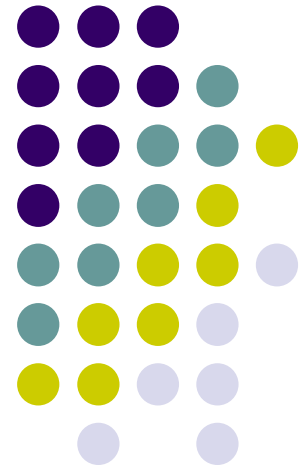# Focal Points
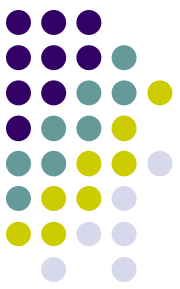
Basic Optics, Chapter 4
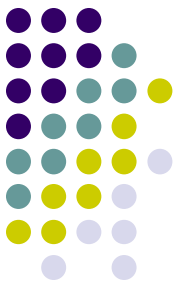
Focal Points

- Every spherical lens has 2 focal points:
  - ***Primary*** *focal point*
  - ***Secondary*** *focal point*

Focal Points: Primary

- Primary focal point: Location at which an **object** could be placed, and light rays associated with the object would exit the lens with zero vergence (i.e., parallel)

Focal Points: Primary

- Primary focal point: Location at which an **object** could be placed, and light rays associated with the object would exit the lens with zero vergence (i.e., parallel)
  - In terms of the Vergence Formula, this means that $V = 0$, and therefore U and P are of equal-but-opposite magnitude
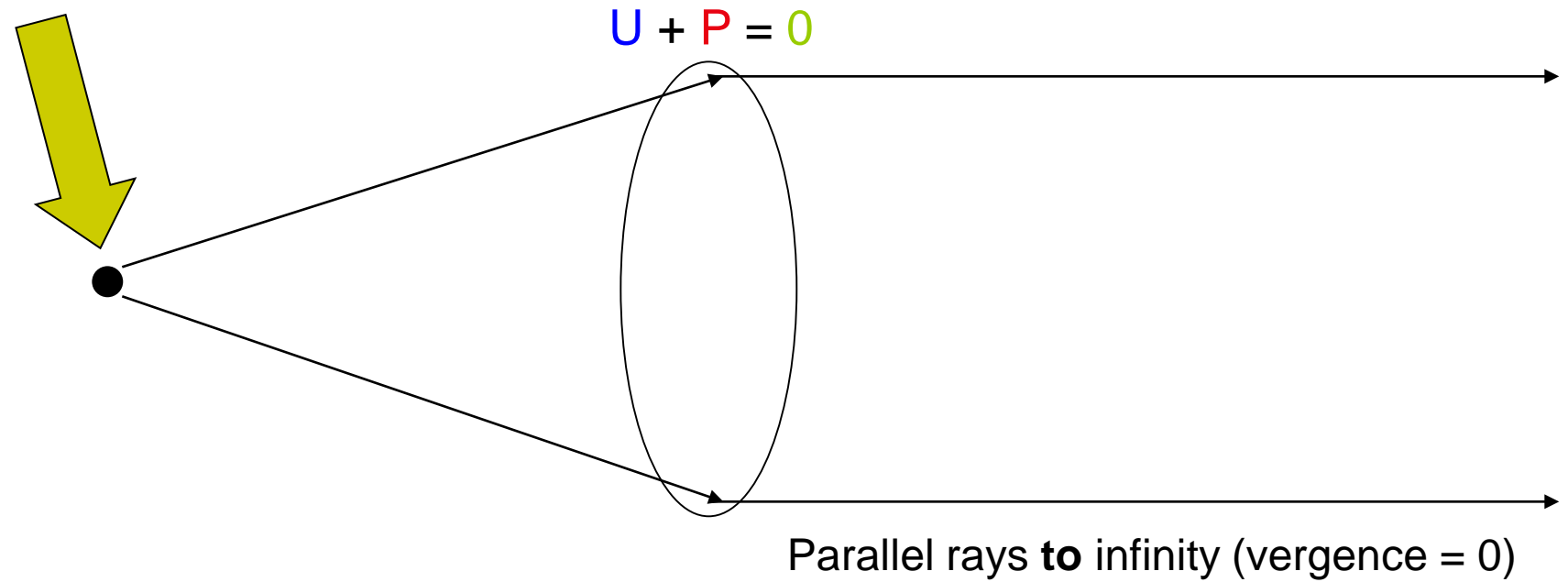
$$U + P = V$$

$$U + P = 0$$

These have to be the same value, with one of them (-), in order for them to sum to zero
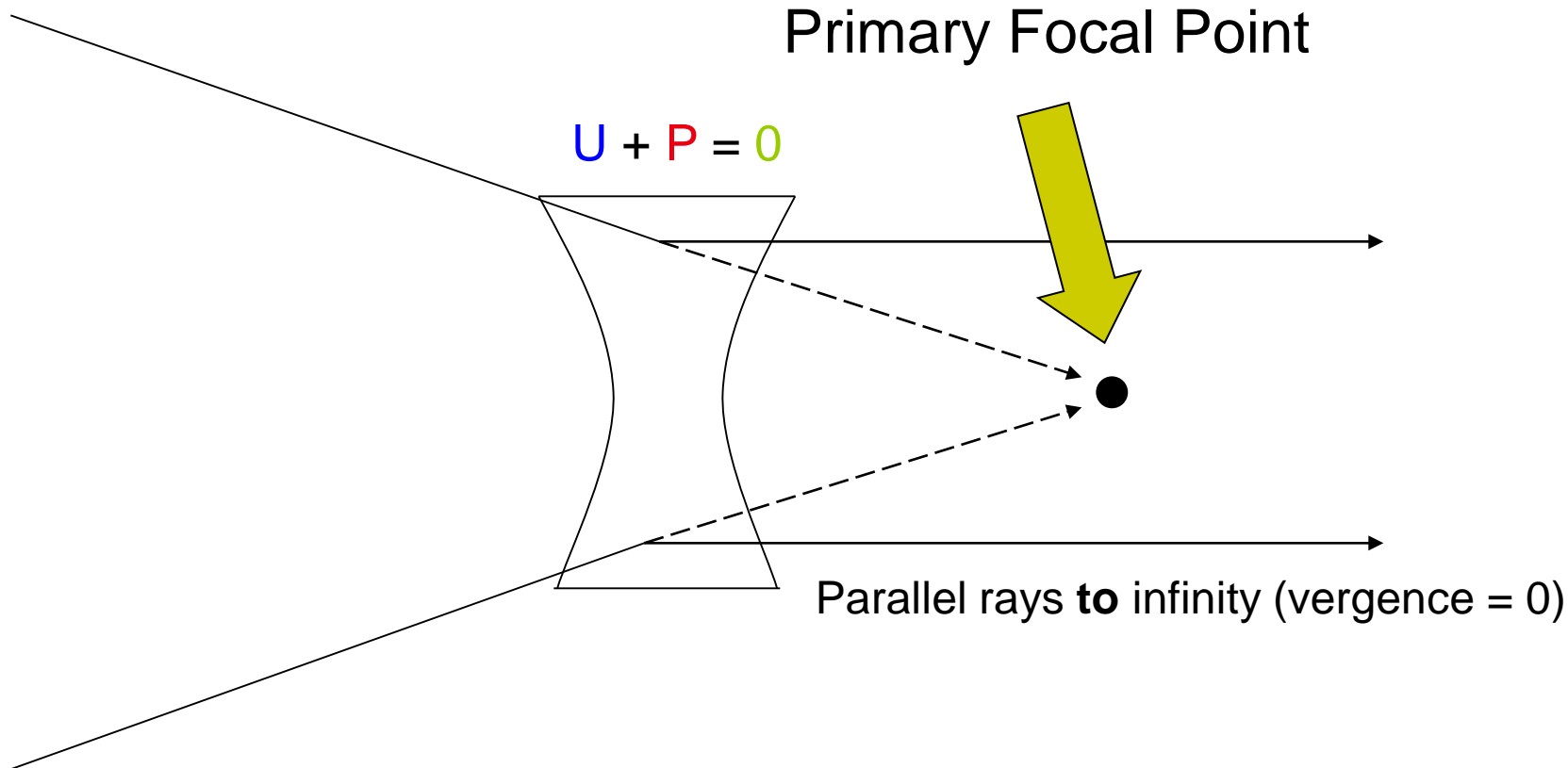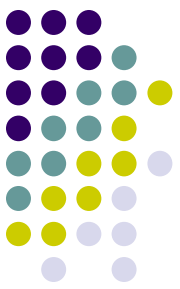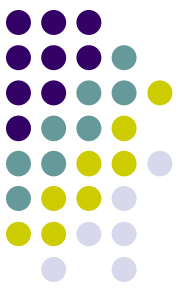
Focal Points: Primary

Primary Focal Point

$$U + P = 0$$

Parallel rays **to** infinity (vergence = 0)

Focal Points: Primary

Primary Focal Point

U + P = 0

Parallel rays **to** infinity (vergence = 0)
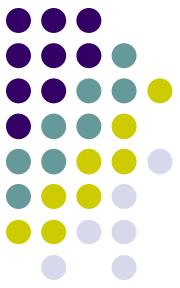
Focal Points: Secondary

- ***Secondary* focal point**: Location at which the **image** is formed when light rays with zero vergence (i.e., parallel) encounter a given lens

Focal Points: Secondary

- ***Secondary*** focal point: Location at which the **image** is formed when light rays with zero vergence (i.e., parallel) encounter a given lens
  - In terms of the Vergence Formula, this means that $U = 0$, and therefore P equals V
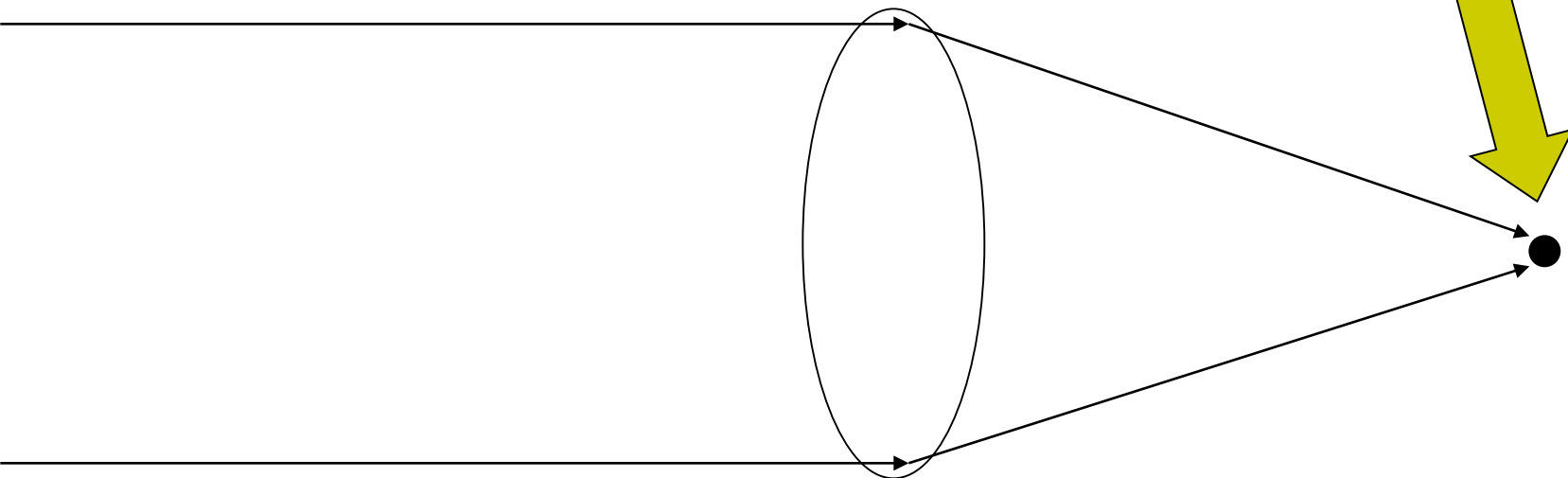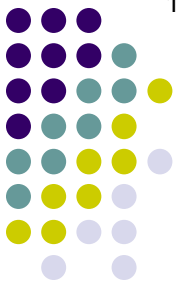
$$U + P = V$$
$$0 + P = V$$
$$P = V$$

Focal Points: Secondary
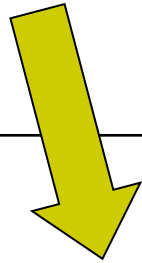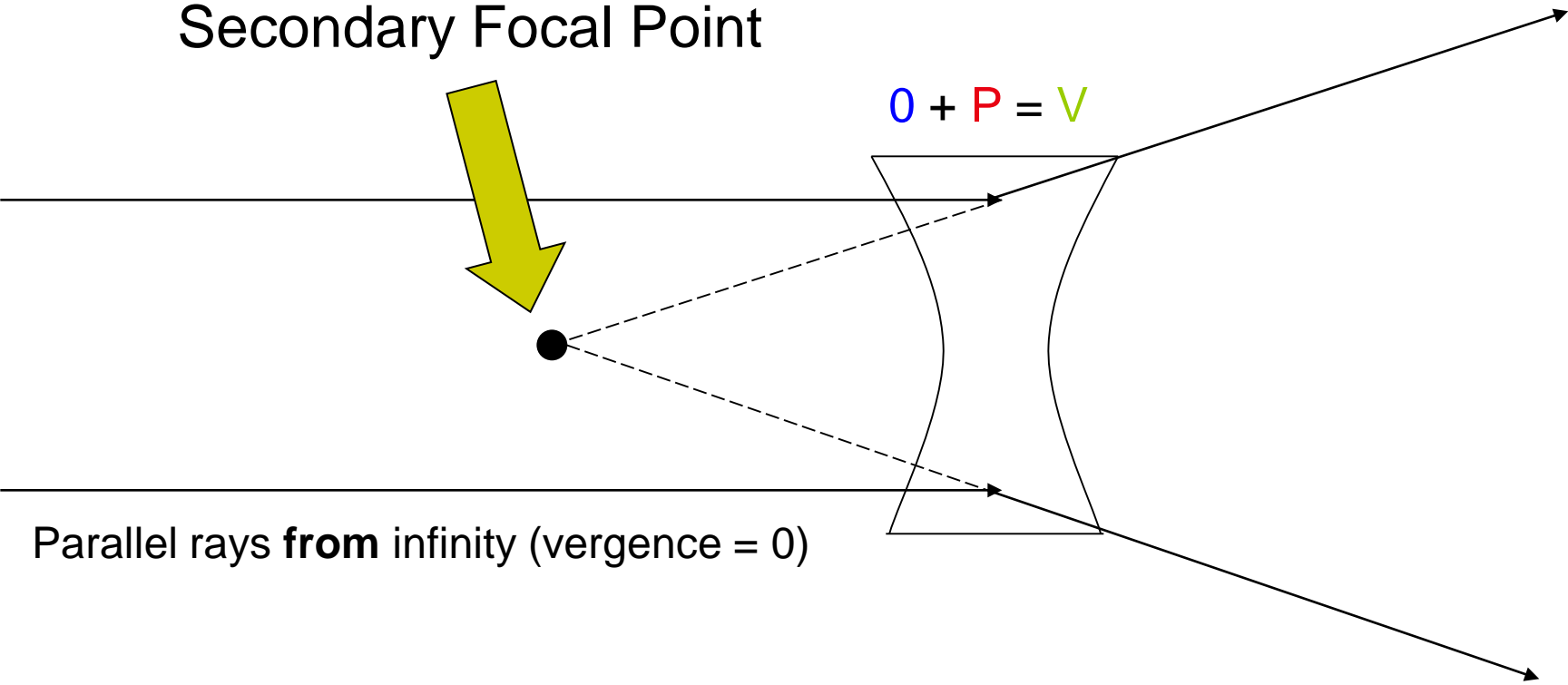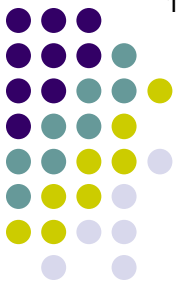
Secondary Focal Point

$0 + P = V$

Parallel rays **from** infinity (vergence = 0)
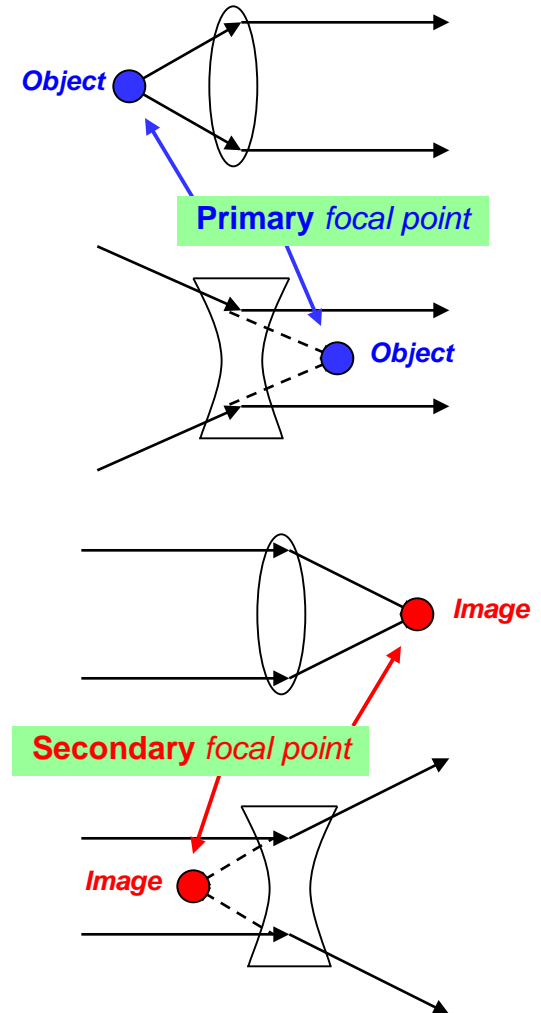
Focal Points: Secondary

Secondary Focal Point

$0 + P = V$

Parallel rays **from** infinity (vergence = 0)

Focal Points

- Note:
  - Primary focal points are *object* locations; secondary focal points are *image* locations

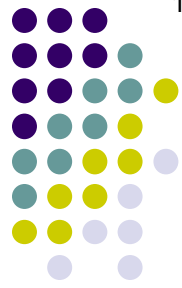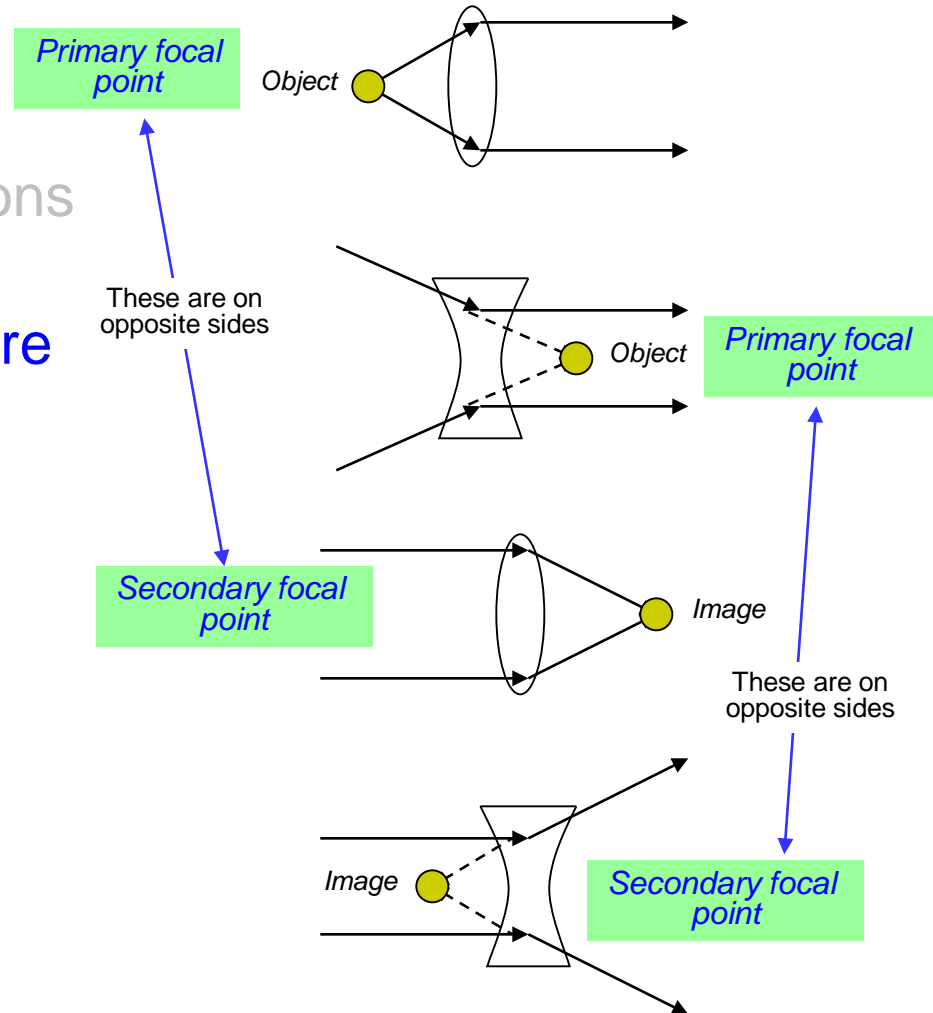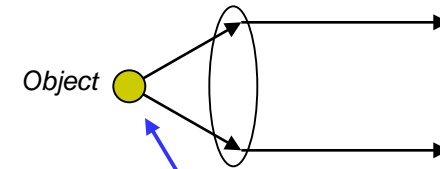**Primary** *focal point*

Secondary *focal point*

Focal Points

- ## Note:
  - Primary focal points are *object* locations; secondary focal points are *image* locations
  - For each lens type, primary and secondary focal points are on opposite sides of the lens

Primary focal point

Object

These are on opposite sides

Primary focal point

Object

Secondary focal point

Image

These are on opposite sides

Image

Secondary focal point

Focal Points

- Note:
  - Primary focal points are *object* locations; secondary focal points are *image* locations
  - For each lens type, primary and secondary focal points are on opposite sides of the lens
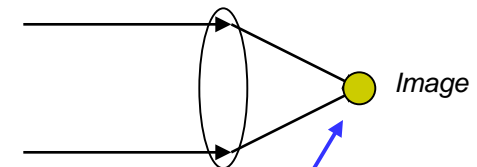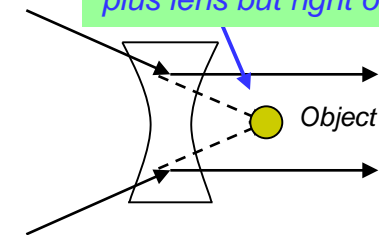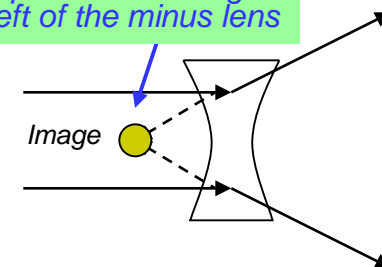 - For plus vs minus lenses, the position of the primary and secondary focal points are reversed

Object

Primary *focal point is to the left of plus lens but right of the minus lens*
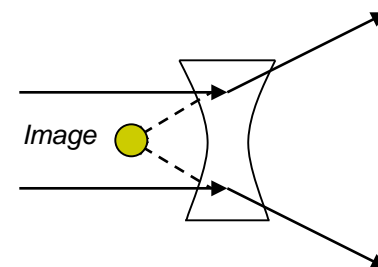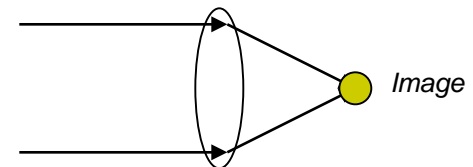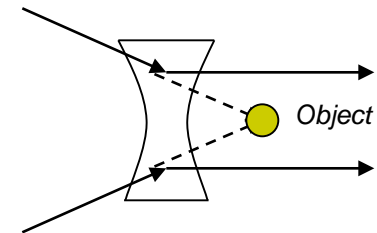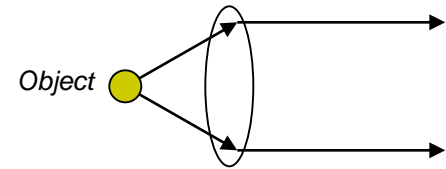
Object

Image

Secondary *focal point is to the right of plus lens but left of the minus lens*

Image

Focal Points

- Note:
  - Primary focal points are *object* locations; secondary focal points are *image* locations
  - For each lens type, primary and secondary focal points are on opposite sides of the lens
  - For plus vs minus lenses, the position of the primary and secondary focal points are reversed
  - Primary and secondary focal points are NOT conjugate points

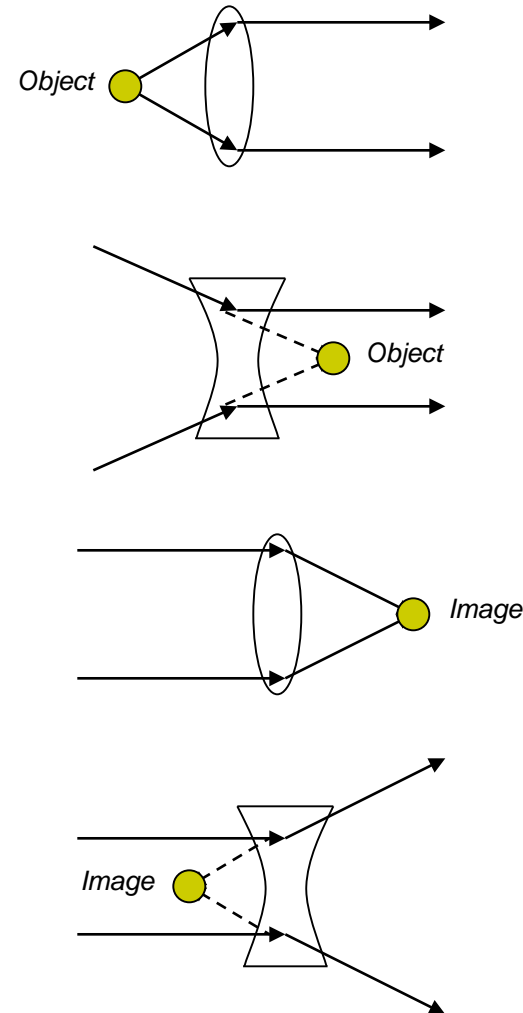Object

Object

Image

Image

Focal Points

- Note:
  - Primary focal points are *object* locations; secondary focal points are *image* locations
  - For each lens type, primary and secondary focal points are on opposite sides of the lens
  - For plus vs minus lenses, the position of the primary and secondary focal points are reversed
  - Primary and secondary focal points are NOT conjugate points

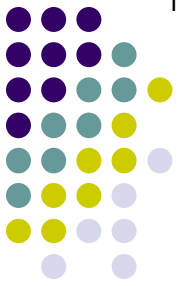*(Huh? What's a conjugate point?)*

Focal Points

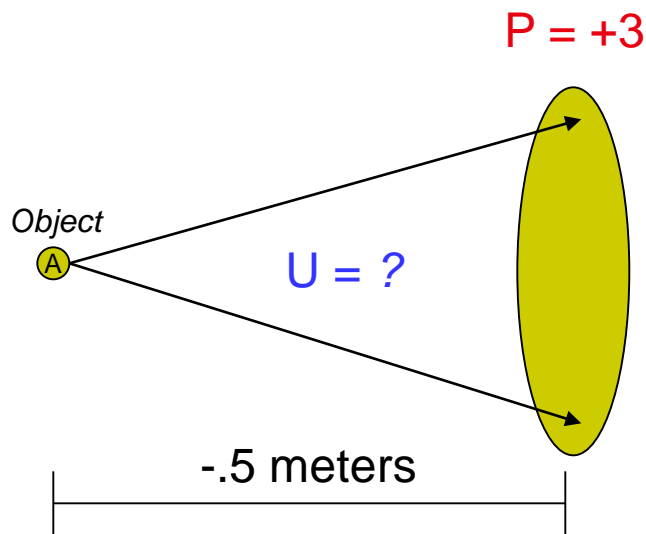- *Conjugate points*: Two points that are *object* and *image* of one another
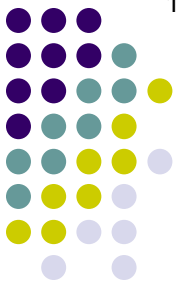
Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = +3

Object

A

U = ?

-.5 meters

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$
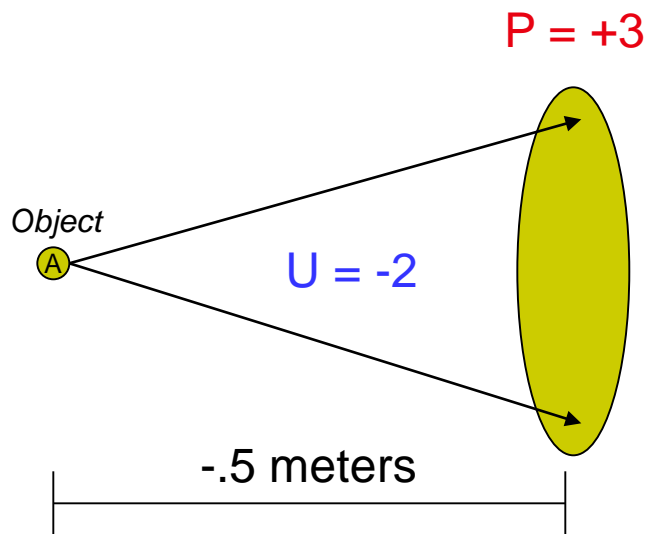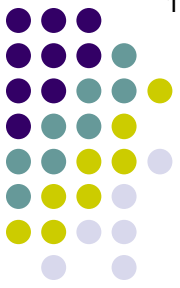
P = +3

Object

A

U = -2

-.5 meters

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = +3

Object

A

U = -2

V = ?

-.5 meters

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = +3

Object

A
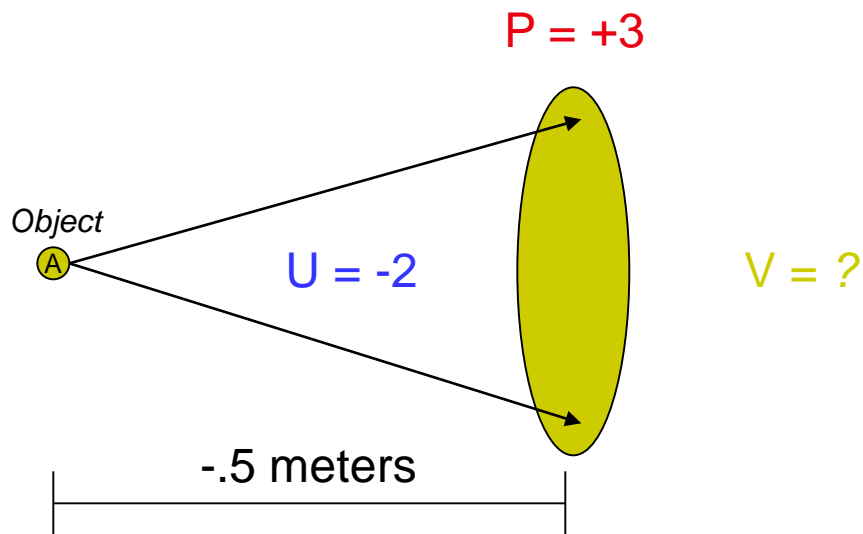
U = -2

V = +1

-.5 meters

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = +3

Object

U = -2

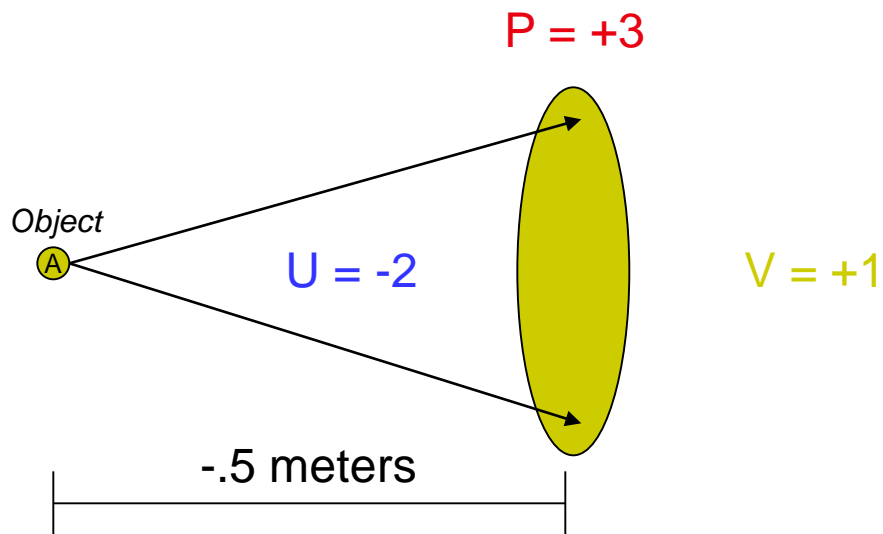V = +1

Image

A

B

-.5 meters

Distance?

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = +3

Object

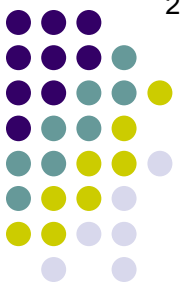U = -2   V = +1

Image

A   B

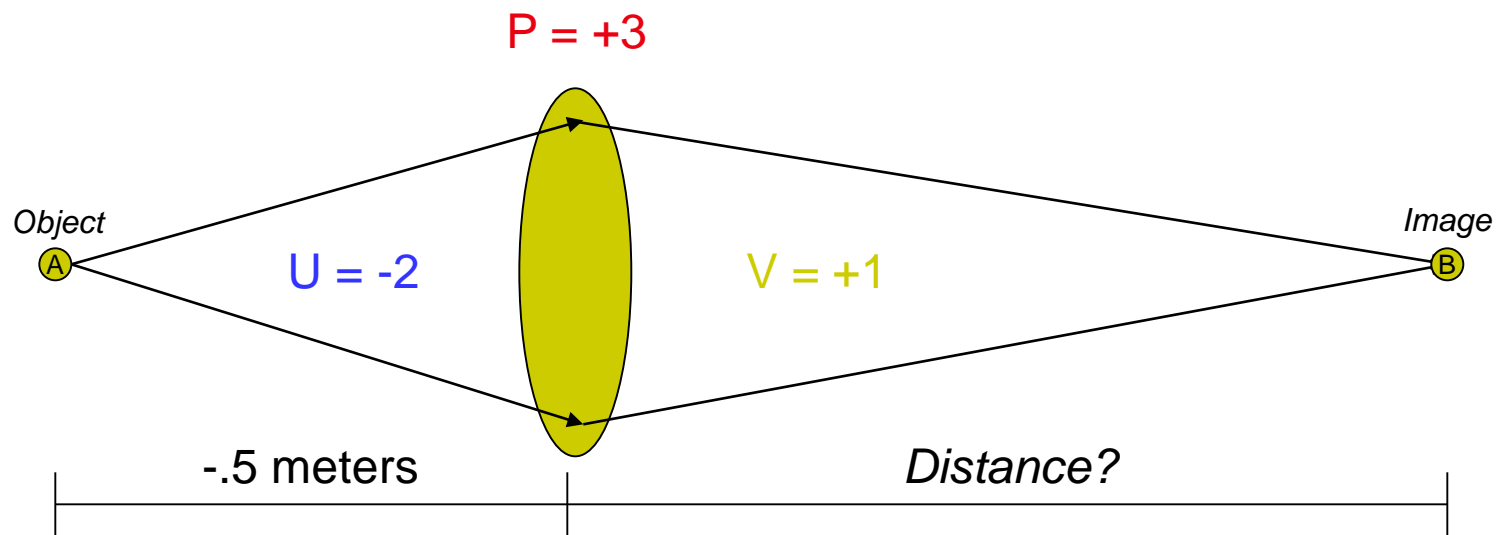-.5 meters   1 meter
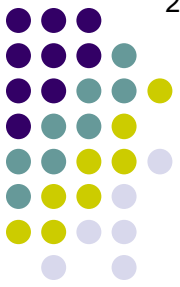
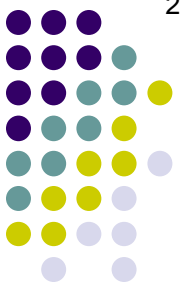# **Focal Points**

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

A and B are conjugate points

P = +3

Object

U = -2

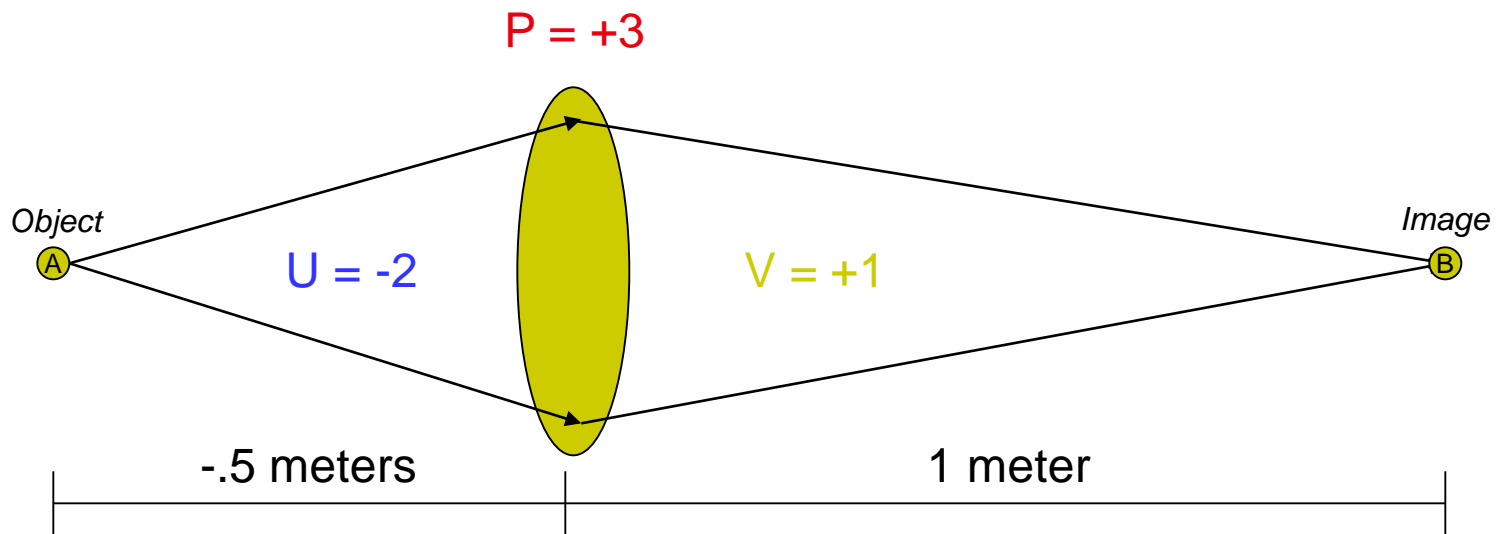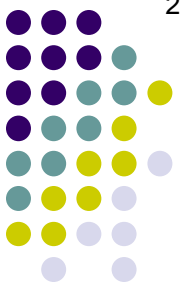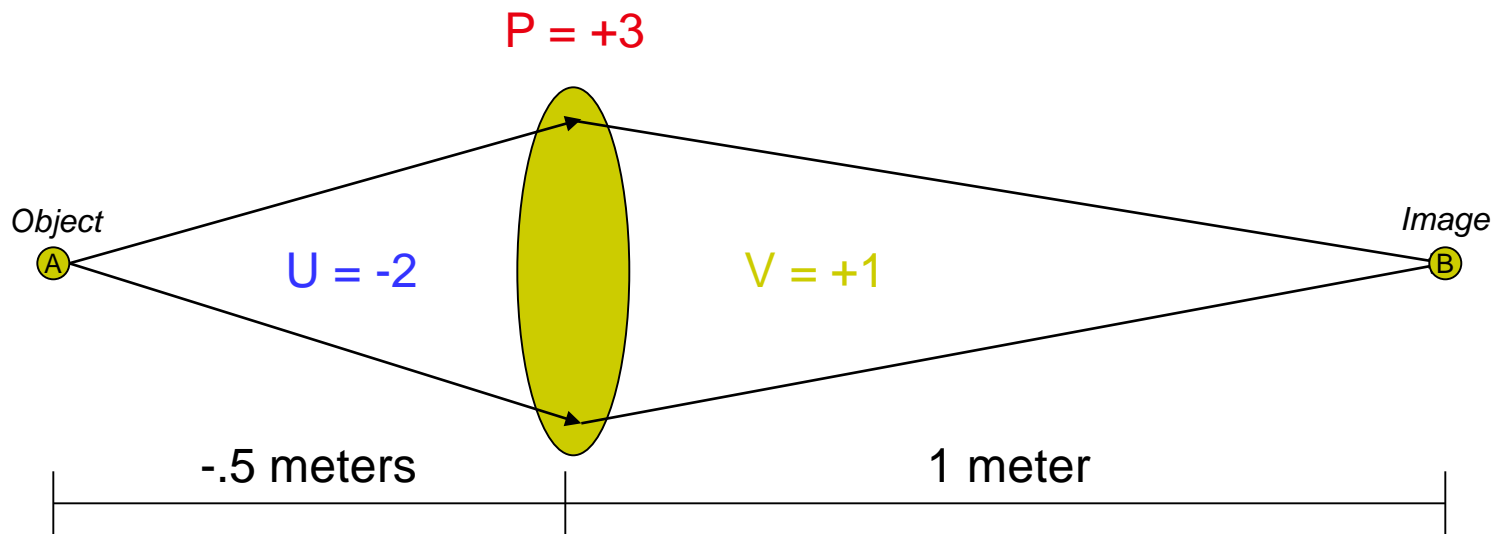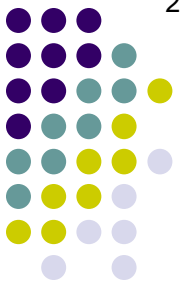V = +1

Image

A

B

-.5 meters

1 meter

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -2

Object

A

-.5 m

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -2

U = -2

Object

A

-.5 m

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$
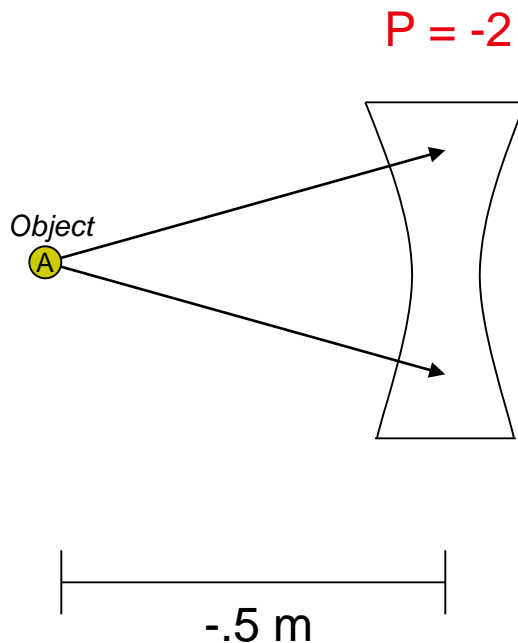
P = -2

U = -2

Object

A

V = -4

-.5 m

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -2

U = -2

Object

Image

A

B

V = -4

-.25 m

-.5 m
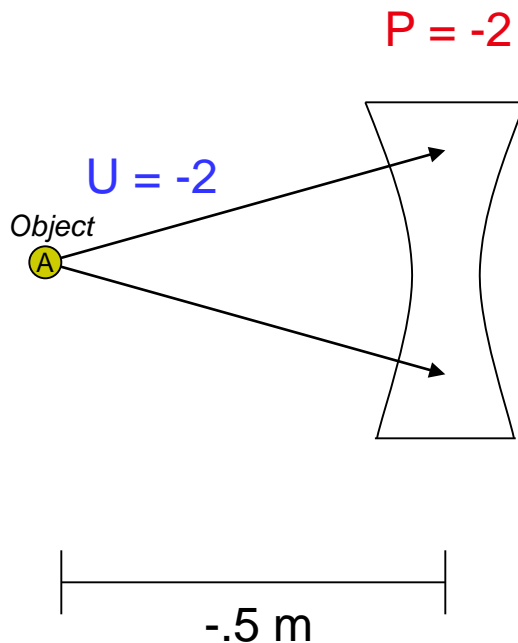
Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -2

U = -2

Object   *Image*

A   B

V = -4   *A and B are conjugate points*

-.25 m

-.5 m

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

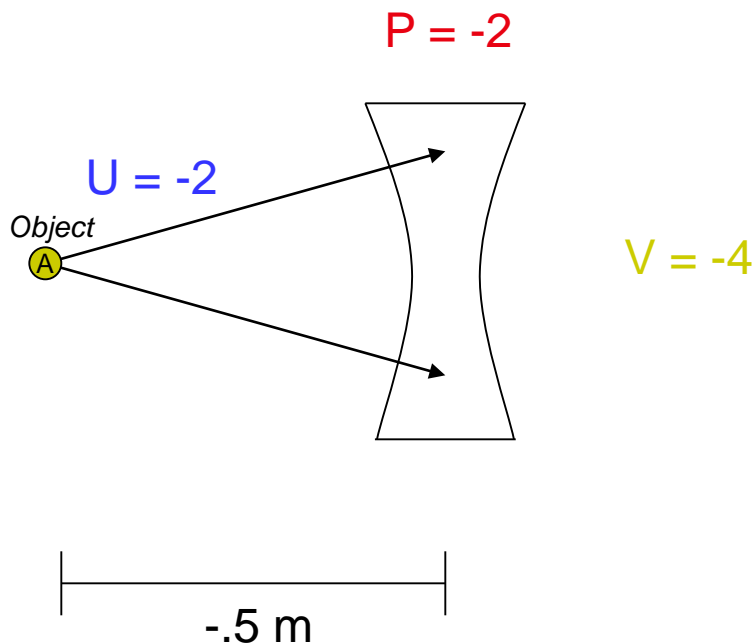# U + P = V

P = -3

Object

Ⓐ

1 meter
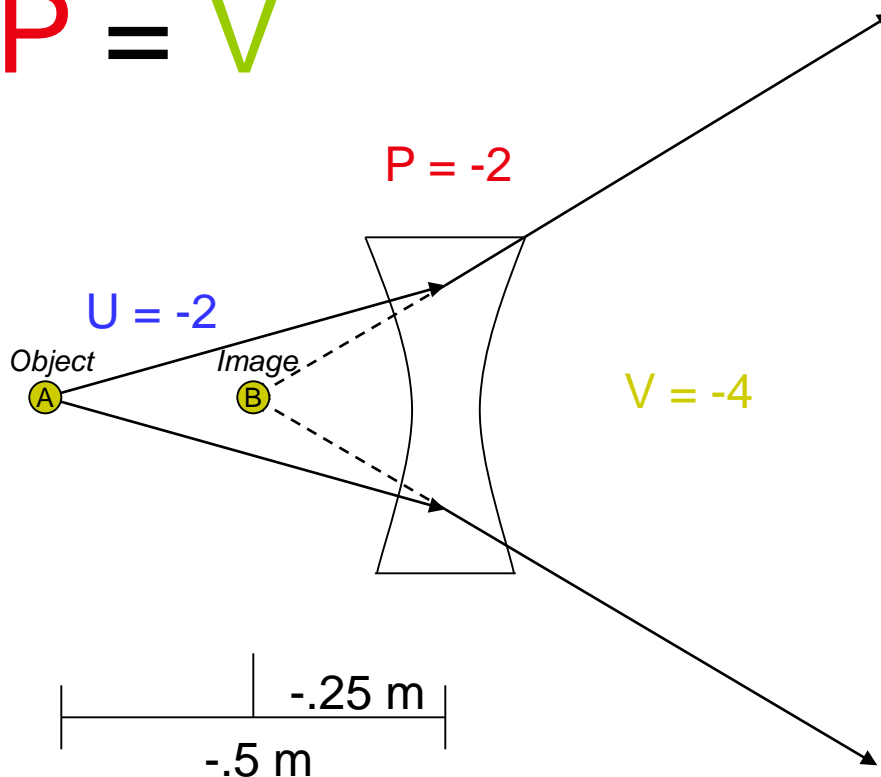
Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -3

U = +1

Object

Ⓐ

1 meter

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -3

U = +1

V = -2

Object

Ⓐ

1 meter

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -3

Image

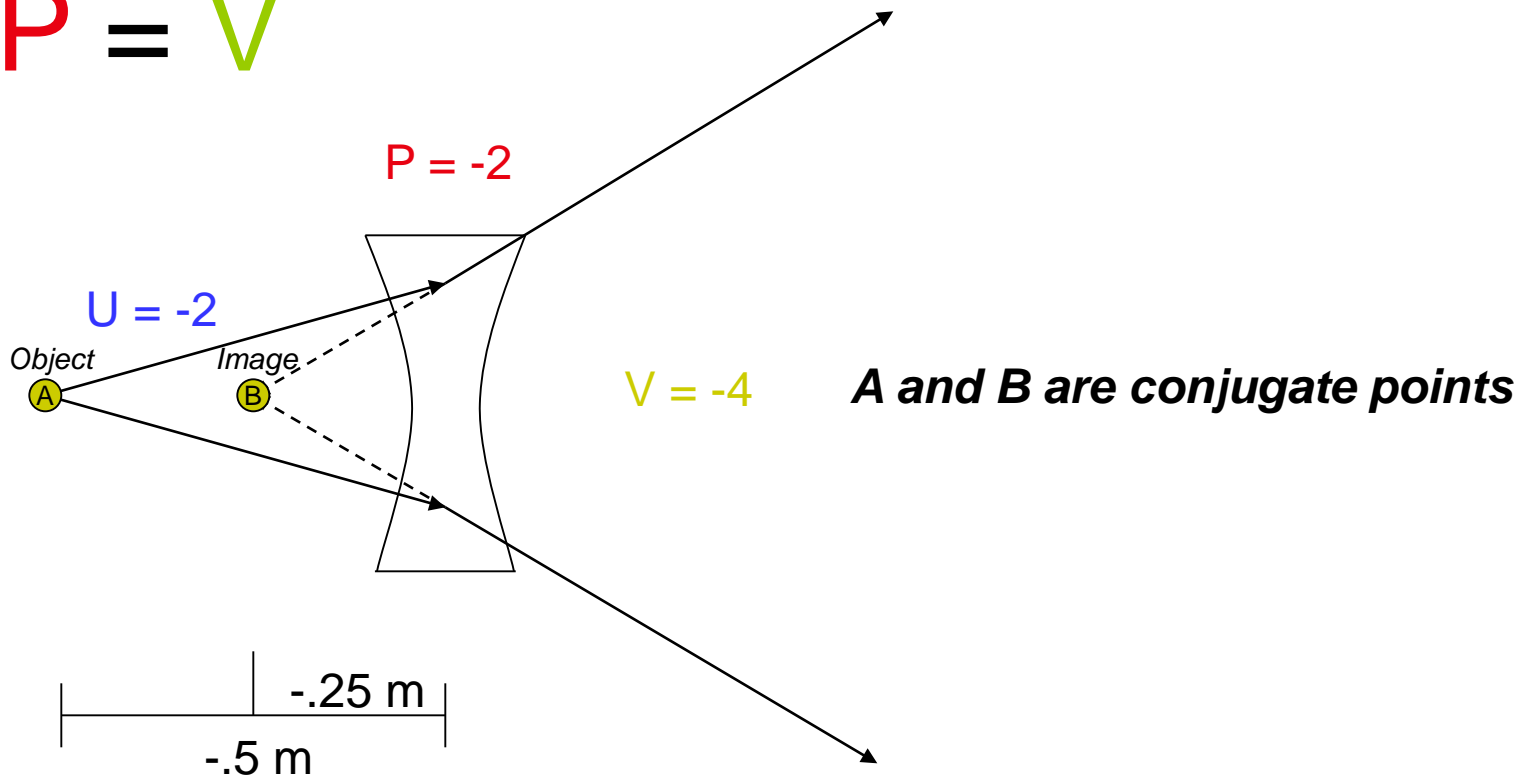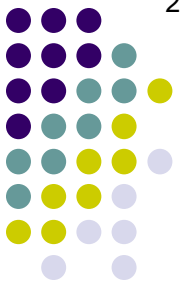B

U = +1
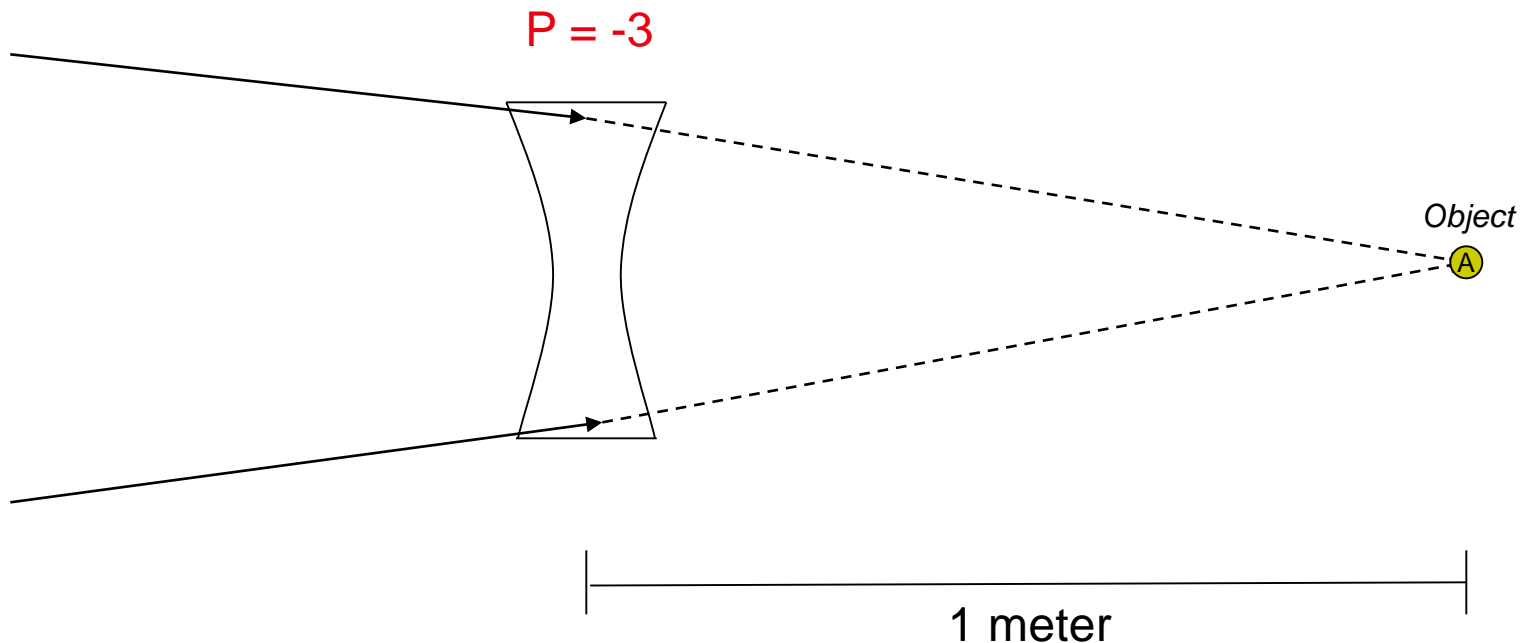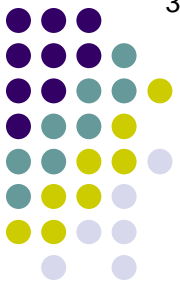
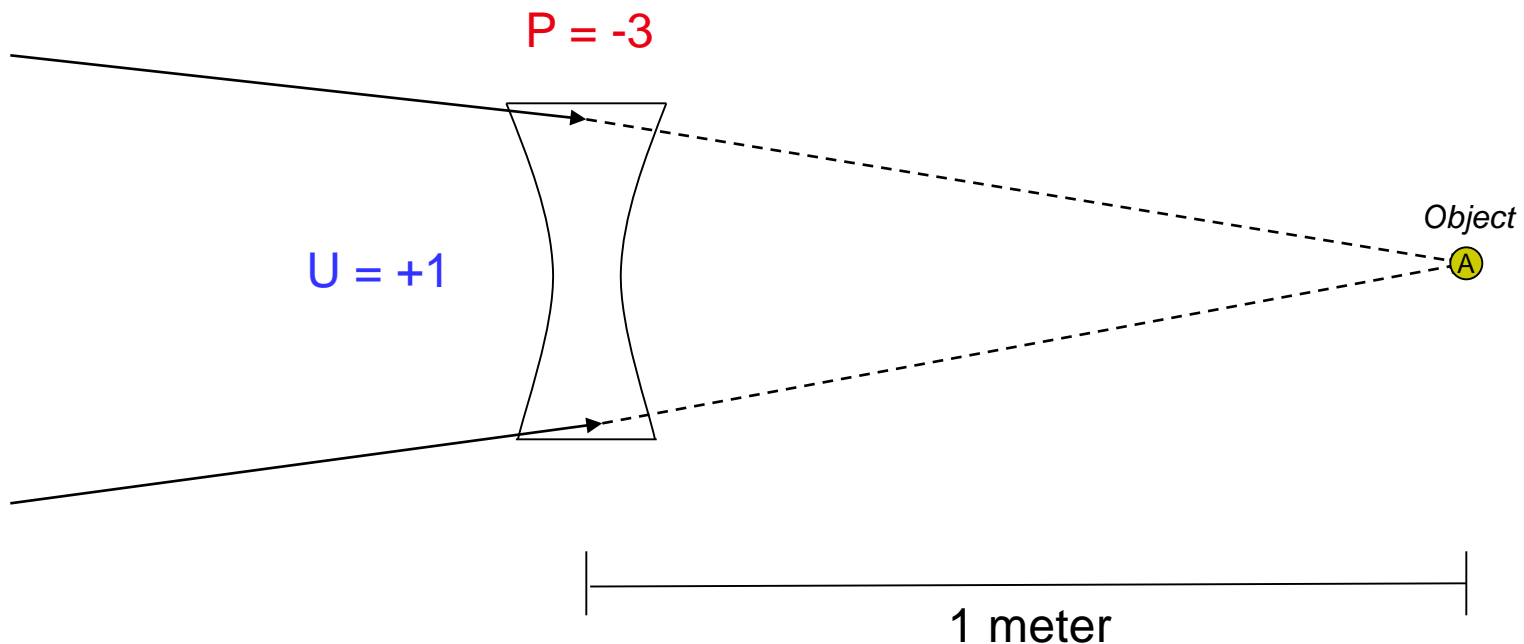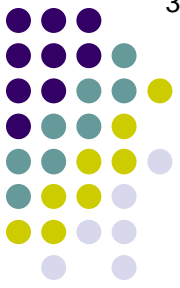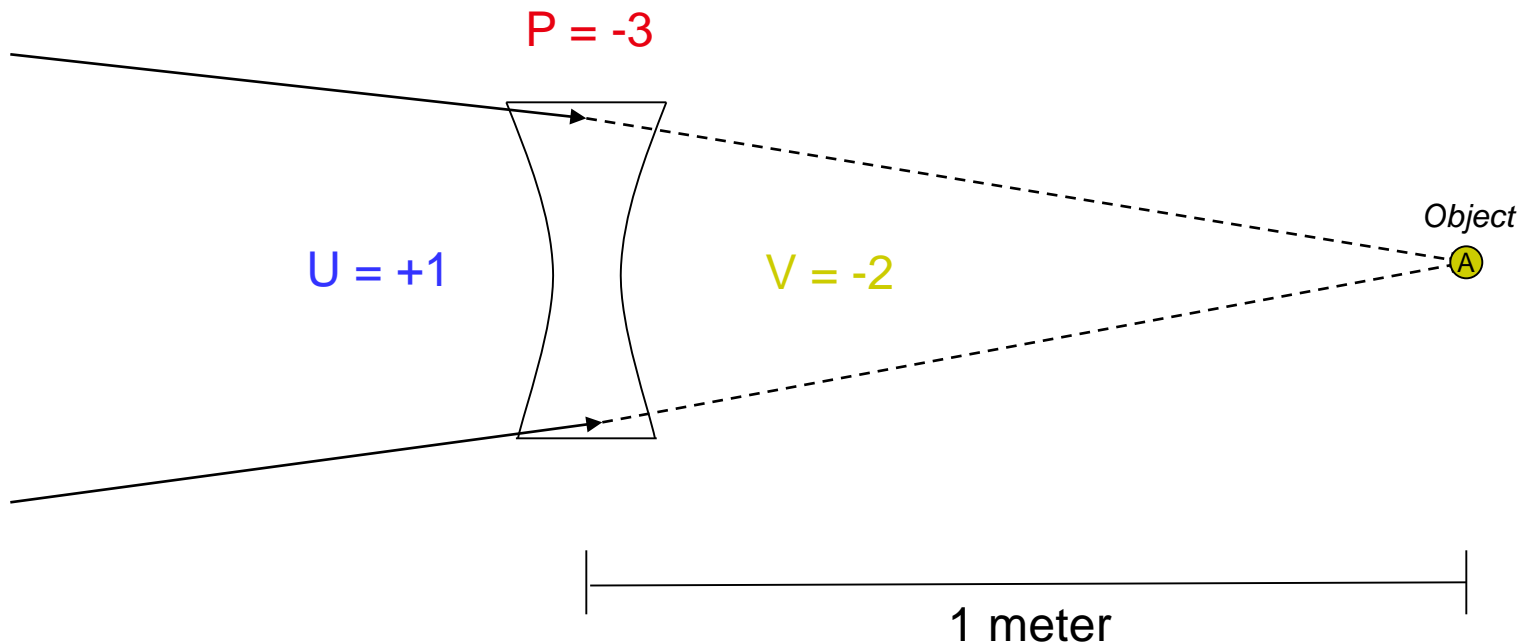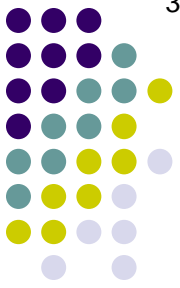V = -2

Object

A

-.5 meters

1 meter

Focal Points

- *Conjugate points*: Two points that are *object* and *image* of one another

$$U + P = V$$

P = -3

A and B are conjugate points

Image

B

U = +1

V = -2

Object

A

-.5 meters

1 meter

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

$$U + P = V$$

Originally, the light was going this way…

P = +3

A and B are conjugate points

Object

U = -2

V = +1

Image

A

B

-.5 meters

1 meter

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

$$U + P = V$$

…but now, it's now going this way

P = +3

A and B are conjugate points?

Image?
A

Object
B

1 meter

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

$$U + P = V$$

…but now, it's now going this way

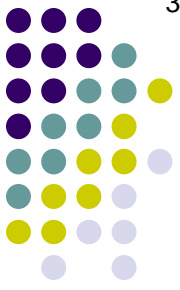P = +3

A and B are conjugate points?

Image?
Ⓐ

U = ?

Object
Ⓑ

1 meter

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

$$U + P = V$$

…but now, it's now going this way

P = +3
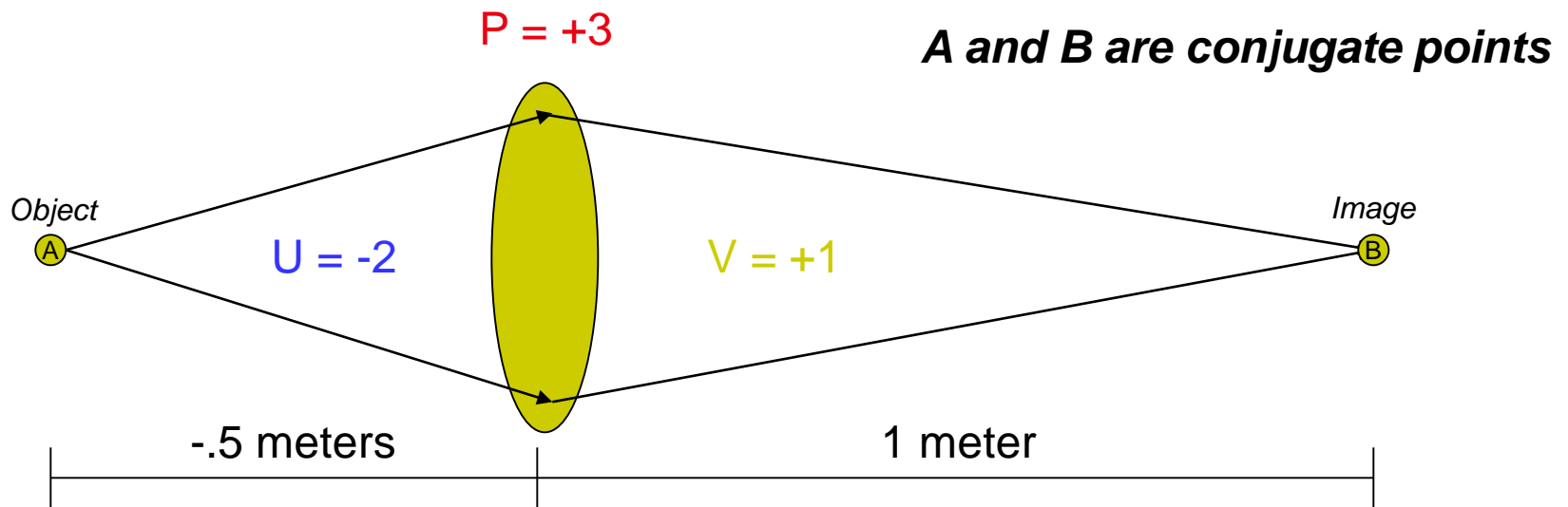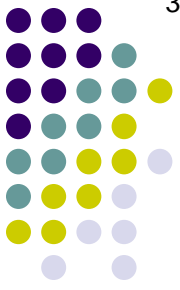
A and B are conjugate points?

Image?
Ⓐ

U = -1

Object
Ⓑ

1 meter

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

$$U + P = V$$

…*but now, it's now going* this *way*

P = +3

A and B are conjugate points?

Image?

A

V = ?

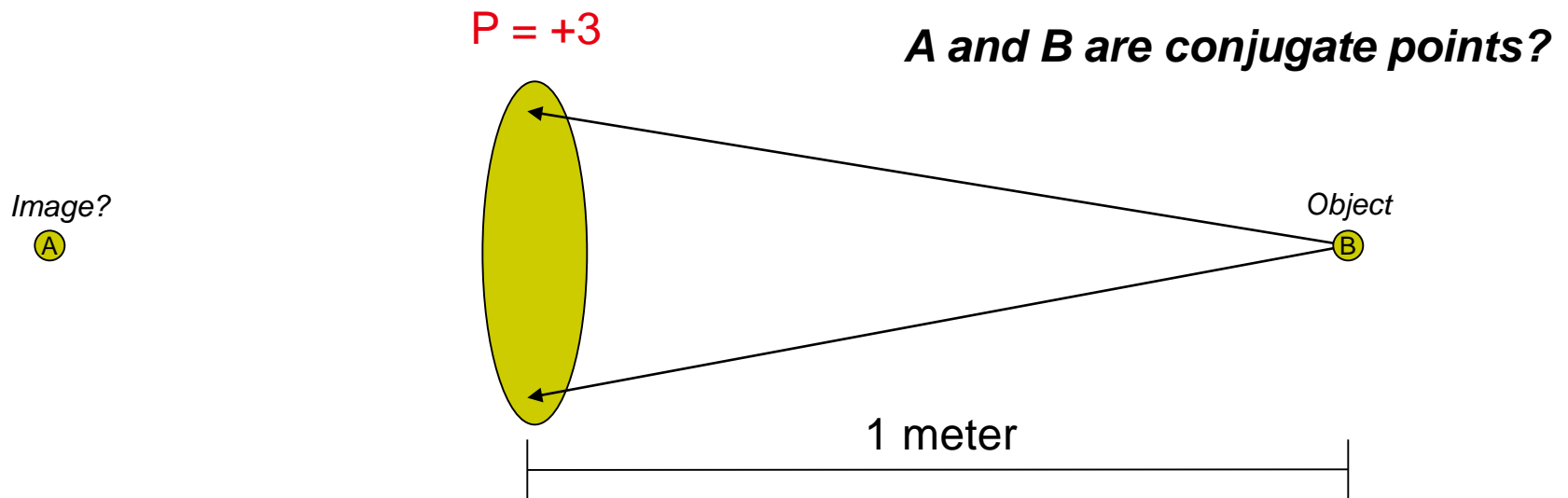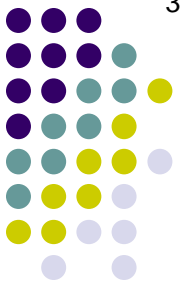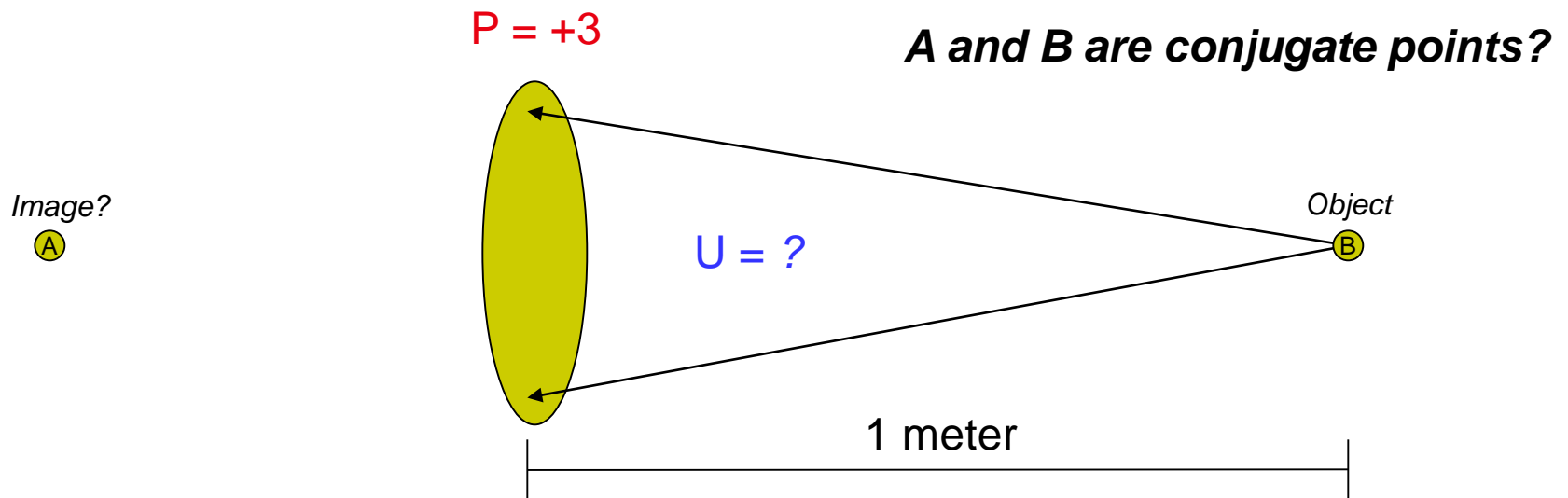U = -1

Object

B

1 meter

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

$$U + P = V$$

← *…but now, it's now going this way*

P = +3

A and B are conjugate points?
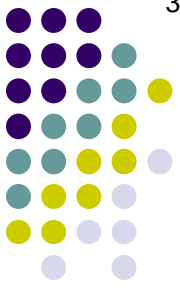
Image?
Ⓐ
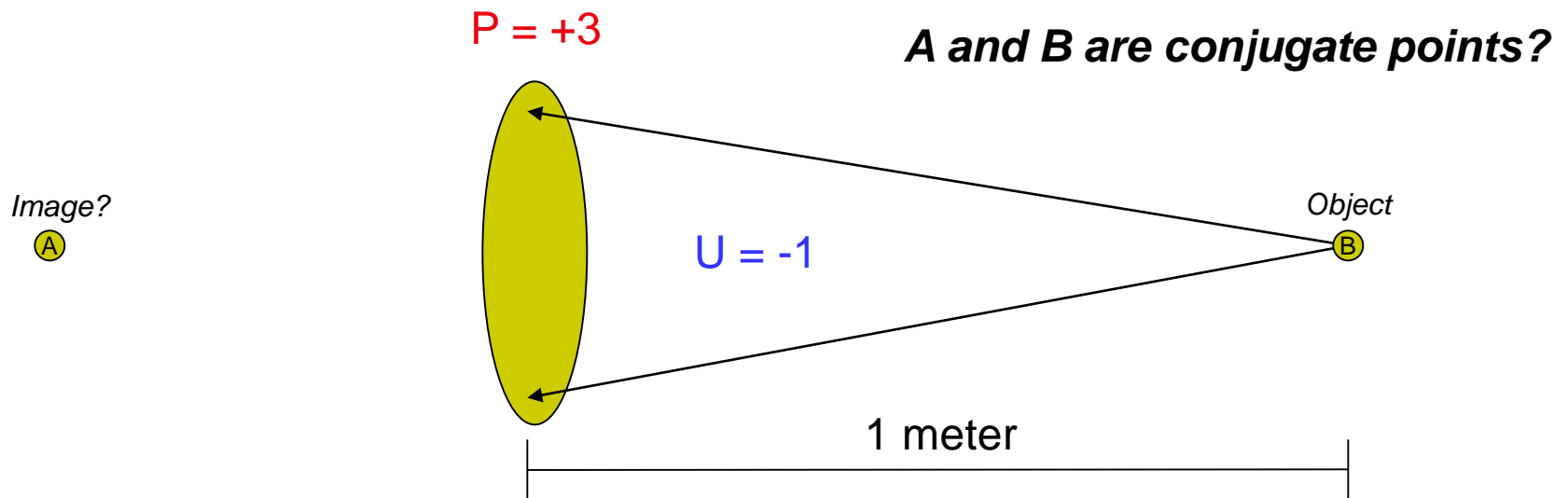
V = +2

U = -1

Object
Ⓑ

1 meter

Focal Points

- *Note that if the direction of the light were reversed, the same two points would be conjugate*

$$U + P = V$$

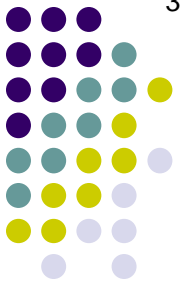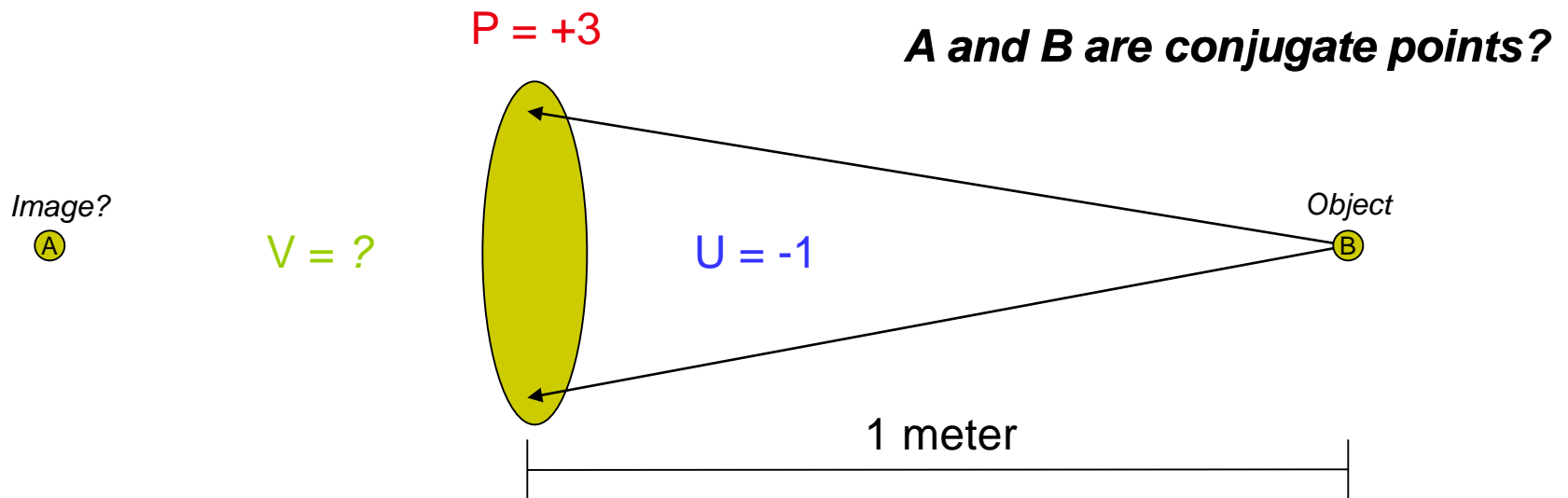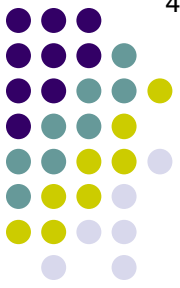*…but now, it's now going this way*

P = +3

A and B are conjugate points!

Image!

Object

V = +2

U = -1

A

B

-.5 meters

1 meter

Focal Points

- Are primary and secondary focal points conjugate to one another?

Focal Points

- Are primary and secondary focal points conjugate to one another? **No!**

Focal Points

-33 cm

Location for an **object**, so that associated rays will leave a lens with zero vergence

Primary Focal Point
for a +3 lens

+3

Parallel rays **to** infinity (vergence = 0)

Focal Points

-33 cm

Location for an **object**, so that associated rays will leave a lens with zero vergence

Primary Focal Point
for a +3 lens

+3

Parallel rays **to** infinity (vergence = 0)
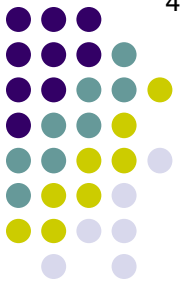
Parallel rays **from** infinity (vergence = 0)

+3

Secondary Focal Point
for a +3 lens

Location at which an **image** is formed by rays with zero vergence hitting the lens

33 cm

Focal Points

-33 cm

Location for an **object**, so that associated rays will leave a lens with zero vergence

+3

Primary Focal Point
for a +3 lens

Parallel rays **to** infinity (vergence = 0)

These two points are NOT conjugate!
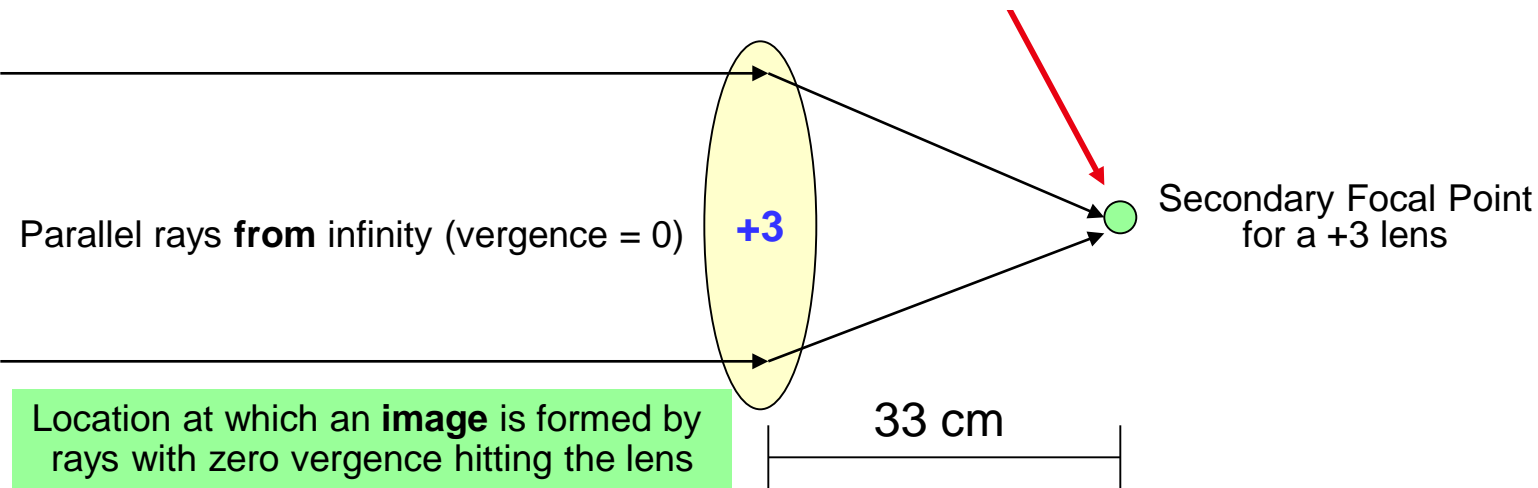
+3

Parallel rays **from** infinity (vergence = 0)

Secondary Focal Point
for a +3 lens

Location at which an **image** is formed by rays with zero vergence hitting the lens

33 cm

Focal Points

- Note:
  - Primary focal points are *object* locations; secondary ~~~~ are *image* locations

By the way…

…the primary focal point is sometimes referred to as the ***anterior focal point***, and the secondary focal point as the ***posterior focal point***. These terms can be confusing in that the 'anterior' focal point of a minus lens is on what would seem to be its posterior side, and the posterior focal point is on its apparently anterior side. Because of this, I will avoid using these terms. Nevertheless, you should be aware of them!

  - Primary and secondary focal points are NOT conjugate points

Anterior
~~Primary~~ *focal point*

Posterior
~~Secondary~~ *focal point*