River Robles

Name UID

1.	2.	3.	Total
40	29	29.5	98.5

excellent

Physics 1CH Midterm #1

April 27, 2017

On all problems, you need to show your work to get full credit.

Below are a set of numerical constants. If you have any questions, please raise your hand to ask for help.

Acceleration of gravity (Earth)	g	$10.0\ m/s^2$
Boltzmann constant	k	1.38×10^{-23} J/K
Electron charge	e	1.60×10^{-19} C
Electron mass	m_e	9.11×10^{-31} kg
		$0.511\ MeV/c^2$
Electron-volt	eV	1.60×10^{-19} J
Permeability of free space	μ_o	$4\pi \times 10^{-7}\ N/A^2$
Permittivity of free space	ε_o	$8.85 \times 10^{-12}\ C^2/N\text{-}m^2$
Planck constant	h	6.63×10^{-34} J-s
Proton mass	m_p	1.67×10^{-27} kg
		$938\ MeV/c^2$
Speed of light in vacuum	c	3.00×10^{8} m/s
Speed of sound in air (20° C)	v_s	340 m/s

Small angle approximation (θ in radians):

$$\sin(\theta) \approx \tan(\theta) \approx \theta$$

Problem 1: Short Answer (40 points total):

a) True or False. In an electromagnetic wave in a vacuum, the electric and magnetic fields are in phase and the electric and magnetic field vectors, $\vec{E}$ and $\vec{B}$, are equal in magnitude. Explain your answer.

False. The first statement is true as a result of Maxwell's Equations (Specifically Ampere's Law and Faraday's Law), but the magnitudes are not equal. Specifically, in vacuo, $|E| = c|B|$.

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b) No matter where you stand in front of a certain mirror, your image appears upright. What type of mirror could this be: convex, concave, or planer, or more than one of these? Explain your answer.

This is convex or planar. The reaso is that an upright image corresponds to a virtual image. Generally, convex and planar mirrors will never focus light beams, they always tend to drive them apart and thereby form an upright virtual image behind the mirror. We see this in the math as well, convex mirrors have a neg. f, so b/c o is positive, i is always negative $\left(\frac{1}{i} = \frac{1}{f} - \frac{1}{o}\right)$. Planar mirrors have $f = \infty$, so a positive o means $\left(\frac{1}{i} = -\frac{1}{o}\right) \Rightarrow i < 0$.

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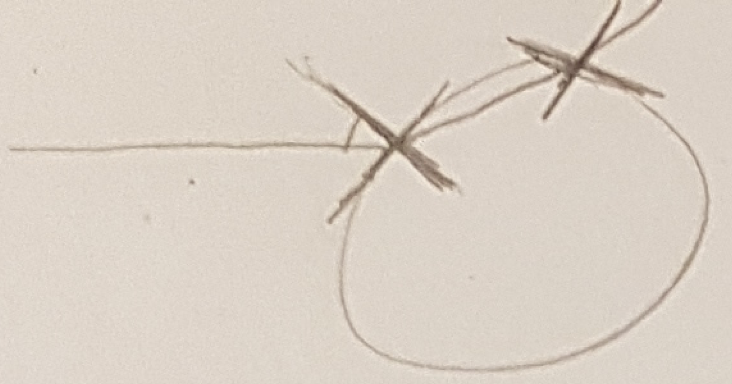
Concave mirrors only form virtual upright images when the object is inside the focal length.



Problem 1 (continued):

c) Light shines through a spherical air bubble that is under water. What type of optical device does the bubble act like: converging, diverging, or planar? Explain your reasoning (there are several different ways to explain this and a good figure would really help).

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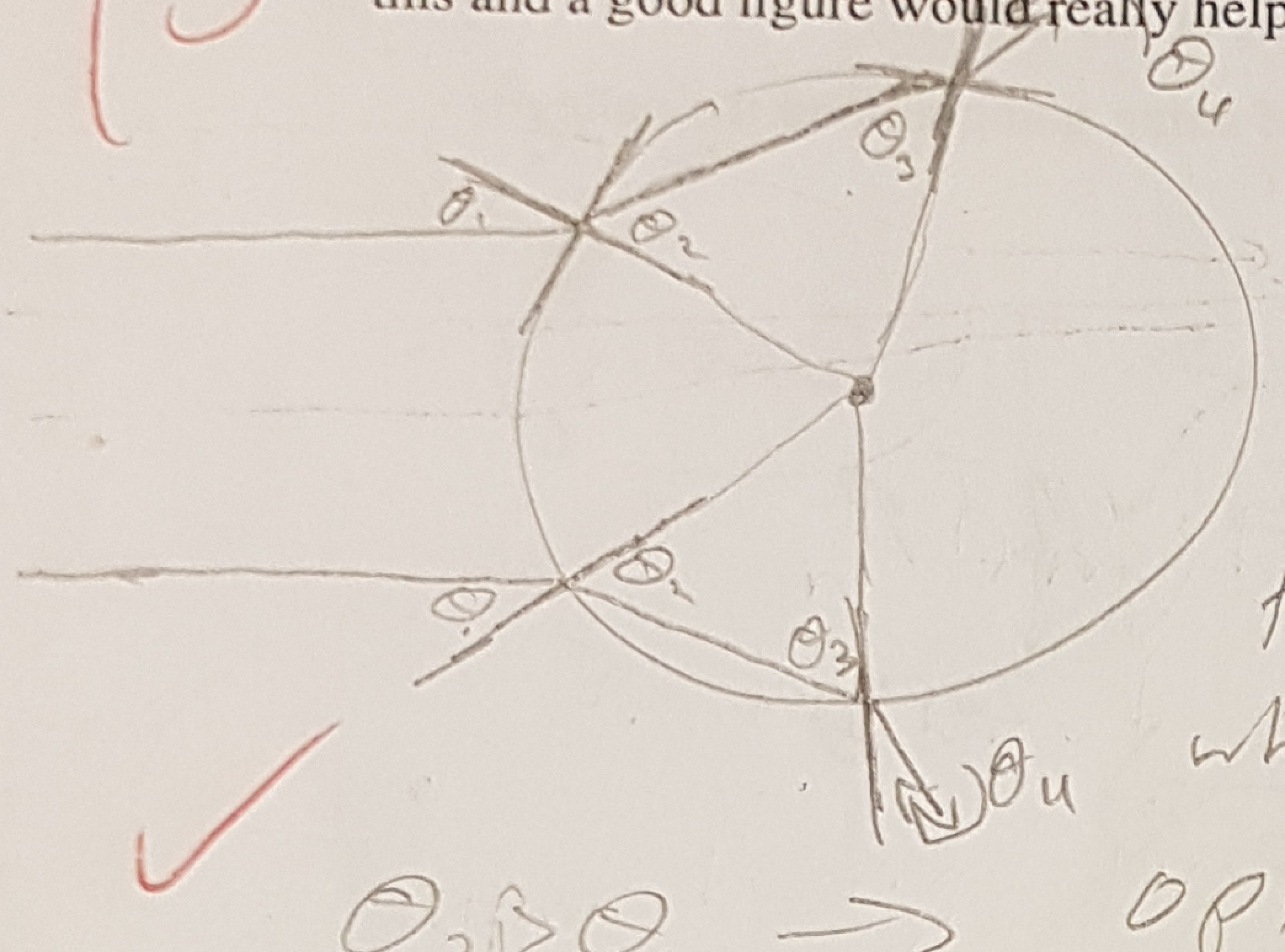

The bubble acts like a diverging lens. As we see in the picture, at the first boundary Snell's Law guarantees that the beam moves away from the normal which for a sphere means further from the optical axis. At the second boundary the opposite must be true, but now the relative concavity of the surface means the beam bends further still from the axis resulting in a diverging beam.

$\theta_2 > \theta_1 \rightarrow$

✓

d) For the diagram below, showing a light ray approaching a boundary between two transparent media, which of the outgoing rays (A, B, C, D) could *not* result from the incoming ray? Explain your answer (it may be useful to say why the allowed rays are allowed).

D is not allowed.

D violates Fermat's Principle — for any point the beam hits along path there is a quicker path the light could have taken.

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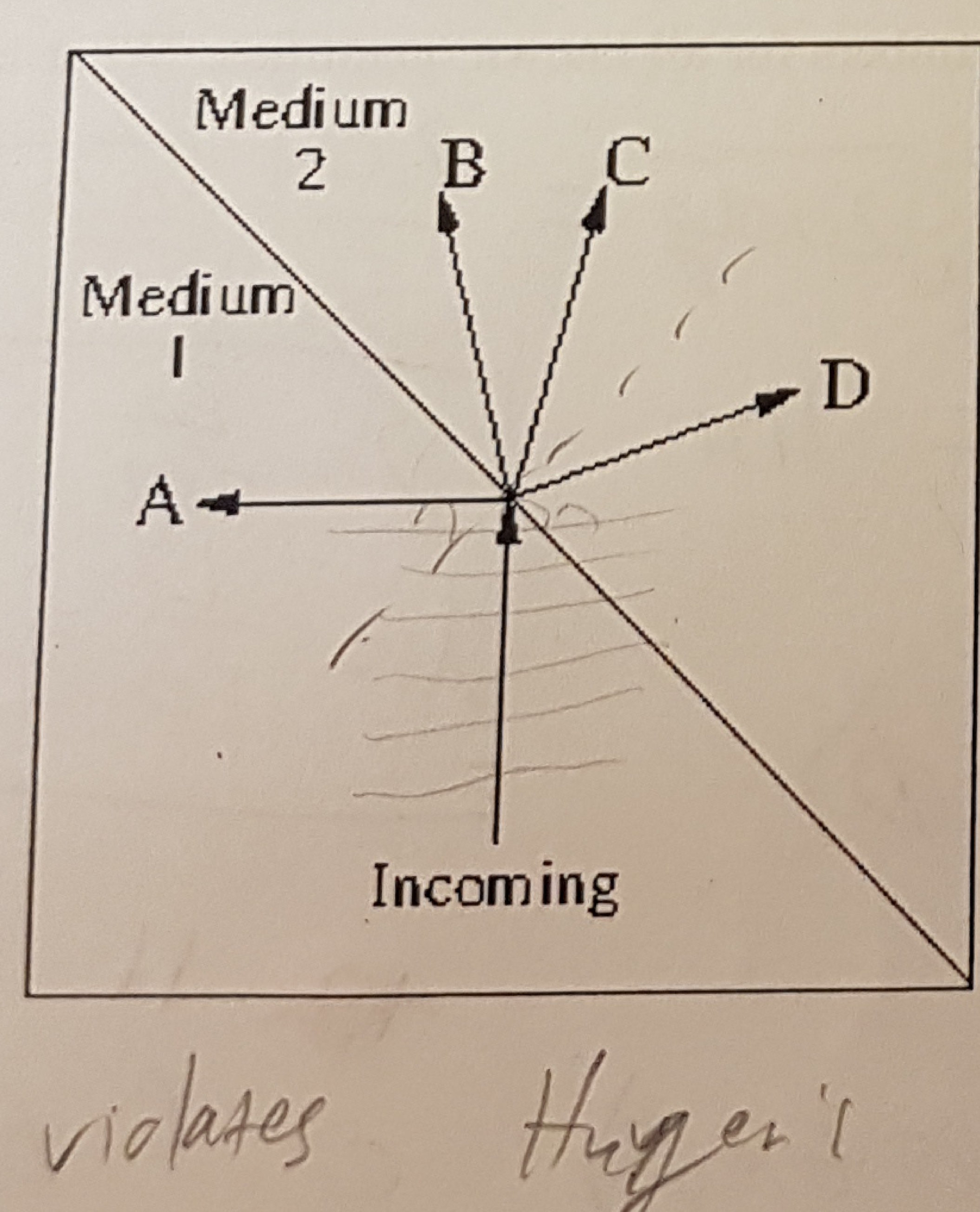

It also violates Huygen's Principle → the wavefronts must be continuous but they clearly would not be for D

good!

Problem 2: String Theory (30 points total)

A long horizontal string of uniform mass density is put under tension by tying one end of the string to a wall and passing the other end over a pully and attaching it to a metal weight that has 200 times the mass of the string. It takes 0.05 s for a pulse to propagate from one end of the string to the other.

a) What is the length, L, of the string? You can assume that the amount of string going around the pulley is neglgible and ignore any sag or deflection in the string due to gravity.

let m = mass of string

$v = \sqrt{\frac{T}{\rho}}$ $\rho = \frac{m}{L}$ $T = 200mg$

$\hookrightarrow v = \sqrt{\frac{200mg}{(\frac{m}{L})}} = \sqrt{200Lg}$

$d = vt \rightarrow L = \sqrt{200Lg}\,(\frac{1}{20}\,s)$

$\rightarrow L^2 = 200Lg\frac{1}{400} \rightarrow L^2 - \frac{1}{2}Lg = 0$ 12

$\hookrightarrow L(L - \frac{1}{2}g) = 0 \Rightarrow$ $\boxed{L = \frac{1}{2}g = 5\,m}$

$\hookrightarrow$ we ignore $L = 0$ as a trivial sol^n

(if $v = \sqrt{200Lg} = 0$, of course $0 = 0\cdot(0.05s)$)

b) A transverse harmonic wave is imposed on the string with an amplitude, $A = 0.2$ m, and a wavelength, $\lambda = L/10$. Assume that the wave moves in the $+x$ direction and is described by a trigonometric function (i.e. sine or cosine or a combination of both). Write down the equation for the wave, $y(x,t)$, subject to the initial conditions that $y(0,0) = 0.2$ m and $\dot{y}(0,0) = 0$ m/s. Substitute numbers for all known quantities. What is the wavelength and frequency of the wave?

$\omega = kv = \frac{2\pi}{\lambda}v = \frac{2\pi}{L}10\cdot\sqrt{200Lg} = \frac{20\pi}{5}\sqrt{200\cdot 50} = 400\pi$

$k = \frac{2\pi}{\lambda} = \frac{2\pi\cdot 10}{L} = \frac{20\pi}{L} = 4\pi$

$\boxed{\nu = \frac{\omega}{2\pi} = 200\,Hz \quad \lambda = \frac{L}{10} = 0.5\,m}$

$y = A\cos(kx - \omega t + \phi)$

$y = 0.2\cos(4\pi x - 400\pi t + \phi)$

$y(0) = 0.2$ if $\phi = 0$ 11

$\dot{y} = 0.2\cdot(-400\pi)\sin(4\pi x - 400\pi t + \phi) = 0$ if $\phi = 0$

so $\boxed{y(x,t) = 0.2\cos(4\pi(x - 100t))}$ meters (-1)

Problem 2 (continued)

c) As the wave passes by a particular fixed point, what is the maximum *transverse* speed of a point on the string?

$\dot{y} = -0.2 \cdot (-400\pi) \sin(4\pi(x - 100t))$

$\text{speed} = \dot{y}_{max} = |+400\pi \cdot 0.2| = 80\pi \approx 251.33 \text{ m/s}$

6

Problem 3: Objects and Images (30 points total)

On an optical bench is a lens with focal length, $f_1 = +20\,\text{cm}$, and a mirror of unknown type (convex, concave, or planar) and unknown focal length. An object, O_1, is located 60 cm to the left of the lens. The mirror is located 40 cm to the right of the lens. The image formed by the mirror, I_2, is inverted and is the same size when compared to the original object O_1.

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a) Determine the position of the image formed by the lens, I_1. Is it real/virtual, upright/inverted, and what is its magnification?

$\frac{1}{O_1} + \frac{1}{i_1} = \frac{1}{f_1}$ +1 $\rightarrow \frac{1}{60cm} + \frac{1}{i_1} = \frac{1}{20cm} \rightarrow \frac{1}{i_1} = \frac{2}{60cm} \rightarrow$ $i = 30cm$ +1

↓ to the right of the lens +1

+1 real, +1 inverted,

$m = -\frac{1}{2}$

$m = \frac{-i_1}{O_1} = -\frac{30cm}{60cm} = -\frac{1}{2}$ +1

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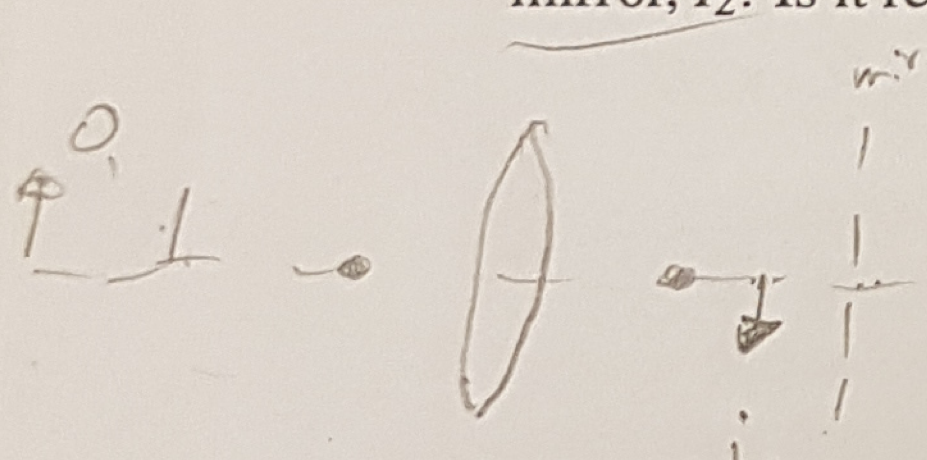
b) Given what you know about the second image, determine the properties of the mirror: is it convex, concave or planer (or is it ambiguous) and what is its focal length? Determine the position of the image formed by the mirror, I_2. Is it real/virtual?



$O_2 = 40cm - i_1 = 10cm$ to the left. +2

i_2 is inverted means no inversion ocurs at the mirror (because it was already inverted by the lens

i_2 same size as O_1 means $m_2 = 2$ +2

So $m_2 = -\frac{i_2}{O_2} \rightarrow i_2 = -2 \cdot 10cm = -20cm$

$\frac{1}{O_2} + \frac{1}{i_2} = \frac{1}{f_2}$ +1

$\frac{1}{10cm} - \frac{1}{20cm} = \frac{1}{f_2}$

$\frac{1}{20cm} = f_2$

$f_2 = 20cm$ +1

concave mirror +1

Position is 20cm +1 to the right +1 of the mirror

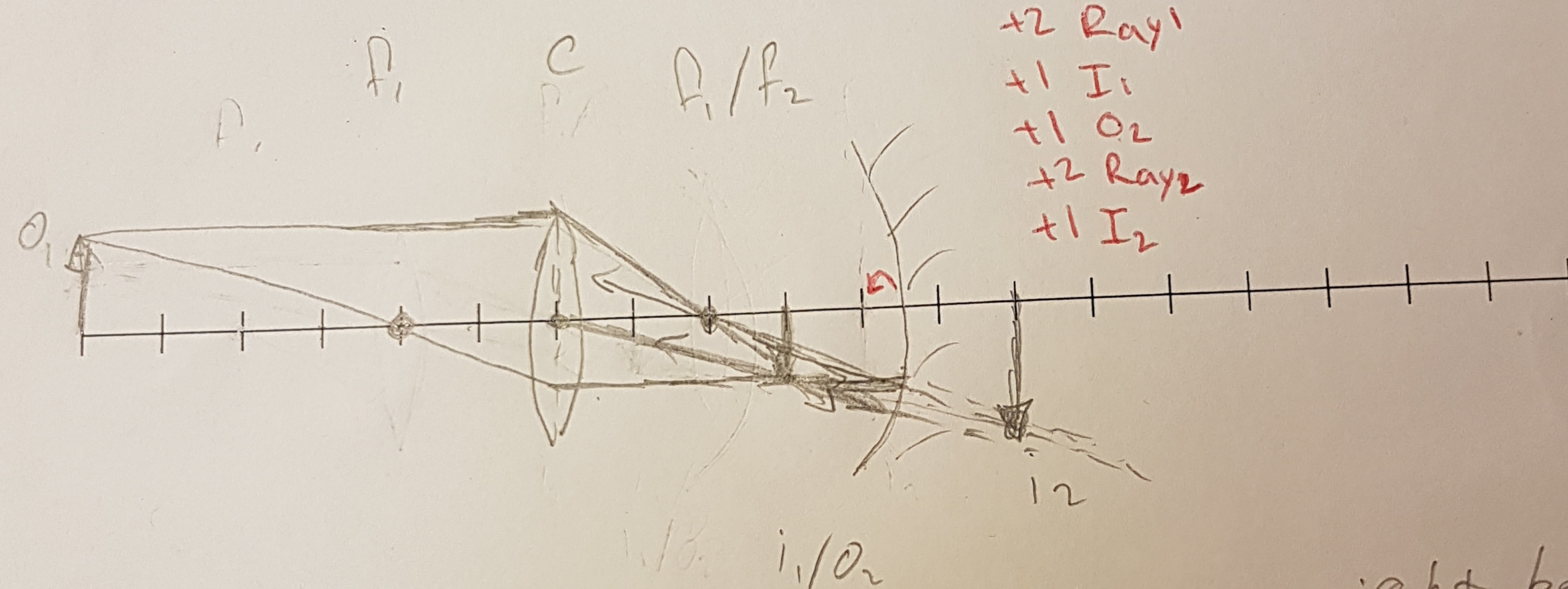
virtual +1

Problem 3 (continued)

13.5

c) On the horizontal axis below, draw the lens and the mirror. Then, provide a ray-trace for at least two rays from the initial object to the first image and then at least two rays from the second object to the second image. Indicate the positions of $O_1, I_1, O_2, I_2, F_1, F_2$, and C, where F_1 identifies the focal points of the lens, F_2 identifies the focal point of the mirror and C identifies the center of the mirror. (You do not have to ray-trace back through the lens to form a third image).

+1 O_1
+1 lens
+0.5 mirror
+2 F_1
+1 C
+1 F_2
+2 Ray1
+1 I_1
+1 O_2
+2 Ray2
+1 I_2



this one might be a little clearer if the first is too messy.