STUDY GUIDE FOR PART I: LIGHT I

The Nature of Light and the Laws of Geometric Optics

A. What is Light?
   1. a form of energy
   2. wave or particle?

B. Waves (review) S- 1
   1. Electromagnetic Waves
      a. Electric field waves
      b. Magnetic field waves
      c. speed: $v = \sqrt{(1/[\mu\varepsilon])}$, $c = \sqrt{(1/[\mu_o\varepsilon_o])} = 3 \times 10^8 m/s$
   2. Types

C. Reflection S-2
   1. Spherical and plane waves
   2. rays and wavefronts
   3. Law of reflection: $\theta_{reflection} = \theta_{incident}$

D. Refraction S-3 to 13
   1. particles and waves
   2. Huygen's principle
   3. Index of refraction: $n \equiv c/v$; (since $v \leq c$, $n \geq 1$)
   4. Snell's law: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$
   5. Total internal reflection and critical angles
   6. Apparent depth: $d_{apparent} \approx d_{real}/n$
   7. Dispersion: $n(\omega)$

SUPPLEMENTARY HOMEWORK PROBLEMS (S-):

1) Given the wavelength of an E&M wave, identify its type, and vice versa.

2) If a person who is 1.8 meters tall is to see all of the person in a mirror, what minimum size mirror does the person need if the person positions the mirror properly?

3) a) What is the speed of light in air? b) What is the speed of light in water (index of refraction of water = 1.33)? c) If red light of wavelength 630 nm (in air) is used, what is the frequency of this light in air? On entering the water, does the light: d) change direction? e) change color? f) change frequency? g) change wavelength? (If YES to any of the above three question, tell what it changes to.)

4) A ray of light coming from the water hits the surface of a swimming pool. The angle the ray makes with the SURFACE is 70°. a) What is the incident angle? b) What is the refracted angle?

5) A ray of light coming from air hits the surface of a swimming pool. (The index of refraction of water is 1.33, remember.) The angle the ray makes with the SURFACE is 70°. a) What is the incident angle? b) What is the refracted angle?

6) A ray of light in an aquarium strikes the glass wall at an angle of 15° with the NORMAL. It then goes through the glass (n=1.65) and enters the air. a) What is the angle of the transmitted ray? b) If the glass were not there (and the water did not spill on the floor - it being held in place by some kind of force field), what would the angle of the transmitted ray be?

7) If a ray of light coming from inside a solid glass tube hits the surface of the glass tube with an angle of 60° measured from the NORMAL, what is the refracted angle? a) if the material outside the glass is air and the index of refraction of the glass is 1.5? c) if the material outside the glass is water?

8) What is the critical angle for an air-water surface?

9) If the critical angle for a certain plastic is 60°, what is its index of refraction?

10) The velocity of sound is 350 m/sec in AIR and 1400 m/sec in WATER. a) What is the critical angle for a sound wave incident on the surface between air and water? b) Which medium has the higher "index of refraction" for sound?

11) a) Can sound in air "critically reflect" from water or can sound in water "critically reflect" from air? b) Can light in air "critically reflect" from water or can light in water "critically reflect" from air?

12) If the depth of a pool of water appears to be 50 cm, how deep is it in actuality?

13) Qualitatively describe how a rainbow is formed.

ANSWERS TO SUPPLEMENTARY PROBLEMS:

2) 0.9 meters long.

3) a) 3.0×10^8 m/sec; b) 2.26×10^8 m/sec; c) 4.76×10^{14} Hz; d) Yes: $q_{water} < q_{air}$; e) No; f) No; g) Yes, 474 nm.

4) a) 20°; b) 27.1°.

5) a) 20.0°; b) 14.9°.

6) a) 20.1°; b) 20.1°.

7) a) No refracted ray; b) 77.6°.

8) 48.75°.

9) 1.15 .

10) a) 14.5°; b) Air.

11) a) Sound in air can "critically reflect"; b) Light in water can "critically reflect".

12) 66.5 cm.

Geometric Optics

A. Thin lenses & focal length: $1/f = [(n_{material} - n_{medium})/(n_{medium})]\,[(1/r_1) + (1/r_2)]$ S-14 to 17

1. converging (convex -thicker in middle- for glass in air)
   a) classic case: $r_1, r_2 > 0$
   b) contact lens case: $r_1 > 0,\ r_2 < 0,\ r_1 < |r_2|$
2. diverging (concave -thinner in middle- for glass in air)
   a) classic case: $r_1, r_2 < 0$
   b) contact lens case: $r_1 > 0,\ r_2 < 0,\ r_1 > |r_2|$.

B. Thin lens formula & image formation:

1. image formation: $(1/f) = (1/s) + (1/s')$
2. magnification: $M = -s'/s = h'/h$

C. Applications S-18 to 21

1. the eye
2. the camera and the projector
3. magnifying glass ($s' = -25$ cm for best use)
4. telescope and microscope (two lens systems)

SUPPLEMENTARY HOMEWORK PROBLEMS (S-):

14) A lens is made from a glass of index of refraction = 1.46, and has radii of curvature of +10 cm and +5 cm. a) Does it matter which way the lens is placed, i.e., does it matter whether the side with the radius of 5 cm is facing left or right? b) What is the focal length of this lens? c) Is this a concave or convex lens? d) Is this a converging or diverging lens? e) Would the focal length change if it were immersed in water, and if so what would it be?

15) A lens is made from a glass of index of refraction = 1.46, and has radii of curvature of -10 cm and -5 cm. a) What is the focal length of this lens? b) Is this a convex or a concave lens? c) Is this a converging or diverging lens?

16) A lens is made from a glass of index of refraction = 1.46, and has radii of curvature of -10 cm and +5 cm. a) What is the focal length of this lens? b) Is this a converging or diverging lens? c) If the radii were changed to +10 cm and -5 cm, would the focal length change, and if so what would it be? d) Is this a converging or diverging lens?

17) Design a lens that has a focal length of 8 cm. 18) A 35 mm camera has a lens of focal length 55 mm. a) A picture of a mountain one mile away is to be taken. How far away should the film be from the lens? b) A picture of a person 5 meters away is to be taken. How far away should the lens be from the film? c) A close-up picture of a person 60 cm away is to be taken. How far away should the lens be from the film? d) In part b, if the person is 5'11" (1.80 m) tall, how big will his image be on the film? e) In part c, if the person's face is 25 cm long, how big will the image be on the film?

19) A projector uses a 70 mm focal length lens. a) How far from the slide should the lens be placed so that the image is focused on a screen 6 meters away? b) If the slide contains an image of a person which measures 20 mm on the film, how big will the image of the person be on the screen? c) If the screen is moved to a distance of 50 cm from the projector, what should the lens to slide distance be? d) How big will the image of the person be now on the screen? e) Should the slide be placed upside-down or right-side-up in the projector if the image on the screen is to be right-side up?

20) A magnifying glass has a focal length of 3 cm. a) Draw a diagram showing the object, lens, image and eye. Include the focal point of the lens in your diagram. b) What should the image distance be if it is used properly? c) What is the magnification of this lens when used properly?

21) DESIGN a microscope with a magnifying power of 270.

ANSWERS TO SUPPLEMENTARY PROBLEMS:

14) a) No; b) 7.25 cm; c) Convex; d) Converging; e) Yes, 34.1 cm.

15) a) -7.25 cm; b) Concave; c) Diverging.

16) a) 21.7 cm; b) Converging; c) Yes, -21.7 cm; d) Diverging.

17) Many possible answers.

18) a) 55.002 mm; b) 55.6 mm; c) 60.6 mm; d) 20.0 mm; e) 25.25 mm.

19) a) 70.8 mm; b) 1.695 meters; c) 81.4 mm; d) 12.3 cm; e) Upside-down.

20) b) -25 cm; c) 9.33 X.

21) Many possible answers.