Your name: Yeh I. Can

Problem 1 In an amusement park, you notice a strange mirror. As you walk directly towards the mirror, you notice that your reflected image flips as you walk past the point of distance 1 m from the mirror. Assuming that the mirror is a spherical mirror, which of the following statements is true? (radius $\equiv |r|$)

(a) The mirror is a convex mirror, and its radius of curvature is 1 m.

(b) The mirror is a convex mirror, and its radius of curvature is 2 m.

(c) The mirror is a concave mirror, and its radius of curvature is 1 m.

(d) The mirror is a concave mirror, and its radius of curvature is 2 m.

Problem 2 You are looking at yourself in a shiny 9.4 cm diameter Christmas tree ball. Your face is 21.5 cm away from the ball's front surface. Your image is

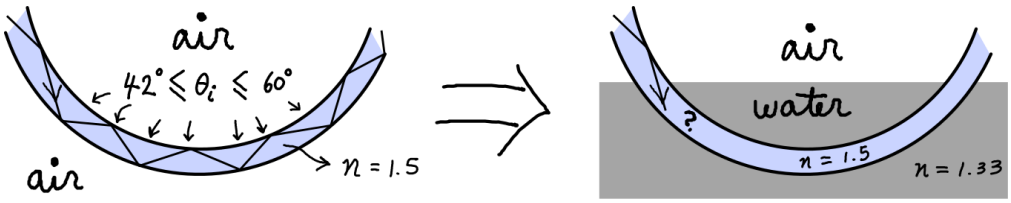
(a) real and upright.

(b) virtual and upright.

(c) real and inverted.

(d) virtual and inverted.

Problem 3 An optical fiber cable is used to transmit light. The index of refraction for for the optical fiber cable is 1.5. The cable is bent as shown, but light is transmitted perfectly through the cable, since the angle of incidence θ_i inside the cable satisfies $42° \leq \theta_i \leq 60°$ throughout the bent section. What happens if water surrounds part of the cable, as shown?



(a) No change. Still perfect transmission of light.

(b) Transmission is reduced, but some light is transmitted.

(c) No transmission of light anymore.

Problem 4 Which of the following statements is false?

(a) A virtual object is always imaged to a real image by a converging lens.

(b) A real object (at a non-zero distance from mirror) is always de-magnified by a convex mirror, i.e., $|m| < 1$.

(c) It is always possible to see, with eye, a real image formed by a mirror or a glass lens.

(d) Angular magnification of a converging lens is a more appropriate measure of the resolving power of the lens than lateral magnification.

Problem 5 What is the focal length of a flat sheet of transparent glass?

(a) zero (b) thickness of glass
(c) infinity (d) undefined

Problem 6 In Young's double slit experiment, a slab of glass of a certain small thickness is placed behind one of the two slits so that the light coming out that slit has a fixed relative phase shift by $\pi/2$, compared to the light coming out of the other slit. What happens to the interference pattern?

(a) No change.

(b) The positions of maxima and minima are exchanged.

(c) Pattern shifts by approximately half the distance between neighboring maximum and minimum.

(d) Pattern disappears since now the light is incoherent.

Problem 7 A soap bubble is made of a thin layer of soapy water of thickness 1000 nm. The index of refraction of the soapy water is 1.4. You are looking directly at a bubble, and the front part of the bubble looks _____.

(a) yellow (570 nm) (b) green (510 nm) (c) blue (475 nm) (d) violet (400 nm)

Problem 8 Linearly polarized light is to have its axis of polarization rotated by 90° by employing some number of polarizers. In which of the following cases does the final beam have the greatest intensity?

(a) 3 polarizers, where each polarizer rotates the axis of polarization by 30°.

(b) 2 polarizers, where each polarizer rotates the axis of polarization by 45°.

(c) 1 polarizer, which rotates the axis of polarization by 90 °.

(d) None of the above, since the axis of polarization never rotates this way.

Problem 9 If Huygens principle holds everywhere, why does a laser beam not spread out?

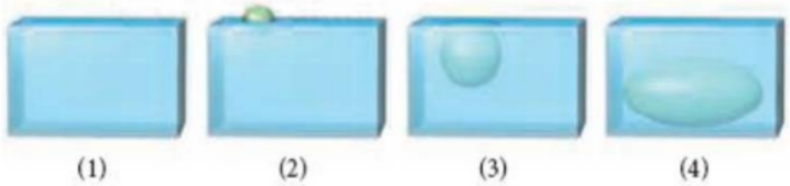
(a) All the light waves that spread in the perpendicular direction from the beam interfere destructively.

(b) It does spread out, but the spread is too small for us to notice it casually.

(c) Huygens principle is not true in general; it applies only to situations where slits, edges, or other obstacles are present.

(d) Lasers employ additional special beams to keep the main beam from spreading.

Problem 10 The figure shows four identical open-top tanks filled to the brim with water and sitting on a scale. Balls flat in tanks (2) and (3), but an object sinks to the bottom in tank (4). Which of the following correctly ranks the weights shown on the scale?



(a) (1) < (2) < (3) < (4)
(b) (1) < (2) = (3) = (4)
(c) (1) < (2) = (3) < (4)
(d) (1) = (2) = (3) < (4)

For the following problems, you must provide short but sufficient derivations. Answer alone will not get you much credit, even if it is correct. **For all problems, full symbolic answers must be given first, before numerical answers, if required, are given.**

Problem 11 A prism has a vertex angle of 55° and an index of refraction of 1.45. A ray of light enters one side of the prism at angle of incidence, θ. As θ is varied from 0 to 90°, there is a range of θ values for which no light emerge from the opposite side of the prism. Find that range.

Your solution:

Problem 12 One morning, Ray realizes that the far points of both his eyes have decreased (to 50 cm) and the near points have decreased (to 18 cm). He goes to an optometrist, who confirms this finding and gets a pair of glasses made for Ray. When Ray wears his new glasses, his glasses sit 2.0 cm in front of his eyes.

(a) What should be the prescription (in D, diopters) for the glass lens (for either eye), assuming it has restored the normal far point for Ray?

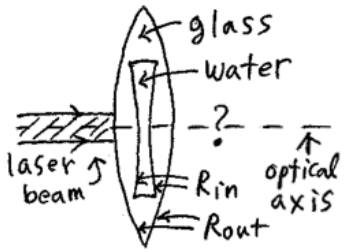
(b) What is Ray's new effective near point with this corrective lens?

(c) One lens surface of the corrective lens is convex with the radius of curvature 10 m. Determine whether the other lens surface of the corrective lens is convex or concave and what its radius of curvature is. Assume that the index of refraction for the lens material is 1.5.

Your solution:

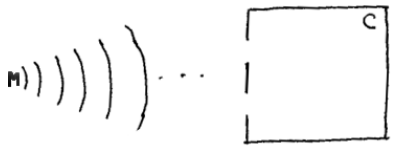
Problem 13 A thin converging lens made of glass (n_g = 1.55) happens to have an inclusion of water (n_w = 1.33) at the center. The lens surfaces have radii of curvature $R_{out} = r_1 = r_2$ = 10 m, and the water inclusion has the shape of a diverging lens with radii of curvature $R_{in} = r_1 = r_2 = -20$ m. The optical axis of the water inclusion is the same as the optical axis of the glass lens. A laser beam of 10 mm diameter hits the center of this lens from the left, parallel to the optical axis. Assume that the diameters of the lens and the water inclusion are (much) greater than 10 mm. (a) Find the position along the optical axis, where the laser light gets focused to a point. Find this position as a function of symbols n_g, n_w, R_{out}, and R_{in}, first, and then find its numerical value (as usual). (b) Is the point calculated in (a) a real image/focus or a virtual image/focus? (c) A screen is placed perpendicular to the optical axis, on the right side of the lens, at distance 20 m away from the lens. Find the diameter of the laser light when it hits this screen. [Consider the initial laser beam as a perfect cylindrical beam and *ignore any diffraction*. Lensmaker's equation: $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$.]

Your solution:



Problem 14 A child is playing in a corner of a room of size 10.00 m × 10.00 m. The room has two completely open doors on a wall, opposite to one of the two walls, in whose shared corner the child is playing. The two doors are separated by 3.00 m (center-to-center), symmetrically positioned so that each door is 3.50 m from each corner that the wall connects to. Mother calls for the child from outside the room, generating a sound of frequency 640 Hz. Mother is standing at equal distance, 20.00 m, from each door, when she does so. Her voice is loud enough so that it is easily audible at 40 m away. The child never responds. Mother walks into the room, and demands explanation for no response. The child says to have never heard the call. Is the child's claim valid? Take the speed of sound to be 340 m/s and the width of door to be 0.70 m.

Your solution:



Problem 15 A 150 g air hockey puck glides at $v_1 = 2.30$ m/s towards another stationary 200 g puck, head-on. The sides of pucks are very sticky (or have Velcros) and, thus, the two pucks undergo a completely inelastic collision to become one body in a time duration of 7 ms. A person suggests that roughly half the decrease in kinetic energy of the two-puck system is transferred to the environment by sound during the collision. You are asked to be a judge to figure out if this idea makes sense. To evaluate this idea, find the implied sound level in decibel at a position 0.8 m from the pucks. What does your answer suggest about the above idea? [$I_0 = 10^{-12}$ W/m^2 corresponds to 0 decibel. Typical sound levels: normal city traffic sound corresponds to 80 dB, while very loud sound at threshold of pain (causing possible ear damage) corresponds to 120 dB. [Hint: the momentum conservation holds during the collision.]

Your solution:

Problem 16 A diffraction grating is used to monochromatize ultra-violet light. Specifically, it needs to resolve 120.00 nm and 120.10 nm wave length lights **in the second order**. The ruling (= groove) density is given by 5000 per cm. The initial beam is incident on the grating at normal angle. (a) At what angle would the second order light for 120.00 nm appear? (b) What is the minimum number of rulings that the grating must have for the required resolution? (c) What is the minimum number of rulings that the grating must have, if the requirement changes to resolving 120.00 nm light from 120.05 nm light? (d) What is the relative intensity of the principal maximum peak of case (c) in comparison to that of case (b), assuming the minimum number of rulings in each case? Assume all other conditions are the same.

Your solution: