Year 12 Science: Light: mirrors, refraction, total internal reflection and lenses

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Light goes from air into glass (n = 1.50) at an angle of incidence of 35°. Find the angle of refraction.

2. Use the table: what is the speed of light in diamond (n = 2.4)?

3. Find the critical angle for light going from water (n = 1.33) into air.

4. A converging lens has f = 20 cm, and an object is 60 cm away. Find the image distance and the magnification.

5. A concave make-up mirror has f = 30 cm, and a face is 10 cm in front of it. Find the image distance and describe the image.

Exam-style question: the magnifying glass

Hemi reads the small print on a museum label with a glass magnifying lens. The lens is converging, with a focal length of 8.0 cm. The letters are 2.0 mm tall, and he holds the lens 6.0 cm from the label.

6. Describe the nature of the image Hemi sees.

7. Calculate the image distance and the height of the image of a letter.

8. Hemi lifts the lens until it is 12 cm from the label. Explain what happens to the image, with a calculation.

9. Explain, in terms of the speed of light, why the glass lens changes the direction of the light.

Fix the mistake

10. Correct this statement: "The ray hits the surface at 30°, so I put 30° into Snell's law."

11. Correct this statement: "For the diverging lens I used f = +12 cm and got a real image."

12. Correct this statement: "Light changes frequency when it goes into glass, which is why its wavelength changes."

13. Correct this statement: "Total internal reflection happens when light goes from air into glass at a big angle."

Answer key (for parents and tutors)

1. Light goes from air into glass (n = 1.50) at an angle of incidence of 35°. Find the angle of refraction.
   $\sin\theta_2 = 1.00 \times \sin 35° \div 1.50 = 0.5736 \div 1.50 = 0.3824$, so $\theta_2 = 22.5°$.
2. Use the table: what is the speed of light in diamond (n = 2.4)?
   $v = c \div n = 3.00 \times 10^8 \div 2.4 = 1.25 \times 10^8$ m s^{-1}.
3. Find the critical angle for light going from water (n = 1.33) into air.
   $\sin\theta c = 1.00 \div 1.33 = 0.7519$, so $\theta c = 48.8°$.
4. A converging lens has f = 20 cm, and an object is 60 cm away. Find the image distance and the magnification.
   1/di = 1/20 − 1/60 = 2/60, so di = 30 cm; m = 30 ÷ 60 = 0.5 (real, inverted, diminished).
5. A concave make-up mirror has f = 30 cm, and a face is 10 cm in front of it. Find the image distance and describe the image.
   1/di = 1/30 − 1/10 = −2/30, so di = −15 cm; m = 15 ÷ 10 = 1.5, so the image is virtual, upright and enlarged 1.5 times, 15 cm behind the mirror.
6. Describe the nature of the image Hemi sees.
   Virtual, upright and enlarged, because the label is inside the focal length (Achieved).
7. Calculate the image distance and the height of the image of a letter.
   1/di = 1/8.0 − 1/6.0 = 3/24 − 4/24 = −1/24, so di = −24 cm (virtual, on the label's side); m = 24 ÷ 6.0 = 4.0; hi = 4.0 × 2.0 = 8.0 mm (Merit for the full working with units).
8. Hemi lifts the lens until it is 12 cm from the label. Explain what happens to the image, with a calculation.
   Now 1/di = 1/8.0 − 1/12 = 1/24, so di = +24 cm and m = 24 ÷ 12 = 2.0: the label is beyond F, so the image becomes real and inverted, twice the size, 24 cm on Hemi's side of the lens. Light from the label really meets there, so the image could be caught on a screen, and with his eye well back from it Hemi sees the print upside down (Excellence links the calculation to the change from virtual and upright to real and inverted).
9. Explain, in terms of the speed of light, why the glass lens changes the direction of the light.
   Light slows down when it enters glass (n = 1.5, so $v = 2.0 \times 10^8$ m s^{-1}) and speeds up when it leaves; it meets the curved surfaces at an angle to the normal, so it refracts, bending towards the normal going in and away from the normal coming out, and the curved shape bends rays from each point towards a common point (Merit, with Snell's law named).
10. Correct this statement: "The ray hits the surface at 30°, so I put 30° into Snell's law."
    Angles are measured from the normal, so a ray 30° from the surface has an angle of incidence of 60°.
11. Correct this statement: "For the diverging lens I used f = +12 cm and got a real image."
    A diverging lens has f negative (−12 cm), and its image is always virtual, with di negative.
12. Correct this statement: "Light changes frequency when it goes into glass, which is why its wavelength changes."
    The frequency stays the same; the speed drops, so by $v = f\lambda$ the wavelength gets shorter.
13. Correct this statement: "Total internal reflection happens when light goes from air into glass at a big angle."
    TIR only happens going from a higher n to a lower n (glass to air), at more than the critical angle.