qquad m = 2\text{kg}$

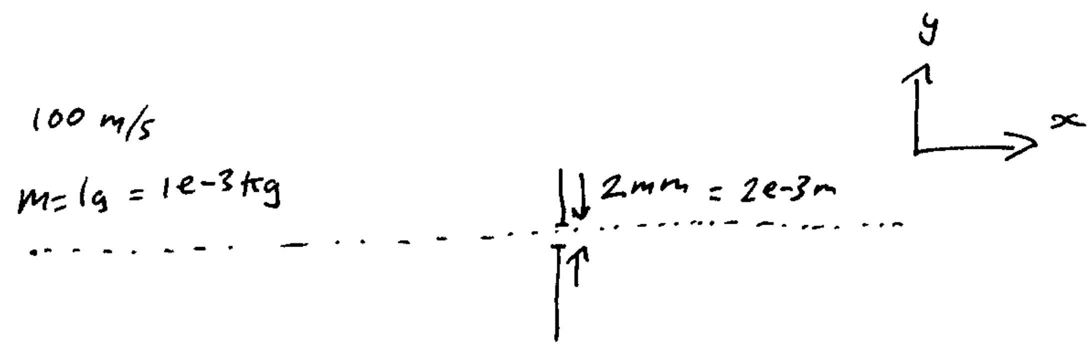
$\Delta v \geq \frac{1}{2} \cdot \frac{1}{1} \cdot \frac{1}{2}$

$\Delta v \geq \frac{1}{4}$

(b) Didn't cover in lectures, so forget about it

$(\Delta E \Delta t \geq \frac{\hbar}{2})$

(4)



$m \Delta v_y \Delta y \geq \frac{\hbar}{2}$

2 mm

$\Delta v_y \geq \frac{\hbar}{2 m \Delta y} \geq \frac{6.63e{-34}}{4\pi (1e{-3})(2e{-3})}$

$\geq 2.6 e{-29}$ m/s

want spread of 1e-3 m in y-dirn

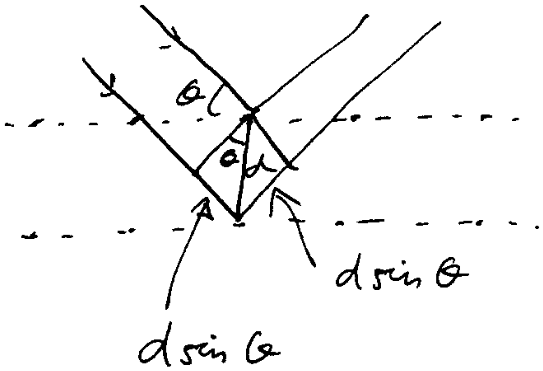
$\Rightarrow$ takes at least $\frac{1e{-3}}{2.6 e{-29}} = 3.8 e25$ s

In this time,
the bullet will have travelled

$(3.8e25)(100) = 3.8e27$ m

Which is several times the size of the universe.

(5)



path length difference $= d\sin\theta + d\sin\theta$

$= 2d\sin\theta$

$= (n)\lambda$ for constructive interference

the order of interference. Bigger n gives weaker signal.

(6) (a) $2d\sin\theta = n\lambda$

$n=1$ first order

$$d = \frac{\lambda}{2\sin\theta} = \frac{1.39\,\text{Å}}{2\sin 14.3} = 2.8\,\text{Å}$$

(b) Pressure $= E\,\frac{\Delta L}{L}$ ← L lattice spacing 2.8 Å

Pressure: Force/Area $= \frac{359}{10^{-4}\,m^2}$

$10^{-4}\,m^2$: 1cm x 1cm crystal

E: Young's modulus $= 34\,GN/m^2$

$$\Delta L = \frac{(359e\cancel{4}^{-5})(2.8e{-10})}{(34)} = 2.96e{-14}$$

so lattice const increases by 3e-14m

$d = 2.8 + 3e{-4}$

calculate θ as for part a.