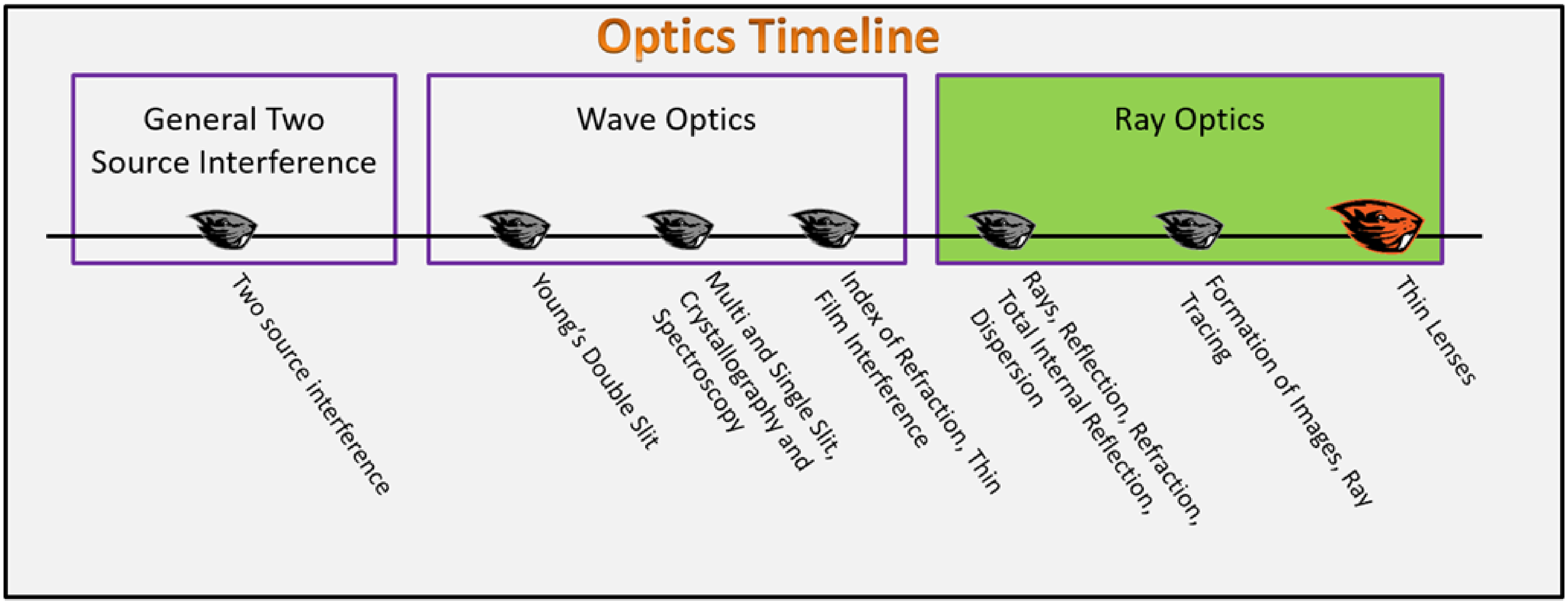
(RO.L3.2-sols) Foundation Stage Solutions

Monday, January 22, 2018 5:44 PM

Ray Optics
Foundation Stage (RO.2.L3)

Lecture 3
Thin Lenses



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos (Thin Lens Equation)
- **Knight** (College Physics : A strategic approach 3rd) :: 18.7 ; 19.2 ; 19.3 ; 19.4 ; 19.5
- ***Knight** (Physics for Scientists and Engineers 4th) :: 34.6 ; 35.1 ; 35.5 ; 35.4
- **Giancoli** (Physics Principles with Applications 7th) :: 23-8 ; 23-9 ; 25-2 ; 25-3 ; 25-4 ; 25-5 ;

Warm up

RO.2.L3-1:

Description: Sketch thin lens ray diagram for single converging lens. Estimate magnification for single lens. Sense make.

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

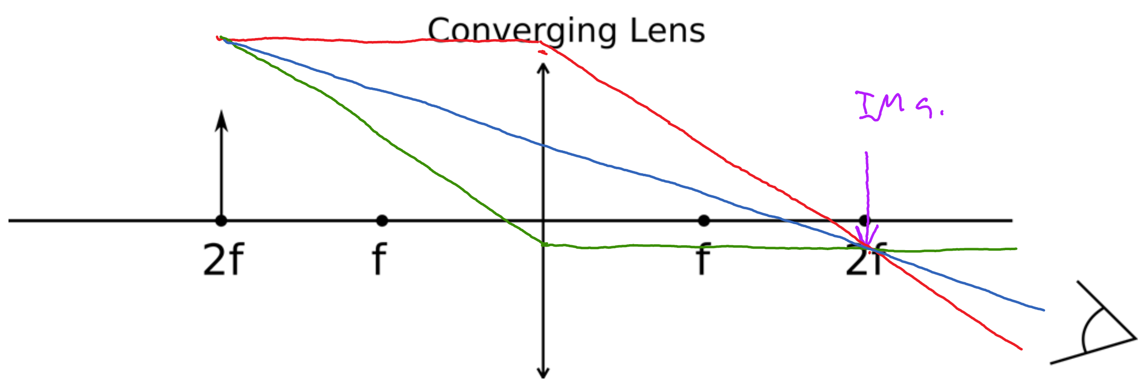
Problem Statement: Below is the start of a physical representation that will be useful when trying to determine how a lens bends light from a source.

(a) Use the ray tracing rules for thin lenses to sketch the location, orientation, and type of image creased using the given lens.

(i) Ray from object, parallel to optical axis, refracts through far focal point.

(ii) Ray from object, through near focal point, refracts parallel to optical axis.

(iii) Ray from object, through center of lens, exits undeflected.



(b) Estimate the magnification.

$M = -1$

(c) How can this location at 2**f** be used for sense making for thin converging lenses?

If $d_o > 2f$ $|M| < 1$ AND $d_I < 2f$

If $f < d_o < 2f$ $|M| > 1$ AND $d_I > 2f$

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Focal length
- Thin lens equation

Key Equations

Key Concepts

- Coming soon to a lecture template near you.

Questions

Act I: Mathematical Model for Thin Lens

RO.2.L3-2:

Description: Sketch thin lens ray diagram for single converging lens. Calculate image distance. Make sense of sign of image distance. Calculate magnification. (2 minutes + 3 minutes + 2 minutes + 2 minutes)

Learning Objectives: [?]

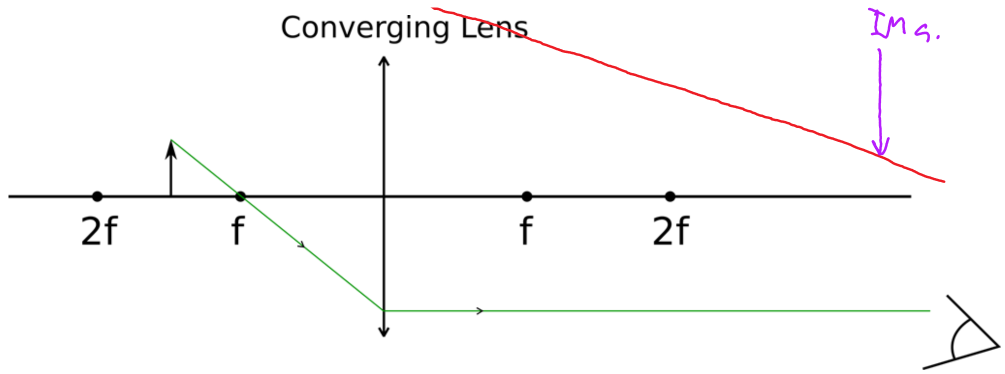
> **Problem Statement:** Below is the start of a physical representation that will be useful when trying to determine how a lens bends light from a source.

(a) Use the ray tracing rules for thin lenses to sketch one of the remaining rays for an object placed 12 cm from a thin converging lens of focal length 8 cm.

(i) Ray from object, parallel to optical axis, refracts through far focal point.

(ii) Ray from object, through near focal point, refracts parallel to optical axis.

(iii) Ray from object, through center of lens, exits undeflected.



$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_I}$$

$$M = -\frac{d_I}{d_o}$$

(b) Calculate the image distance.

$$\frac{1}{8\,cm} = \frac{1}{12\,cm} + \frac{1}{d_I}$$

$$d_I = 24\,cm$$

(c) What does the sign of the image distance tell us in this single lens system?

d_I (+)

(1) Real image on same side as object.
(2) Real image on opposite side of object.
(3) Virtual image on same side as object.
(4) Virtual image on opposite side of object.

(d) Calculate the magnification.

$$= \frac{-24}{12}$$

$$M = -2$$

Inverted

RO.2.L3-3:

Description: Sketch thin lens ray diagram for single converging lens. Calculate image distance. Make sense of sign of image distance. Calculate magnification. (2 minutes + 3 minutes + 2 minutes + 2 minutes)

Learning Objectives: [?]

Problem Statement: Use the ray tracing rules for thin lenses to sketch one of the remaining rays for an object placed 2 cm from a thin converging lens of focal length 8 cm.

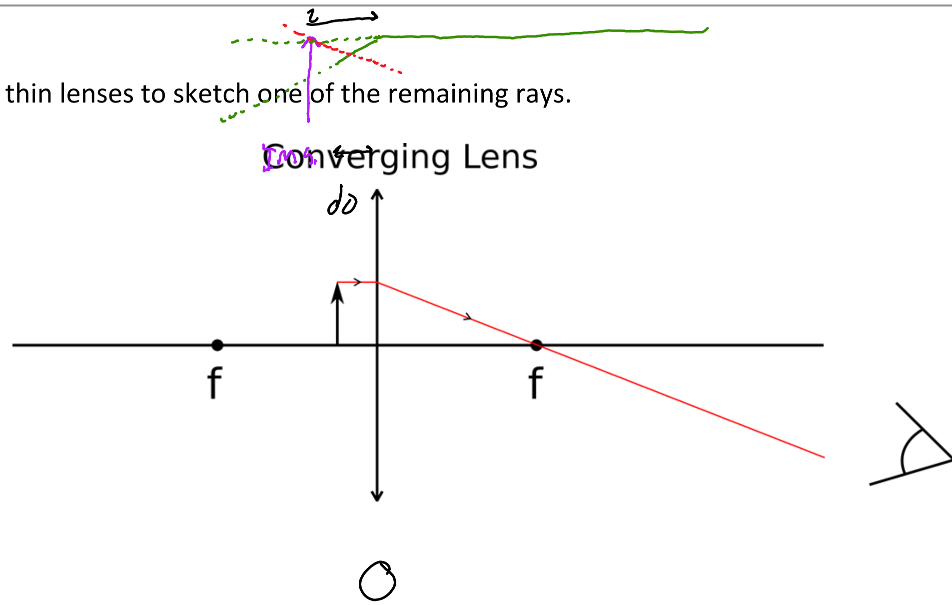
(a) Use the ray tracing rules for thin lenses to sketch one of the remaining rays.

(i) Ray from object, parallel to optical axis, refracts through far focal point.

(ii) Ray from object, through near focal point, refracts parallel to optical axis.

(iii) Ray from object, through center of lens, exits undeflected.

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_I}$



$M = \frac{-d_I}{d_o}$

(b) Calculate the image distance.

$\frac{1}{8\,cm} = \frac{1}{2\,cm} + \frac{1}{d_I}$

$d_I = -2.67\,cm$

(c) What does the sign of the image distance tell us in this single lens system?

(1) Real image on same side as object.
(2) Real image on opposite side of object.
(3) Virtual image on same side as object.
(4) Virtual image on opposite side of object.

(d) Calculate the magnification.

$\frac{-(-2.67)}{2}$

$M = 1.34$

RO.2.L3-4:

Description: Calculate focal length of thin lens given object and image distance. (4 minutes)

Learning Objectives: [?]

Problem Statement: A thin converging lens of unknown focal length is used in a lab to project an image on a screen that is 25 cm from the lens. The object used to make the image is placed 37.5 cm from the lens. What is the focal length of this lens?

$d_I = 25$

$d_o = 37.5$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_I}$$

$$\frac{1}{f} = \frac{1}{37.5\,cm} + \frac{1}{25\,cm}$$

$$f = 15\,cm$$

RO.2.L3-5:

Description: Calculate image distance for converging lens with object at f. (4 minutes)

Learning Objectives: [?]

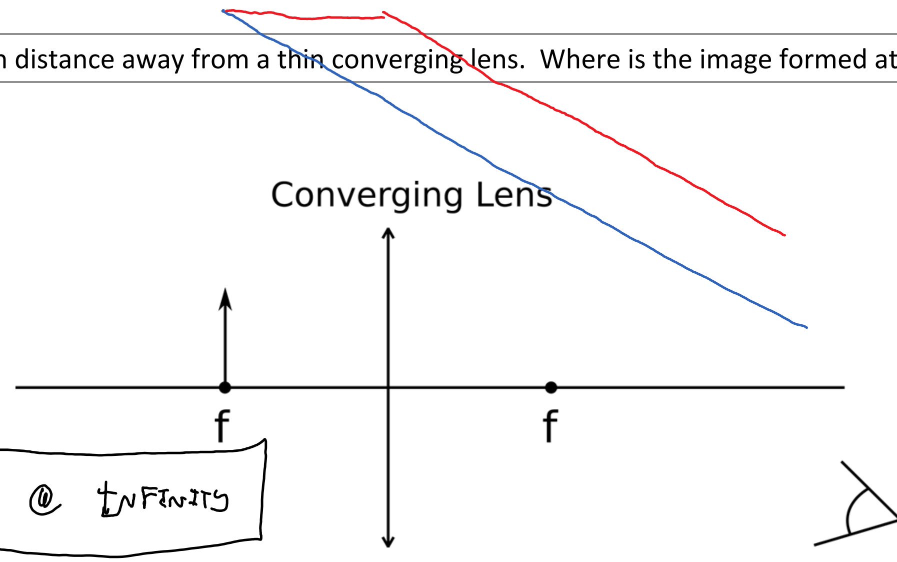
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_I}$$

Problem Statement: An object is placed a focal length distance away from a thin converging lens. Where is the image formed at?

$$\frac{1}{f} = \frac{1}{f} + \frac{1}{d_I}$$

$$0 = \frac{1}{d_I}$$

$$d_I = \frac{1}{0} \rightarrow \infty$$



d_I @ INFINITY

RO.2.L3-6:

Description: Sketch thin lens ray diagram for single diverging lens. Calculate image distance. Make sense of sign of image distance. Calculate magnification. (2 minutes + 3 minutes + 2 minutes + 2 minutes)

Learning Objectives: [?]

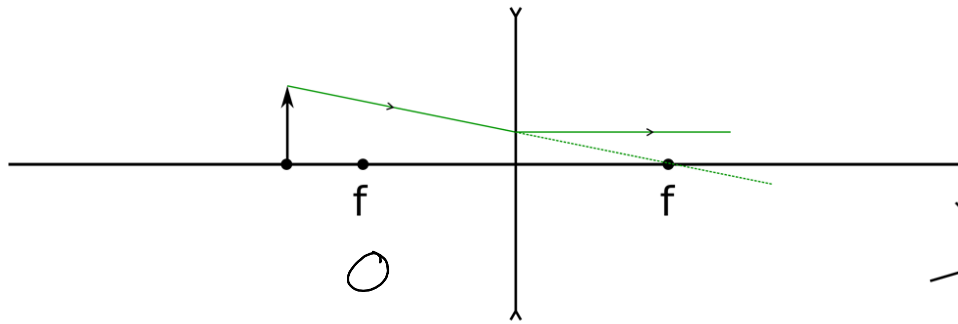
Problem Statement: Use the ray tracing rules for thin lenses to sketch one of the remaining rays for an object placed 12 cm from a thin diverging lens of focal length 8 cm.

(a) Use the ray tracing rules for thin lenses to sketch one of the remaining rays.

(i) Ray from object, parallel to optical axis, refracts as if it came from near focal point.

(ii) Ray from object, towards far focal point, refracts parallel to optical axis.

(iii) Ray from object, through center of lens, exits undeflected.



(b) Calculate the image distance.

(c) What does the sign of the image distance tell us in this single lens system?

(1) Real image on same side as object.
(2) Real image on opposite side of object.
(3) Virtual image on same side as object.
(4) Virtual image on opposite side of object.

(d) Calculate the magnification.

RO.2.L3-7:

Description: Conceptual question about thin lenses and real vs virtual images. (2 minutes + 2 minutes)

Learning Objectives: [?]

USE CONVERGENT LENS

Problem Statement: Benny the beaver wishes to create a fire for warmth. In order to create this fire, he needs to create a real image of the sun on the log using a single lens.

(a) Which of the following lenses can never create a real image by itself?

CONVERGENTS... REAL, VIRTUAL, AND @ ∞

(1) Converging
(2) Diverging
(3) None of the above

(b) Which of these lenses will always create a real image by itself?

(1) Converging
(2) Diverging
(3) None of the above

Act II: The Eye as a Lens

RO.2.L3-8:

Description: Calculate focal lengths, and near and far points for eye as a single lens. (3 minutes + 3 minute + 3 minute + 3 minutes)

Learning Objectives: [?]

Problem Statement: You can change the shape of the lens inside your eye to create an image on the back of your eye (your retina) of objects at different distances. Since your eye does not change size and the image needs to be made on the retina, the image distance must stay the same. Your near point is the shortest distance from the lens in your eye to an object for which you can make a clear image on your retina. If the object moves any closer to your eye than the near point, the object becomes out of focus (e.g. fuzzy). The average human eye has a near point of about 25 cm.

The average eye length from the front to the back is about 24 mm.

Assume that the lens of the eye is at the front of the eye and is a thin converging lens. Also assume that your eye is made of air except for the lens.

24 mm

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{f} = \frac{1}{25cm} + \frac{1}{2.4 cm}$

$f = 2.19 cm$

(a) Emmetropia (normal vision) occurs when your eye is the perfect length allowing the light rays to converge exactly on the retina when an object is at infinity and when at a near point of about 25 cm. **When looking at an object placed at her near point, what is the focal length of an average human's lens?**

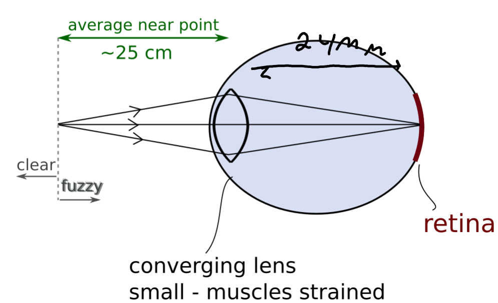
$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{f} = \frac{1}{\infty} + \frac{1}{2.4cm}$

$f = 2.4 cm$

Emmetropia (normal vision)

Focus on near object

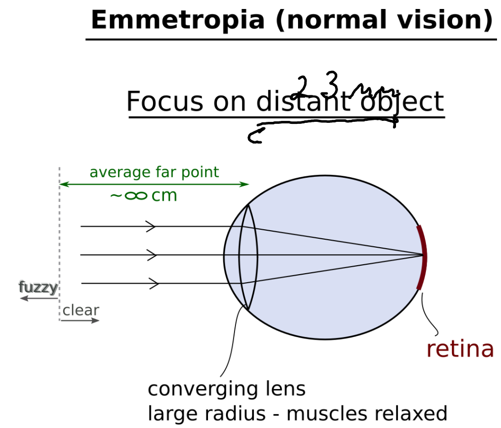


(b) Emmetropia (normal vision) occurs when your eye is the perfect length allowing the light rays to converge exactly on the retina when an object is at infinity and when at a near point of about 25 cm. **What is the focal length of her lens when looking at the moon which is really really far away?**

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_I}$$

$$\frac{1}{2.19\,cm} = \frac{1}{d_o} + \frac{1}{2.3\,cm}$$

$$d_o \approx 40.8\ cm$$

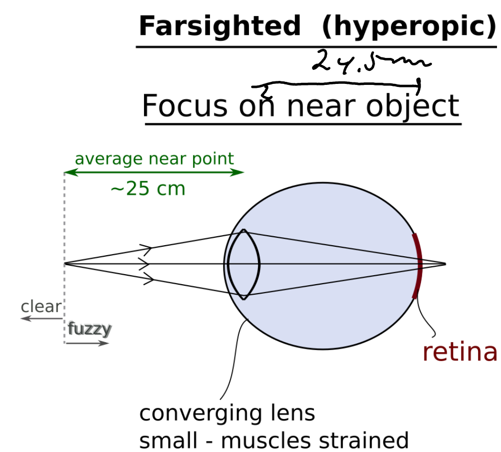


(c) Hyperopia (farsighted) can occur when your eye is too short causing light rays to converge behind the retina when an object is placed at the average human near point. **Assume the lens is still limited to the same range of focal lengths. If somebody has an eye length of only 23 mm, what is their near point?**

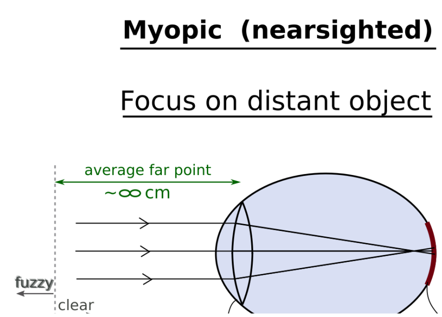
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_I}$$

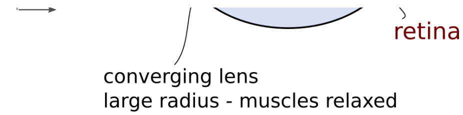
$$\frac{1}{2.4\,cm} = \frac{1}{d_o} + \frac{1}{2.45\,cm}$$

$$d_o \approx 118\ cm$$



(d) Myopia (nearsighted) can occur when your eye is too long causing light rays to converge in front of the retina when an object is placed at the average human far point of infinity. **Assume the lens is still limited to the same range of focal lengths. If somebody has an eye length of about 24.5 mm, what is their far point?**





Act III: Combination of Thin Lenses

RO.2.L3-9:

Description: TBD

Learning Objectives: [?]

Problem Statement: TBD

Conceptual questions for discussion

1. Focal length dependence on n question

Hints

RO.2.L3-1: No hints.

RO.2.L3-2: No hints.

RO.2.L3-3: No hints.

RO.2.L3-4: No hints.

RO.2.L3-5: No hints.

RO.2.L3-6: No hints.

RO.2.L3-7: No hints.

RO.2.L3-8: No hints.

RO.2.L3-9: No hints.