

Fundamental Optics Principles

Name _____

Date _____

Score _____ / 93

- Show your work. Write vergences and powers with a sign (+ or -) and units (D).
- Light travels left to right. Distances to the left of a lens are negative.
- Check your answers in the interactive worksheet on the course site.
- Convert distances to meters before taking a reciprocal.
- Use $n(\text{air}) = 1.000$ and $n(\text{water}) = 1.333$ unless told otherwise. $c = 3.00 \times 10^8$ m/s.
- Parts F and G are extensions. They introduce the Lensmaker's and Thin Lens equations using the vergence ideas from this lecture.

A Vergence & Collimation

$$V = \frac{1}{d(\text{m})} \quad \text{Diverging light: negative} \cdot \text{Converging light: positive} \cdot \text{Collimated: } 0 \text{ D}$$

- A1** A point source is 2 m from an observer. What vergence reaches the observer? (2 pts)

Answer: _____ D

- A2** What is the vergence of light 25 cm from a point source? (2 pts)

Answer: _____ D

- A3** A lens focuses light to a point 50 cm away. What vergence does the light have as it leaves the lens? (2 pts)

Answer: _____ D

- A4** An observer measures -0.10 D of divergence from a point source. How far away is the source, in meters? (2 pts)

Answer: _____ m

A5 Which observer receives light with the greatest magnitude of vergence? (1 pt)

- (A) 10 cm from the source (B) 1 m from the source
(C) 6 m from the source (D) 100 m from the source

A6 Optical infinity is 6 m. What is the actual vergence of light from a point source 6 m away? (2 pts)

Answer: _____ D

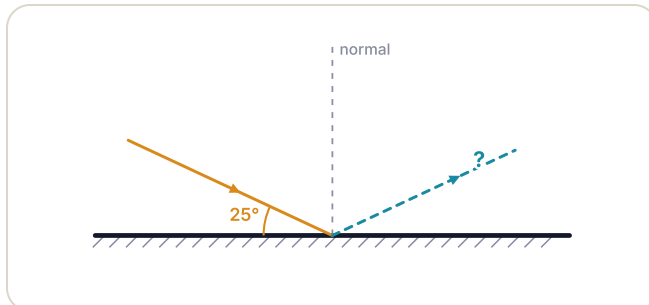
A7 Collimated light has a vergence of: (1 pt)

- (A) 0 D (B) +1.00 D
(C) -1.00 D (D) Infinite

B Reflection

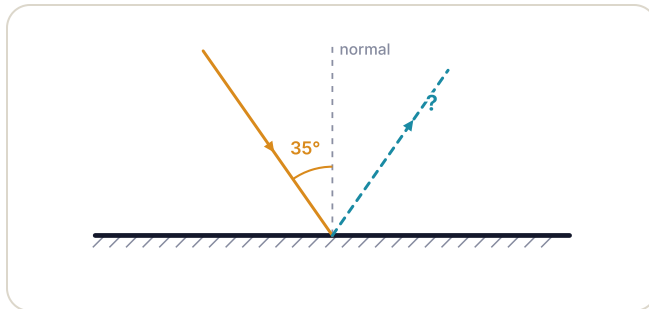
$\theta_i = \theta_r$ Angles from the normal · angle from surface = 90° – angle from normal

B1 A ray strikes a mirror 25° from the surface. At what angle does it leave, measured from the surface? (2 pts)



Answer: _____ °

- B2** A ray strikes a mirror 35° from the normal. What angle does the reflected ray make with the mirror's surface? (2 pts)



Answer: _____ °

- B3** A ray strikes a mirror 30° from the normal. What is the angle between the incident ray and the reflected ray? (2 pts)

Answer: _____ °

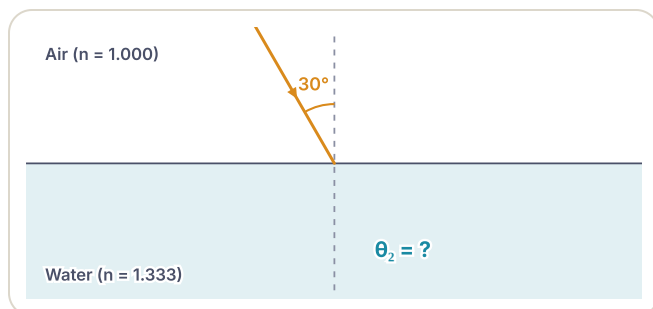
- B4** Challenge: a ray strikes a mirror 20° from the surface. What is the angle between the incident and reflected rays? (3 pts)

Answer: _____ °

C Refraction, Snell's Law & Index of Refraction

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad n = \frac{c}{v}$$

- C1** Light passes from air into water at 30° from the normal. What is the angle of refraction? (3 pts)



Answer: _____ °

- C2** Light passes from air into crown glass ($n = 1.523$) at 45° . What is the angle of refraction? (3 pts)

Answer: _____ °

- C3** How fast does light travel in water ($n = 1.333$)? Give your answer in units of 10^8 m/s. (2 pts)

Answer: _____ $\times 10^8$ m/s

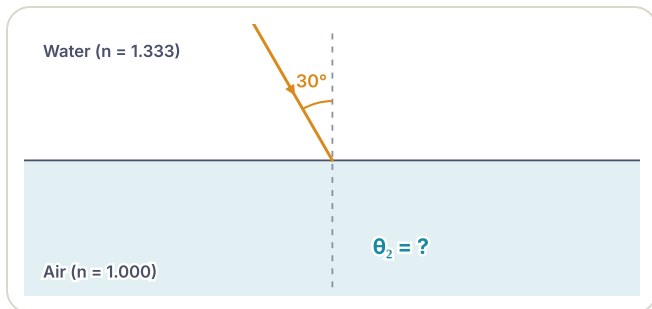
- C4** Light travels at 1.89×10^8 m/s in a lens material. What is its index of refraction, and which material is it? (2 pts)

Answer: _____

- C5** When light passes from air into water, it bends: (1 pt)

- (A) Toward the normal (B) Away from the normal
(C) It does not bend (D) It all reflects

- C6** Light leaves water and enters air, striking the surface at 30° from the normal. What is the angle of refraction in air? (3 pts)



Answer: _____ °

- C7** A ray in air hits an unknown material at 40° and refracts to 25° . What is the material's index? (3 pts)

Answer: _____

- C8** Challenge: beyond what angle in water (from the normal) does light fail to escape into air at all? (3 pts)

Answer: _____ °

D Lenses, Focal Points & the Vergence Equation

$$P = \frac{1}{f(\text{m})} \quad V = U + P \quad U = \text{vergence entering the lens} \cdot V = \text{vergence leaving}$$

- D1** A lens converges collimated light to a point 20 cm behind it. What is its power? (2 pts)

Answer: _____ D

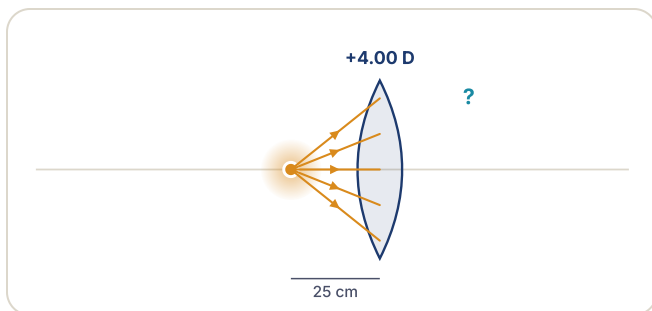
- D2** After passing through a lens, collimated light appears to diverge from a point 50 cm in front of it. What is the lens power? (2 pts)

Answer: _____ D

- D3** What is the focal length of a +8.00 D lens, in centimeters? (2 pts)

Answer: _____ cm

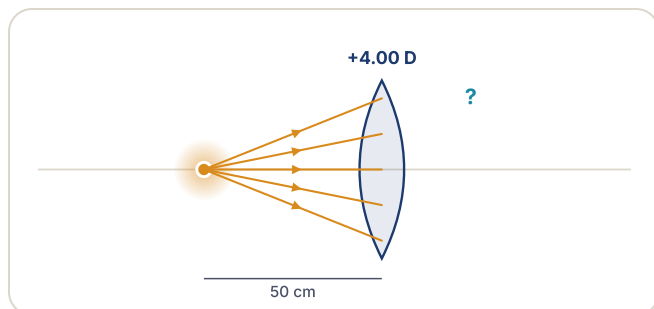
- D4** A point source sits 25 cm to the left of a +4.00 D lens. What vergence leaves the lens? (3 pts)



Answer: _____ D

D5 The same source is moved to 50 cm left of the +4.00 D lens. What vergence leaves the lens?

(3 pts)



Answer: _____ D

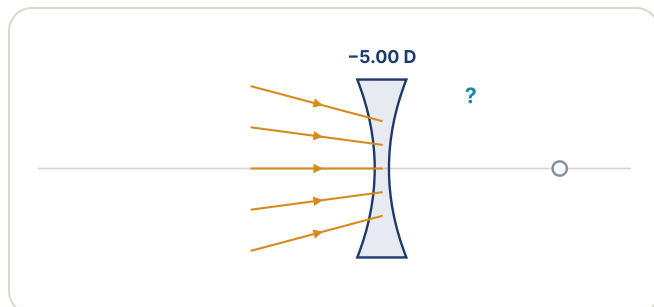
D6 For question D5, how far to the right of the lens does the light come to a focus, in centimeters?

(2 pts)

Answer: _____ cm

D7 Converging light of +2.00 D strikes a -5.00 D lens. What vergence leaves the lens, and is it converging or diverging?

(3 pts)



Answer: _____ D

D8 Using this lecture's convention, the focal point where collimated light seems to originate for a negative lens is:

(1 pt)

- ☐ (A) Real, to the right of the lens
- ☐ (C) Real, to the left of the lens

- ☐ (B) Virtual, to the left of the lens
- ☐ (D) At the center of the lens

E Applications & Concepts

- E1** Why can a high-index lens be thinner than a CR-39 lens of the same prescription? (1 pt)
- ☐ A It bends light more per unit of curvature, so less curvature (and material) is needed
- ☐ B It reflects more light
- ☐ C It slows light down less
- ☐ D It has a higher Abbe value
- E2** A spear-fisher sees a fish ahead and below. To hit it they should aim: (1 pt)
- ☐ A At the image
- ☐ B Beyond the image
- ☐ C Below the image
- ☐ D Above the image
- E3** In a primary rainbow, which color appears on the outside (top) of the bow? (1 pt)
- ☐ A Violet
- ☐ B Green
- ☐ C Red
- ☐ D Blue
- E4** Which lens material is the usual choice for a child's safety glasses? (1 pt)
- ☐ A Crown glass
- ☐ B CR-39
- ☐ C Polycarbonate
- ☐ D High-index 1.74
- E5** True or false: a lens with a focal length of 2 m is stronger than a lens with a focal length of 0.5 m. (1 pt)
- ☐ A True
- ☐ B False
- E6** In two or three sentences, explain why a mirage appears on a hot road. (3 pts)

F Extension: The Lensmaker's Equation

A lens's power depends on its material (n) and the curvature of its two surfaces. For a thin lens in air:

$$P = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

R_1 is the front surface radius and R_2 the back surface radius, **in meters**. A radius is positive when its center of curvature lies to the *right* of the surface, and negative when it lies to the left. A flat surface has $R = \infty$ (so $1/R = 0$).

- F1** A biconvex lens has $n = 1.50$, $R_1 = +20$ cm and $R_2 = -20$ cm. What is its power? (3 pts)

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Answer: _____ D

- F2** The same shape is made in 1.74 high-index plastic. What is its power now? (3 pts)

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Answer: _____ D

- F3** A plano-concave polycarbonate lens ($n = 1.586$) has a flat front ($R_1 = \infty$) and a back surface with $R_2 = +10$ cm. What is its power? (3 pts)

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Answer: _____ D

- F4** Design problem: what front radius (in cm) gives a plano-convex crown glass lens ($n = 1.523$, flat back) a power of +4.00 D? (3 pts)

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Answer: _____ cm

G Extension: The Thin Lens Equation

The thin lens equation is the vergence equation written with distances. The object distance u is negative for a real object to the left of the lens; a positive image distance v means a real image to the right.

$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} \quad \Longleftrightarrow \quad V = U + P \quad m = \frac{v}{u}$$

Magnification m : negative means inverted, positive means upright; $|m| > 1$ means enlarged.

- G1** An object is 40 cm to the left of a +5.00 D lens. Where is the image? (Signed distance in cm.) (3 pts)

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Answer: _____ cm

- G2** What is the magnification of the image in G1? (2 pts)

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Answer: _____

- G3** The object moves to 10 cm left of the same +5.00 D lens. Where is the image now? (Signed distance in cm.) (3 pts)

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Answer: _____ cm

- G4** An object is 50 cm to the left of a -4.00 D lens. Where is the image? (Signed distance in cm.) (3 pts)

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Answer: _____ cm

G5 Challenge: where must an object be placed so a +10.00 D lens forms a real image 30 cm to its right? (Signed distance in cm.) (3 pts)

Answer: _____ cm