## Unit 5.B - Geometric Optics

## Essential Fundamentals of Geometric Optics

1. Convex surfaces bend outwards, concave ones bend inwards (like a cave).
2. A virtual image appears to be 'inside' a mirror or lens, while a real image needs a screen to see.
3. Depending on geometry, mirrors or lenses can make real, virtual, or both types of image.
4. Distances on the object side of the mirror or lens are positive, and those 'through' the mirror or lens are negative (see conventions resource for more details).
5. Magnification factor is a measure of size comparison between object and image.
6. Aberration is any distortion that an image has which causes it to be non-congruent to the object.

## Equation Sandbox

In Unit 5.B, some of the following equations will be used. Practice isolating variables to prepare for it.


## 5.B. 1 Problems - Plane Mirrors

 Section 23.1 of your textbook.1. An object 5.0 cm tall is placed $40 . \mathrm{cm}$ from a plane mirror: answer the following three questions. Find:
A. The distance from the object to the image
B. The height of the image
C. The images' magnification
2. A small dog sits 3.0 m in front of a plane mirror.
A. Where is the dog's image in relation to the mirror?
B. If the $\operatorname{dog}$ jumps at the mirror at a speed of $1.0 \mathrm{~m} / \mathrm{s}$, how fast does the dog approach its image?
3. If you hold a $900 . \mathrm{cm}^{2}$ square plane mirror 45 cm from your eyes and can just see the full length of an 8.5 m flagpole behind you, how far are you from the pole?

| Possible 5.B. 2 Pts.: 7 |  |  |
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| Late, Incomplete, | No work, |  |
| No Units Fee: | -1 | -2 |
| Final Score: | 17 |  |

## 5.B. 2 Problems - Spherical Mirrors Section 22.3 of your textbook.

1. A candle with a flame 1.5 cm tall is placed 5.0 cm from the front of a concave mirror. A virtual image is formed 10.0 cm behind the mirror.
A. Find the focal length and radius of curvature of the mirror.
B. How tall is the image of the flame?
2. An object is placed $50 . \mathrm{cm}$ in front of a convex mirror and its image is found to be $20 . \mathrm{cm}$ behind the mirror.
A. What is the focal length of the mirror?
B. What is the lateral magnification?
3. A virtual image of magnification +0.50 is 15 cm in front of a spherical mirror.
A. The mirror is (1) convex, (2) concave, (3) flat. Explain.
B. Find the radius of curvature of the mirror.
4. A child looks at a reflective Christmas tree ball ornament that has a diameter of 9.0 cm and sees an image of her face that is half the real size. How far is the child's face from to ball?

| Possible 5.B.3 Pts.: 5 |
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| Late, Incomplete, No work, |
| No Units Fee: $-1 \quad-2$ |
| Final Score: $\quad / 5$ |

## 5.B. 3 Problems - Lenses \& Aberrations <br> Section 23.3-22.5 of your textbook.

1. When an object is placed at 2.0 m in front of a diverging lens, a virtual image is formed at 30 cm in front of the lens. What are the focal length of the lens and the lateral magnification of the image?
2. An object 4.0 cm tall is in front of a converging lens of focal length 22 cm . The object is 15 cm away from the lens.
A. Use a ray diagram to determine whether the image is (1) real or virtual, (2) upright or inverted, and (3) magnified or reduced.
B. Calculate the image distance and lateral magnification.
3. A symmetric converging glass lens with an index of refraction of 1.62 has a focal length of 30 cm in air.
A. When the lens is immersed in water, the focal length will (1) increase, (2) remain the same, (3) decrease. Explain.
B. What is the focal length when the lens is submerged in water?

| AP Physics 2 | Unit 5.B.1 Lab - Spherical Mirrors |  |
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| Reminder: Update Table of Contents |  | Correction Credit: <br> Half |

## Objective:

You and your team will take measurements allowing you to calculate the focal points, radii of curvature, and magnification factors of concave and convex circular mirrors.

## Mission 1: Concave Mirrors

## Part $\alpha$ : Ray Diagram

Stand back approximately three meters from the concave mirror and look at yourself. You should see yourself as a virtual, inverted, shrunken image.

Use the following ray diagram template to predict where the real image forms. The focal point (F)

| Spherical Mirror Lab (5.B.1) Guide |  |  |
| :---: | :---: | :---: |
| Table of Contents, Title/Date, Complete Synopsis, Two Purposes, Legible |  | / 2 |
| Mission 1: <br> Concave <br> Mirror Data Table | Virtual image drawing | 12 |
|  | Object to mirror dist. | / 1 |
|  | Screen to mirror dist. | / 1 |
|  | Object height | / 1 |
|  | Image height | / 1 |
| Mission 2: Convex Mirror Data Table | Team member height | / 1 |
|  | Image height | / 1 |
|  | Distance: person/mirror | / 1 |
| Analysis 1: Focal length Mission 1. |  | / 1 |
| Analysis 2: Radius of curvature M.1. |  | / 1 |
| A. 3: Mag. Factor Mission 1, two ways. |  | / 2 |
| Analysis 4: Image distance Mission 2. |  | / 1 |
| Analysis 5: Focal length Mission 2. |  | / 1 |
| Analysis 6: Radius of curvature M.2. |  | / 1 |
| A. 7: Mag. Factor Mission 2, two ways. |  | / 2 |
| Question 1: Focal length comparison. |  | / 2 |
| Q. 2: Mag. Comp. for both mirrors, 2 ways. |  | 13 |
| Work Not Shown Fee: |  | -1-2-3 |
| Late Lab Fee: |  | -5 |
| Total: |  | / 25 | and center of curvature (C) have been provided for you. Pick a point on the object, and draw the three rays mentioned earlier to determine where that point appears. Repeat this process for another point on the object, and that will show you the object's location, then draw the image. Transfer this image into your Lab Book.



## Part B: Measurements of focal length: Data Table

Use the concave circular mirror and the screen setup to experimentally determine the focal length of your mirror. Since there is only one mirror and one screen, we will do this as a class.

1. Place the illuminated object between 3.0 and 4.0 meters from the mirror's apex, and measure this exact distance. Record this, and all other values in a well-organized and labeled data table.
2. Determine where the real image forms by moving the screen until the image is in focus and record this exact distance. Note: focus will not be crystal clear - the mirror is slightly distorted.
3. Measure the height of the actual object, and the height of the image (remember - it's negative) on your screen. This will be a little difficult due to the blurriness.

## Mission 2: Convex Mirrors

You must accomplish this mission without touching the mirror's surface.

1. Measure the height of one member of the team, and record it in a new data table.
2. Have that person move away from the mirror until a 15.2 cm ruler taped to the mirror appears to be the same height as the person being measured - from the perspective of that person. Group members may have to move the ruler as the person moves farther away.
3. Record the exact distance from the mirror to the person.

## Analysis: Answer these completely in your Lab Books, and note mirror conventions.

1. Calculate the exact focal length of the concave mirror from Mission 1 (will be positive).
2. Calculate the radius of curvature for the concave mirror from Mission 1 (will be positive).
3. Calculate the magnification factor in Mission 1 two ways, using distances of object and image, and heights of object and image.
4. Calculate the image distance of the virtual person in Mission 2.
5. Calculate the focal length of the convex mirror in Mission 2.
6. Calculate the radius of curvature for the convex mirror.
7. Calculate the magnification factor in Mission 2, using both distances of object and image, and heights of object and image.

## Questions: Rephrase and answer each in at least three complete sentences for full credit.

1. How do your values of focal length compare between your measurements of the convex mirror and the concave one?
2. For both mirrors, you computed magnification using two different methods. How did the magnification factor calculations compare?

| AP Physics 2 | Unit 5.B - Geometric Optics |  |  |  |  |
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| Application Problems, AP Test Preparation Questions |  |  |  |  |  |
| Presentation <br> Points: | $/ 5$ | Late Fee: | -2 | Completion <br> (Booklet Check) | $/ 5$ |

Your grade on this problem set depends on the presentation you provide for your assigned problems, and whether all problems are complete when you submit your Booklet at the end of the Unit.

## Application Problems

1. Use the ray diagram template to predict where the cyclops will see its own virtual image.

2. Describe chromatic aberration in a convergent lens; then draw a conceptual picture that shows this.
3. What is the focal length of a converging lens when an object 1.3 m in front of the lens forms an image 1.8 m on the side opposite the object?
4. An object 3.0 cm tall is placed 20.0 cm from the front of a concave mirror with a radius of curvature of 30.0 cm . Where is the image formed, and how tall is it?

## AP Multiple Choice Questions

1. An object is placed 60 cm in front of a concave spherical mirror whose focal length is 40 cm . Which of the following best describes the image?

Nature of Image
A. Virtual
B. Real
C. Virtual
D. Real
E. Real

Distance from mirror
24 cm
24 cm
120 cm
120 cm
240 cm
2. An object is placed 60 cm from a spherical convex mirror. If the mirror forms a virtual image 20 cm from the mirror, what's the magnitude of the mirror's radius of curvature?
A. 7.5 cm
B. 15 cm
C. 30 cm
D. 60 cm
E. 120 cm
3. The image created by a converging lens is projected onto a screen that's 60 cm from the lens. If the height of the image is $1 / 4$ the height of the object, what's the focal length of the lens?
A. 36 cm
B. 45 cm
C. 48 cm
D. 72 cm
E. 80 cm
4. Which of the following is true concerning a bi-concave lens? (Both surfaces are concave.)
A. Its focal length is positive
B. It cannot form real images
C. It cannot form virtual images
C. It can magnify objects
D. None of the above

| AP Physics 2 |  | Unit 5.B Review - Geometric Optics |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Points: | $/ 20$ | Late or <br> Incomplete Fee: | $-2-4-6$ | Correction <br> Credit: | Final <br> Score: |  |

Solve these problems here, THEN enter your responses in the bubble sheet provided.

Each question is worth two points.

1. A convex mirror with a focal length of 0.25 m forms a 0.080 m tall image of an automobile at a distance of 0.24 m behind the mirror. How far away is the car located?
A. 1.0 m
B. 3.0 m
C. 6.0 m
D. 8.0 m
E. 10.0 m
2. A convex mirror with a focal length of 0.25 m forms a 0.080 m tall image of an automobile at a distance of 0.24 m behind the mirror. What's its real height?
A. 2.0 m
B. 1.0 m
C. 1.5 m
D. 2.5 m
E. 2.8 m
3. A convex mirror with a focal length of 0.25 m forms a 0.080 m tall image of an automobile at a distance of 0.24 m behind the mirror. What is the magnification factor?
A. 2.50
B. 1.25
C. 0.50
D. 0.04
E. 0.16
4. An object is 25 cm in front of a converging lens with a focal point of 10 cm . What is the image distance?
A. 3.5 cm
B. 16.7 cm
C. 8.9 cm
D. 11 cm
E. 12.1 cm
5. If a converging lens is submerged in water, how will its focal length compare to when it is in the air?
A. Longer
B. Shorter
C. The Same
6. An object is 15 cm in front of a diverging lens with a focal point of 5.0 cm . Find the image distance.
A. -1.25 cm
B. -2.55 cm
C. -3.05 cm
D. -3.75 cm
E. -4.00 cm
7. An object is 15 cm in front of a diverging lens with a 5.0 cm focal point. Find the magnification factor.
A. 0.25
B. 0.50
C. 0.75
D. 1.25
E. 1.00
8. If you have a concave mirror with a focal length of 15 cm , where would you have to place a sheet of paper so that the image projected onto it is five times as far as the object is?
A. 6.0 cm
B. 12 cm
C. 18 cm
D. 36 cm
E. 90 cm
9. A concave spherical mirror can be used to project an image onto a sheet of paper, allowing the magnified image of an illuminated object to be accurately traced. If you have a concave mirror with a focal length of 15 cm , will the image be upright or inverted?
A. Inverted
B. Upright
10. A maker of lenses uses crown glass to make a biconvex lens in a spotting scope. What is the focal length of his lens if the first radius of curvature is 15.7 cm , and the second is 12.2 cm ?
A. -6.0 cm
B. -12 cm
C. -20 cm
D. -36 cm
E. -90 cm
