Optics Test

2017 Princeton University Science Olympiad Invitational

TEAM SIZE: Up to 2
TIME: 50 minutes
ALLOWED RESOURCES: All reference materials to be used during all parts of the competition must be initially secured in a 3-ring binder, so that regardless of orientation none can fall out. Competitors may bring any measuring toots, premade templates, writing utensils and any type of calculators for use during any part of the competition. Competitors must not bring lasers or minors.

School Name: _____

Team #: _____

Part 1: _____ / 40

Part 2: _____ / 12

Part 3: _____ / 30
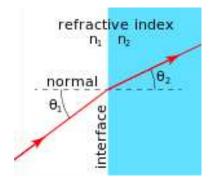
Total: _____ / 82

INSTRUCTIONS:
- Welcome to the 2017 Princeton University Science Olympiad Invitational!! Please fill in the blanks for your school name and team number on this title page.
- All answers must be written on the answer sheet. Nothing written in this test packet will be graded.

Part I: Multiple Choice (2 points each)

1. Light reflects off a wooden table. As a result, you can see all the details of the wood including its granularity, ridges, etc. This is an example of what kind of reflection?
   a. Diffuse Reflection
   b. Personal Reflection
   c. Specular Reflection
   d. Spiritual Reflection

2. Examine the following gorgeous image of a set of mountains whose reflection you can see in the water. This is an example of what kind of reflection?

   a. Diffuse Reflection
   b. Personal Reflection
   c. Specular Reflection
   d. Spiritual Reflection

3. Consider the following image shamelessly stolen from Wikipedia. If $\theta_1 > \theta_2$, which of the following is a true statement about the relationship between n_1 and n_2?

   a. $n_1 > n_2$
   b. $n_1 < n_2$
   c. $n_1 = n_2$
   d. Nothing conclusive can be said about the relationship between n_1 and n_2.

4. Consider a ray of light encountering a boundary between two materials. What happens when the angle of incidence is greater than or equal to the critical angle?
    a. The light starts thinking critically
    b. The light disperses into all different directions
    c. The light reflects off the surface instead of refracting
    d. The light passes through the boundary without changing directions

5. Why does dispersion occur when light passes through prisms?
    a. Red light travels faster than blue light through the prism
    b. Blue light travels faster than red light through the prism
    c. The wavelets of light interfere due to the prisms' shape and its interference produces the phenomenon of dispersion
    d. No matter at what angle of incidence, light will disperse in the second medium, the two boundaries of prisms merely amplify the effect

6. Often the side view mirrors found on the front doors of cars have the words "Objects in mirror are closer than they appear". From this statement, what type of mirrors are these?
    a. Convex
    b. Concave
    c. Plain

7. Convex mirrors can only produce what kind of image?
    a. Real
    b. Diluted
    c. Faded
    d. Virtual

8. Given two polarizing filters, you should position the two polarizers such that their axes of polarization are at what angle so that the intensity of light is reduced the most?
    a. 0 degrees
    b. 30 degrees
    c. 45 degrees
    d. 60 degrees
    e. 90 degrees

9. Which of the following statements about the eye are false? (Choose 1 or more)
    a. Cones are more sensitive to light than rods
    b. You have a higher proportion of rods in the outer regions/edges of your retina, while you have a higher proportion of cones in the central region of your retina
    c. Your blind spot is located at the fovea of your eye.
    d. You have more "green" cones than "red" cones

10. An object is placed 10cm in front of a mirror and a real image is formed exactly 10cm in front of the mirror. What kind of mirror is it?
    a. Convex
    b. Concave
    c. Plain
    d. One of those kinds of fun curvy mirrors you find at carnivals

11. A mirage is formed due to a gradient in refractive index of the air. This difference in refractive index can be best described as:
    a. Increasing as the distance to the observer increases
    b. Decreasing as the distance to the observer increases
    c. Increasing as the distance to the ground increases
    d. Decreasing as the distance to the ground increases

12. Which of the following statements are true?
    a. Mirages and hallucinations can both be captured on camera
    b. Mirages and hallucinations both cannot be capture on camera
    c. Mirages can be captured on camera, while hallucinations cannot
    d. Mirages cannot be captured on camera, while hallucinations can

13. Every point on a wavefront is a source of wavelets. What is the name of this principle?
    a. Fermat's Principle
    b. Principle of Least Action
    c. Hyugen's Principle
    d. Bernoulli's Principle

14. A light source that emits pure green light is shown on a white wall. A light source that emits pure blue light is also shown on the same spot on the wall. What color do you see?
    a. Yellow
    b. Cyan
    c. Magenta
    d. Red

15. If you have myopia, in what way is your eyeball distorted?
    a. Eyeball is elongated in the horizontal direction
    b. Eyeball is shortened in the horizontal direction
    c. Eyeball

16. Hypermetropia can be corrected with what kind of glasses?
    a. Sunglasses
    b. 3-D Glasses
    c. Concave Lens Glasses
    d. Convex Lens Glasses

17. The image that appears on the retina of your eyes is
    a. Real and inverted
    b. Real and upright
    c. Virtual and inverted
    d. Virtual and upright

18. The mirror equation is merely an approximation for spherical mirrors because incoming parallel rays to the principal axis of a spherical mirror do not all meet perfectly at the focus. However, the mirror equation holds true exactly for a mirror of which of the following shapes?
    a. Hexagonal
    b. Hyperbolic
    c. Ellipsoid
    d. Parabolic

19. Consider an object starting between a convex lens and its focal point. I move the object closer to the lens, what happens to its image?
    a. Increases in size and moves closer to the lens
    b. Decreases in size and moves closer to the lens
    c. Increases in size and moves further from the lens
    d. Decreases in size and moves further from the lens

20. Which of the following images has a larger f-stop?
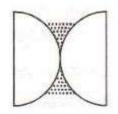   a. The one on the left
    b. The one on the right

Part II: Matching (1 point each)

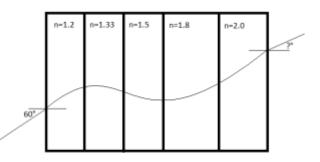Fill in the letter of the correct function of each part of the eye.

1. Pupil ___
2. Lens ___
3. Optic Disc ___
4. Fovea ___
5. Cornea ___
6. Optic Nerve ___
7. Retina ___
8. Ciliary muscle ___
9. Sclera ___
10. Macula ___
11. Aqueous Humor ___
12. Vitreous Humor ___

a. A layer of nerves at the back of the eye that senses light and converts it to electrical impulses that are sent to the brain.
b. A transparent structure inside the eye that focuses incoming rays of light.
c. An aperture at the front of the eye that increases in size in dark environments to let more light into the eye and decreases size in well-lit environments for the opposite reason.
d. A small central area at the back of the eye with a high concentration of rods and cones and is responsible for central, high-resolution color vision.
e. A small pit in the back of the eye composed of closely packed cones and is responsible for approximately half the nerve fibers in the optic nerve.
f. A thin circular structure that is responsible for controlling the size of the pupil.
g. The structure through which electric signals are carried from the eye to the brain.
h. A protective outer layer of the eye containing collagen and elastic fiber.
i. The physical blind spot of the eye.
j. A transparent, watery fluid that is secreted by the ciliary epithelium.
k. Transparent jellylike tissue that fills the eye.
l. The structure that changes the shape of the lens.

Part II: Short Answer (3 points each)

1. An object is placed in front of a converging lens with focal length of 20cm. If the resulting image is inverted and twice the size of the object, what is the distance between the object and the lens in centimeters?

2. (Tiebreaker #2) Two planoconvex lenses each with focal length 10 cm and refractive index 3/2 are placed as shown below. Water with refractive index 4/3 is filled between. The whole system is in air. What is the optical power of the system (in m^{-1})?
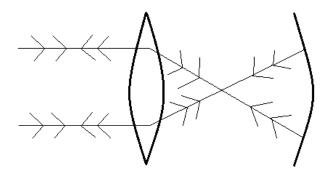

3. (Tiebreaker #1) An object is placed in front of a convex lens of focal length 30cm. A plain mirror is placed 15cm behind the lens. The resulting image of this system coincides with the object. What distance in centimeters is the object from the lens?

4. Consider the following setup: There are multiple blocks of material with the specified index of refraction set up side by side. If light enters these blocks at an angle of incidence of 60°, at what angle to the normal does the light exit the block?

5. (Tiebreaker #3) Consider square $ABCD$ of side length 1 meter. Mirrored walls are erected on each side of the square. A laser shoots a ray of light from vertex A such that the first wall it reaches is wall CD at exactly 3/16 meters away from corner D. How many times does ray of light bounce off a wall before hitting a corner of the square (hitting the corner does not count as a bounce)?

6. Tim is a vain male who stands at 180cm tall. If he stands 5 meters away from a mirror whose bottom edge is at the same height as the midpoint between the bottom of his foot and his pupil, what is the minimum length in centimeters that the mirror must be for him to see his entire body in the mirror?

7. Three polarizing films are placed on top of each other such that the angle between the axis of polarization for each neighboring film is 30 degrees. Light passes through these three films. If the intensity of the incoming light is I_0, what is the intensity of the outcoming light?

8. A convex lens is made from glass with index of refraction 1.5. The radius of curvature of both sides of the lens is 10cm. a concave mirror with radius of curvature 15cm is placed directly behind the convex lens, and beams of light parallel to the principal axis approach the system, while the outcoming beams are also parallel to the principal axis. What is the distance between the lens and the mirror in centimeters?

9. An object of height 6cm is placed in front of a convex mirror of focal length 6cm. What is the magnification of the image?

10. What is the critical angle of the boundary between two media where the index of refraction of one medium is 2.25 and the index of refraction of the other image is 1.125?