Answer Key (160pts total):

MCQ (2pts each):

1. B 2. B 3. A 4. D 5. A 6. A 7. A 8. A 9. A 10. A 11. C 12. A 13. D 14. A 15. B	16. C 17. C 18. B 19. B 20. A 21. A 22. C 23. A 24. D 25. A 26. B 27. D 28. B 29. A 30. A

FRQ (5pts each, award partial credit based on how thorough their explanations are, below are some sample explanations):

1. Fiber optics utilize the principle of total internal reflection to transmit light signals through thin strands of glass or plastic. Total internal reflection occurs when light traveling in a medium with a higher refractive index encounters a boundary with a lower refractive index at an angle greater than the critical angle. Applications include telecommunications, medical imaging, and data transmission.
2. A convex lens is thicker at the center than at the edges. It converges parallel rays of light to a focal point. The distance between the lens and the focal point is the focal length. For objects beyond the focal point, real and inverted images are formed. As objects move closer, the image becomes virtual, upright, and magnified.
3. Chromatic aberration occurs due to the dispersion of light into its component colors. It results in color fringing in images. This can be minimized by using achromatic lenses that combine multiple lens elements to focus different colors at the same point, reducing the effect of dispersion.
4. Polarization refers to the orientation of light waves. Natural sources include sunlight reflecting off surfaces. Artificial sources include polaroid filters. Polarizing filters are used to reduce glare, enhance contrast, and improve visibility in certain conditions, such as photography or sunglasses.

5. A concave mirror is curved inward and forms real, inverted images. Applications include shaving mirrors, satellite dishes, and reflectors in headlights. The focal point is located in front of the mirror. Image size depends on the object's distance from the mirror.
6. Diffraction is the bending of light waves around obstacles or through openings. It's noticeable when the size of the opening is comparable to the wavelength of light. Examples include the spreading of light around door edges or the interference pattern produced by a narrow slit.
7. The camera aperture controls the amount of light entering the camera. A wider aperture (smaller f-number) allows more light, affecting exposure. However, it also impacts depth of field. Choosing the right aperture involves a trade-off between exposure and depth of field.
8. Dispersion is the separation of white light into its component colors. A prism accomplishes this by refracting different colors by different amounts. The order of colors in the spectrum is red, orange, yellow, green, blue, indigo, and violet (ROYGBIV).
9. Optical power measures a lens's ability to converge or diverge light. It is measured in diopters. Converging lenses have positive power, while diverging lenses have negative power. The formula for optical power (P) is P = 1/f, where f is the focal length in meters.
10. A convex lens is used to correct hypermetropia by converging incoming light before it reaches the retina. This compensates for the short focal length of the hypermetropic eye. The corrected lens allows the eye to focus on near objects more effectively.

Extended Problem (40pts total, award partial credit based on how much work they show that is relevant and correct in the context of the problem, award full points if any part matches the answer no matter how much work is shown, sample solution shown below):

a. Use geometry angle tracing and the law of reflection. (3pts)

$$\beta = \alpha + 2\gamma$$

b. By small angle approximation, write each angle as a ratio of the height between the x-axis and the point of reflection, and the distance along the x-axis to the point of reflection. (8pts)

$$\alpha = \frac{h}{o}, \beta = \frac{h}{i}, \gamma = \frac{h}{r}$$

Plug this into the equation in part a.

$$\frac{h}{i} = \frac{h}{o} + \frac{2h}{r}$$

$$\frac{1}{i} = \frac{1}{o} + \frac{2}{r}$$

c. Set up similar triangles to form a ratio. (4pts)

$$\frac{h}{o} = \frac{h'}{i}$$

$$h' = h\frac{i}{o} = h\frac{r}{r+2o}$$

d. Use Pythagorean theorem to find the object distance of a point on the ring. (6pts)

$$o'' = \sqrt{(o + r)^2 + h^2} - r$$

Plug into the equation from part b to find image distance.

$$i'' = \frac{o''r}{r+2o''} = \frac{(\sqrt{(o+r)^2+h^2}-r)r}{2\sqrt{(o+r)^2+h^2}-r}$$

e. Set up similar triangles between the object and image. (4pts)

$$\frac{h}{o''+r} = \frac{h''}{r-i''}$$

$$h'' = h\frac{r-i''}{o''+r} = h\frac{r}{2\sqrt{(o+r)^2+h^2}-r}$$

f. Plug in the numbers to find image distance. Then find error. (8pts)

$$i = \frac{1}{\frac{1}{10}+\frac{2}{5}} = 2cm$$

$$\%i = \left|\frac{2-\frac{(\sqrt{(10+5)^2+5^2}-5)5}{2\sqrt{(10+5)^2+5^2}-5}}{2}\right| = 0.015$$

$$h' = 5 * \frac{5}{5+2*10} = 1cm$$

$$\%h = \left|\frac{1-5*\frac{5}{2\sqrt{(10+5)^2+5^2}-5}}{1}\right| = 0.061$$

Note the error is very small, even in an extreme case like this one.

g. Draw the four corners first as points along the connection between each corner to the sphere's center, then fill in the edges to the best of your intuition. Make sure no point is further than halfway between the sphere's surface and center. The front and back edges should also curve outwards, getting closer to the sphere's surface when approaching the horizontal axis. (7pts)