(1)

(a) Each rocket will cross the dotted line in a time:

$$\Delta t_0 = \frac{L}{s} \quad \text{where } L \text{ is the rocket length in the observer's frame.}$$

Note: Δt_0 is a proper time for the observer.

$$L = \frac{L_0}{\gamma} \qquad \left(\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-(0.850)^2}} = 1.898 \right)$$

$$= \frac{200\,m}{1.898} = 105.3\,m$$

$$\Delta t_0 = \frac{105.3\,m}{0.850c} = 413\,ns \checkmark$$

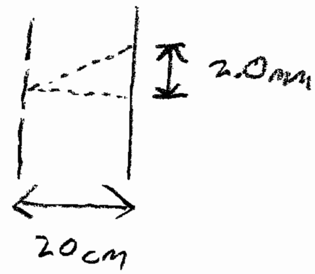
(b) $$\Delta t = \gamma \Delta t_0 = 784\,ns \checkmark$$

(c) $$u = \frac{u' + v}{1 + \frac{u'v}{c^2}} = \frac{-0.850c + (-0.850c)}{1 + \frac{(-0.850c)(-0.850c)}{c^2}} = -0.987c \checkmark$$

② Working with the $m=0$ interference minimum.

$$d\sin\theta = \left(m+\tfrac{1}{2}\right)\lambda$$

$$\tan\theta = \frac{2.0\,\text{mm}}{20\,\text{cm}} = \frac{1}{100}$$



$$d = \frac{1}{2}\frac{\lambda}{\sin\theta} = 50\lambda$$

$$\sin\theta \approx \tan\theta = \frac{1}{100}$$

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

$$E = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mE}$$

$$\lambda = \frac{h}{\sqrt{2mE}} = \frac{hc}{\sqrt{2(mc^2)E}} = \frac{1240\,\text{eV}\cdot\text{nm}}{\sqrt{2(511\cdot10^3\,\text{eV})(5.0\,\text{eV})}} = 0.549\,\text{nm}$$

use this if you like.

I'll use this version, instead.

$$d = 50(0.549\,\text{nm}) = 27.5\,\text{nm} \checkmark$$

$$a\sin\theta = m\lambda \quad \text{(I'll pick } m=1\text{)}$$
$$d\sin\theta = m\lambda \quad \text{(I have to use } m=10\text{)}$$

$$a\sin\theta = \lambda$$
$$d\sin\theta = 10\lambda$$

$$\frac{a}{d} = \frac{1}{10} \quad \text{(independent of wavelength)}$$

$$a = \frac{d}{10} = 2.75\,\text{nm} \checkmark$$

$a = 2.75\,\text{nm}$ for any particle ✓

③ $E = \frac{h^2}{8mL^2} n^2 \Rightarrow L = \frac{hn}{\sqrt{8mE}}$

Use: $n = 3$

$m = M_{electron}$

$E = 1.92 \cdot 10^{-16}\ J$

$= 5.32 \cdot 10^{-11}\ m$ ✓

$\lambda = \frac{2L}{n} = 3.55 \cdot 10^{-11}\ m$ ✓

$P = \Delta x\, \psi^2 = \Delta x \frac{2}{L}\left(\sin^2 \pi \frac{x}{L}\right)$

$= \left(\frac{L}{20}\right)\frac{2}{10} \sin^2 \pi \frac{L/4}{L} = \frac{1}{10} \sin^2 \frac{\pi}{4} = \frac{1}{20}$ ✓

We're given: $E_3 = 1200\,eV$

$E_2 = (1200\,eV)\frac{2^2}{3^2} = 533\,eV$

$E_p = E_3 - E_2 = 667\,eV$

$\lambda = \frac{c}{f} = \frac{c}{E_p/h} = \frac{hc}{E_p} = 1.86\ nm$ ✓

(4) (a) Event #1: light leaves emitter
Event #2: light arrives at mirror

$$\Delta t = \gamma\left(\Delta t' + \frac{v}{c}\frac{\Delta x'}{c}\right)$$

$v = 0.95c$
$\gamma = 3.2$

Δt: Bridget's frame
$\Delta t'$, $\Delta x'$: Belinda's frame

$\Delta x' = +2.0\,m$

$$\Delta t' = \frac{2.0\,m}{c} = 6.67\,ns$$

$\Delta t = 41.6\,ns$ ✓

(b) $$\Delta t = \gamma\left(\Delta t' + \frac{v}{c}\frac{\Delta x'}{c}\right)$$

Event #1: light leaves mirror
Event #2: light arrives at emitter

$\Delta x' = -2.0\,m$

$\Delta t'$, v, γ are the same as in part (a).

$\Delta t = 1.07\,ns$ ✓

Extra: Let the time for the light to make the round trip be ΔT

Belinda: $\Delta T_{Bel} = 2 \times \left(\frac{2.0\,m}{c}\right) = 13.3\,ns$

Bridget: $\Delta T_{Brid} = \gamma\,\Delta T_{Bel} = 42.7\,ns$

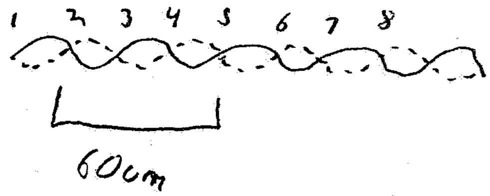
but we should also be able to say...

$\Delta T_{Brid} = \Delta t_{part\,a} + \Delta t_{part\,b}$
$= 41.6\,ns + 1.07\,ns = 42.7\,ns$ ✓

Multiple Choice and Short Answer

(1) a ✓

(2)



$$60\,cm = 3\left(\frac{\lambda}{2}\right)$$

$$\lambda = \frac{2}{3}(60\,cm) = 40\,cm$$ ✓

(3) $v_m = \omega x_m = 2\pi f x_m = 1.3\ m/s$ ✓

(4) $\omega = 10\ s^{-1}$ $\quad T = \frac{1}{f} = \frac{2\pi}{\omega} = 0.63\,s$ ✓

(5) c ✓

(6) $v = \sqrt{\frac{\tau}{\mu}}$ $\quad \tau = v^2\mu = (\lambda f)^2\mu = (2Lf)^2\mu$ ✓

(7) $f' = f\,\frac{v \pm v_D}{v \pm v_S} = (5.0\,Hz)\,\frac{2.0\,m/s + 10\,m/s}{2\,m/s} = 30\,Hz$ ✓

(8) $\vec{E}$ points along $-z$

$\vec{B}$ points along $-x$

(9) fastest medium is #3

slowest medium is #2

(10) $|m| = 3 \Rightarrow i = 3p = 1200\ mm$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{i} \Rightarrow f = 300\ mm$ ✓

(11) b ✓

(12) II, IV ✓

(13) d ✓

(14) $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \Rightarrow$ λ decreases by half ✓

(15) $E = mc^2$

$m = \frac{E}{c^2} = \frac{P \Delta t}{c^2} = 3.6 \cdot 10^{-8}\ kg$ ✓

(16) $\left.\begin{array}{l} d \sin\theta = 3\lambda \\ a \sin\theta = 2\lambda \end{array}\right\}$ $\frac{d}{a} = \frac{3}{2}$

$d = \frac{3}{2}a = 1200\ nm$ ✓