Mirrors

Basic Optics, Chapter 25

Mirrors

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  - Also like lenses, questions and problems involving mirrors are fair game on the OKAP

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  - Also like lenses, questions and problems involving mirrors are fair game on the OKAP
- Mirrors come in three flavors:
  - *Plane* (flat)
  - *Concave*
    - Shaped like the inside of a spoon—ie, like ‘a cave’
  - *Convex*
    - Like the back surface of a spoon

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  - Change the direction of light, but do not alter its vergence (vergence out = vergence in)

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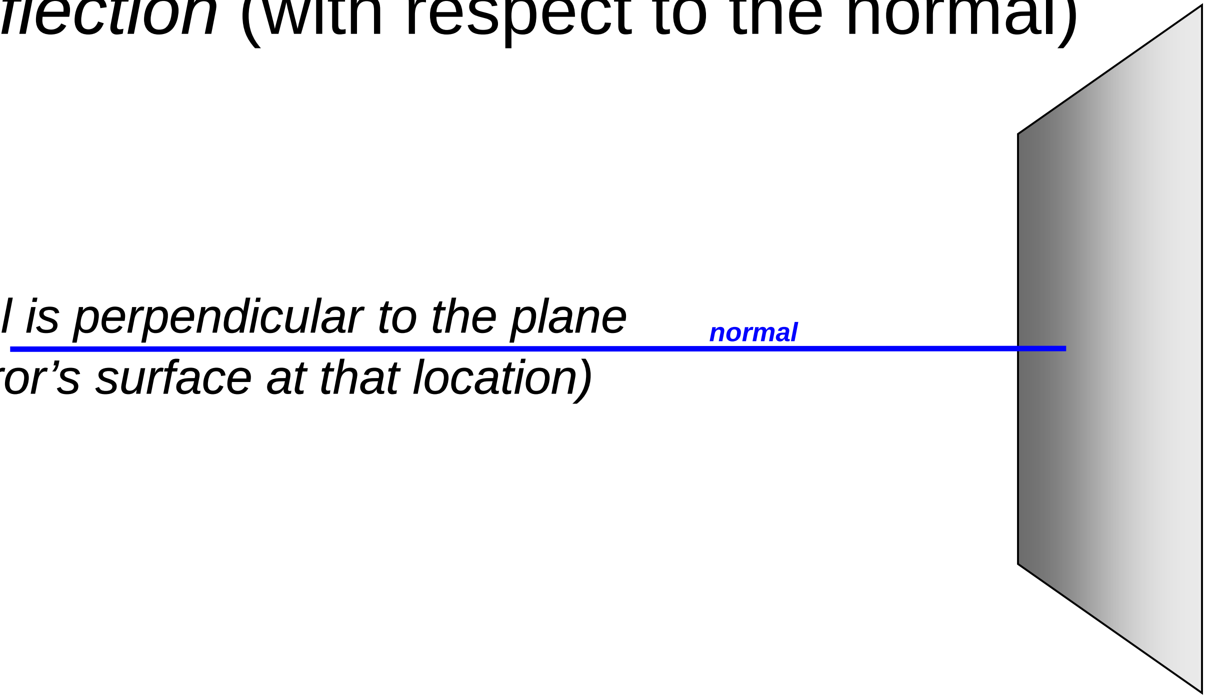
  - The only rule you need to remember is that, for any light ray, the *angle of incidence* equals the *angle of reflection* (with respect to the normal)

(The normal is perpendicular to the plane of the mirror's surface at that location)



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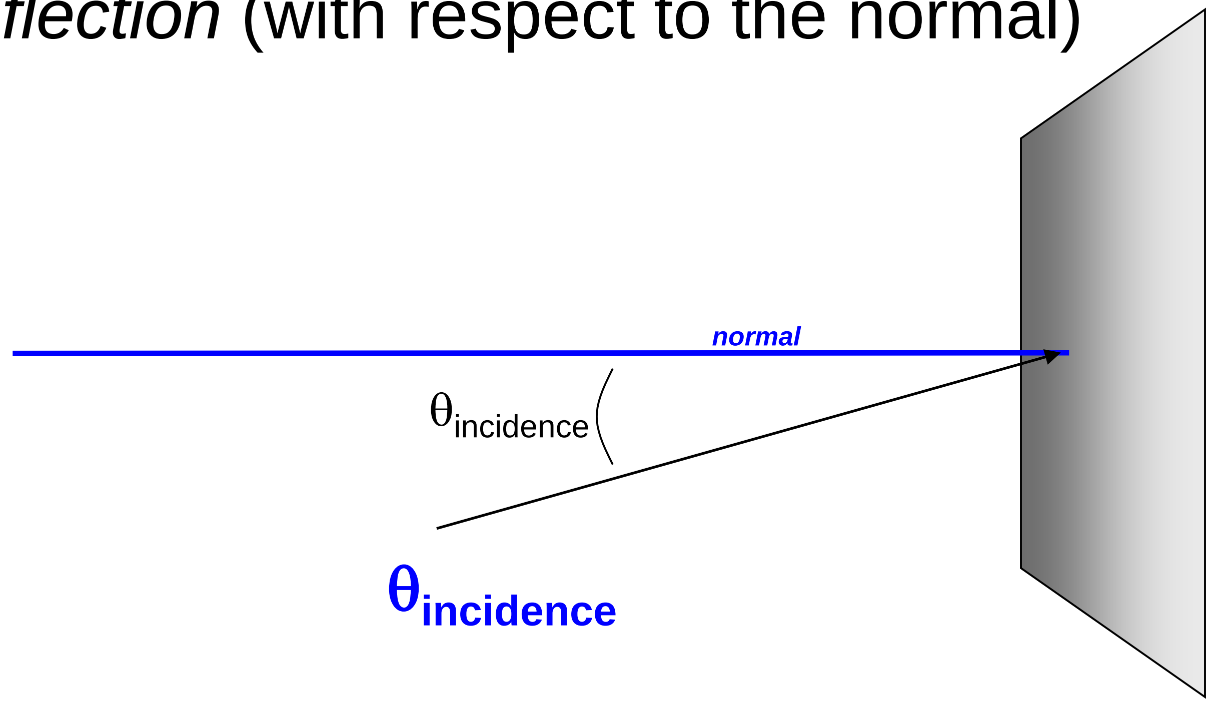

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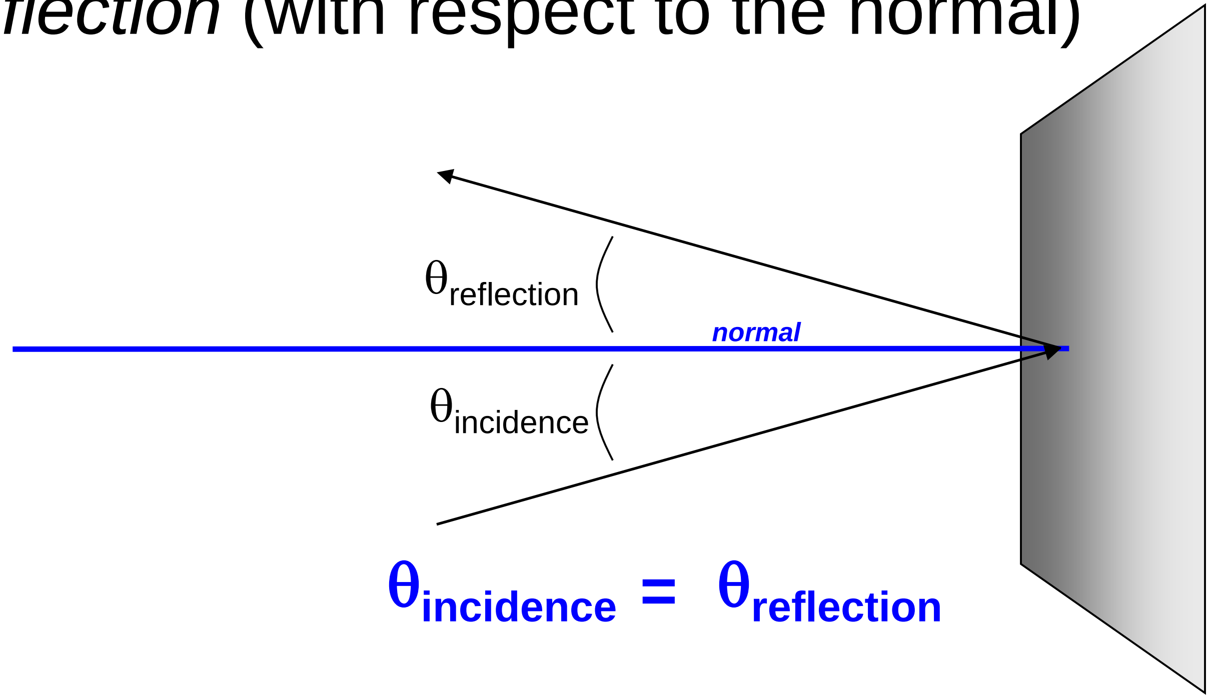
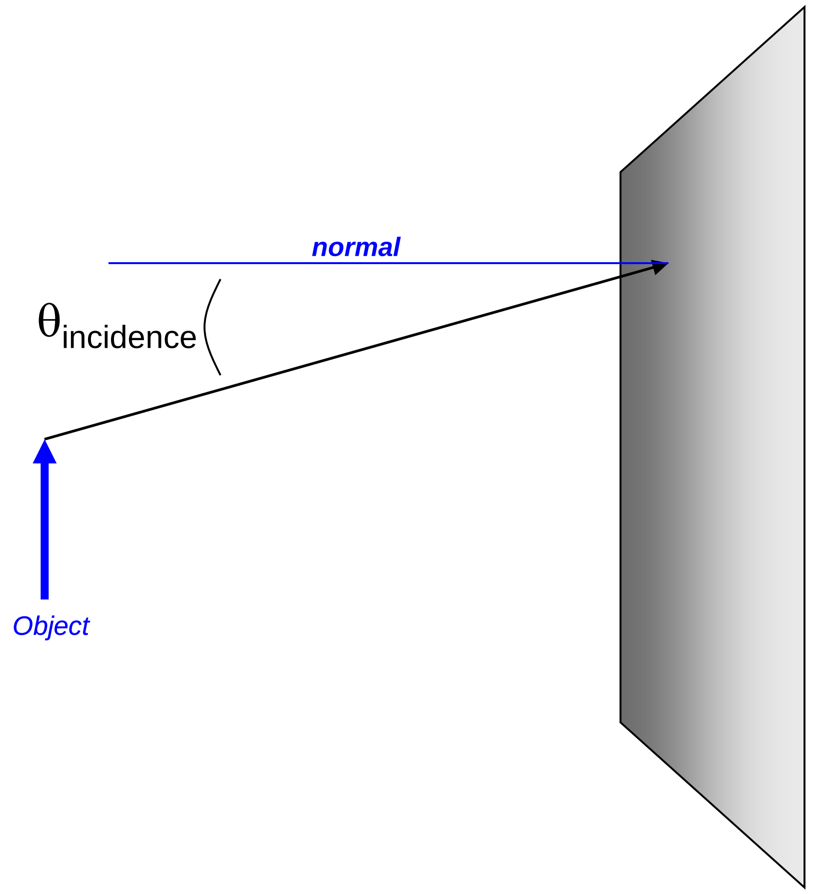


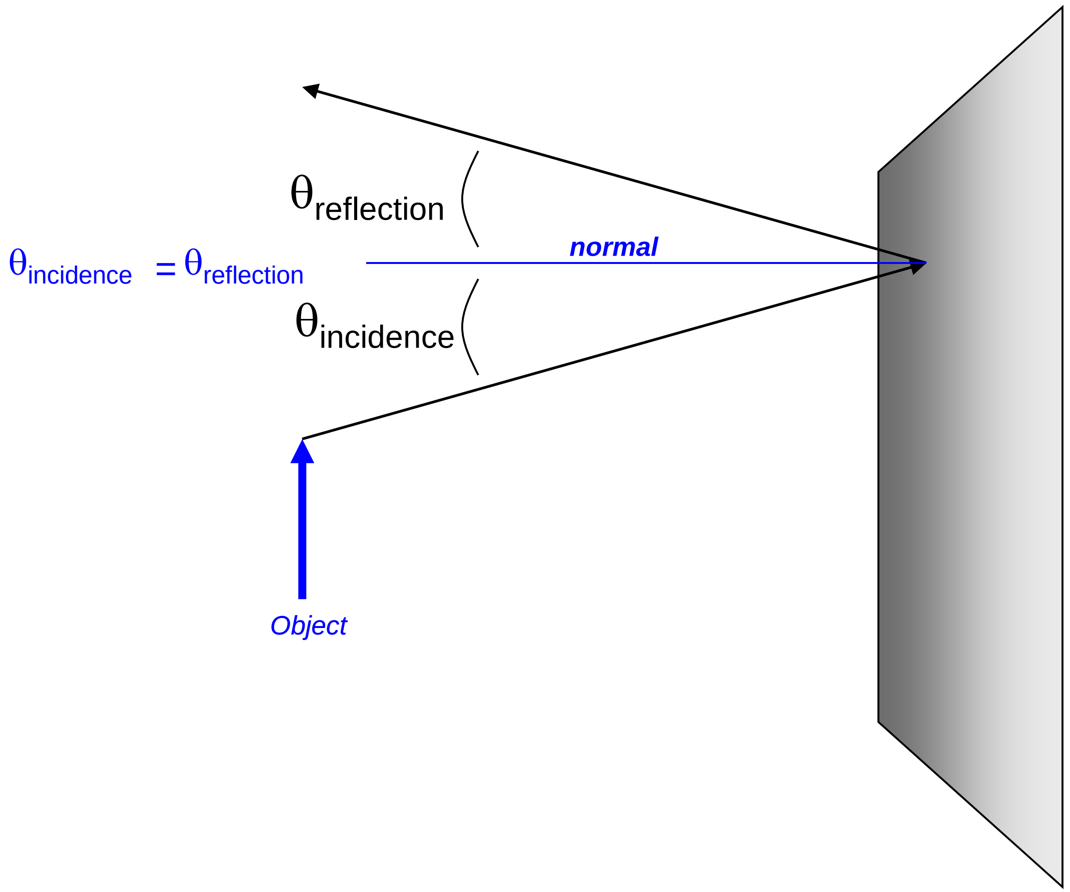
$$\theta_{incidence} = \theta_{reflection}$$

Mirrors

$\theta_{incidence}$

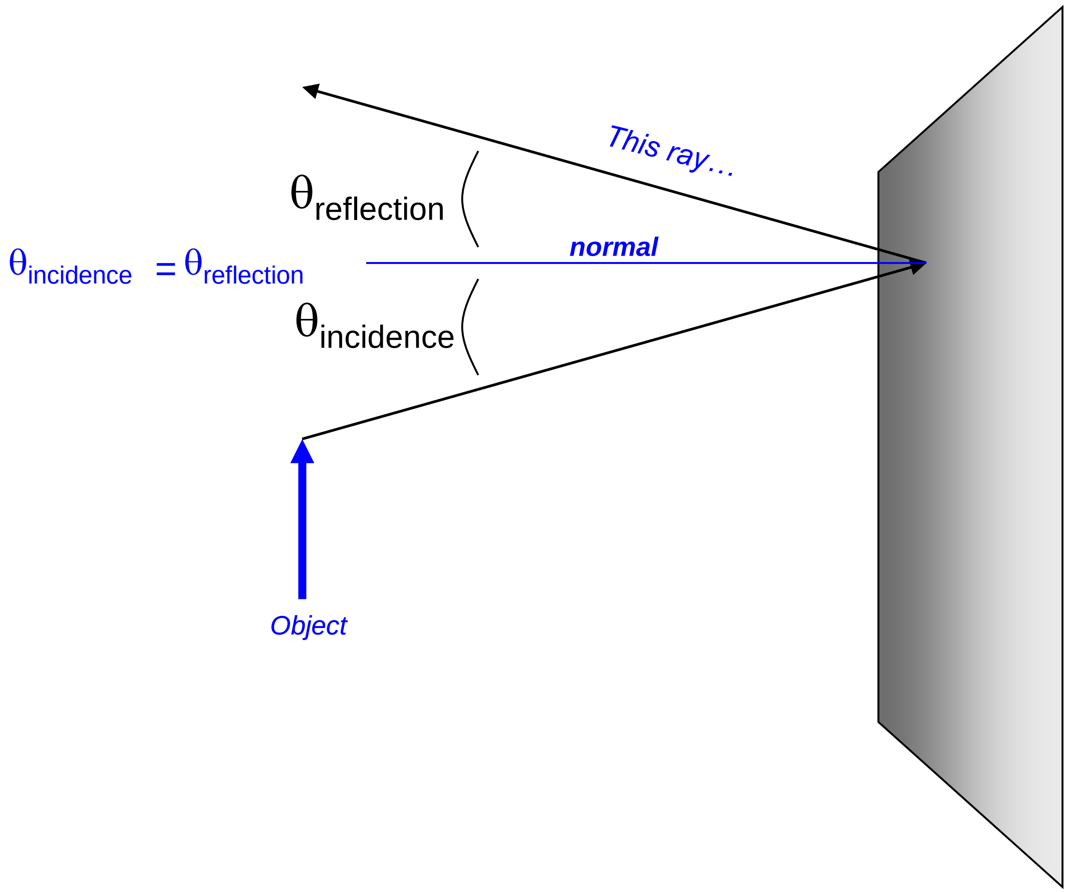


Mirrors



$\theta_{reflection}$
normal
$\theta_{incidence} = \theta_{reflection}$
$\theta_{incidence}$
Object

Mirrors


This ray…
$\theta_{reflection}$
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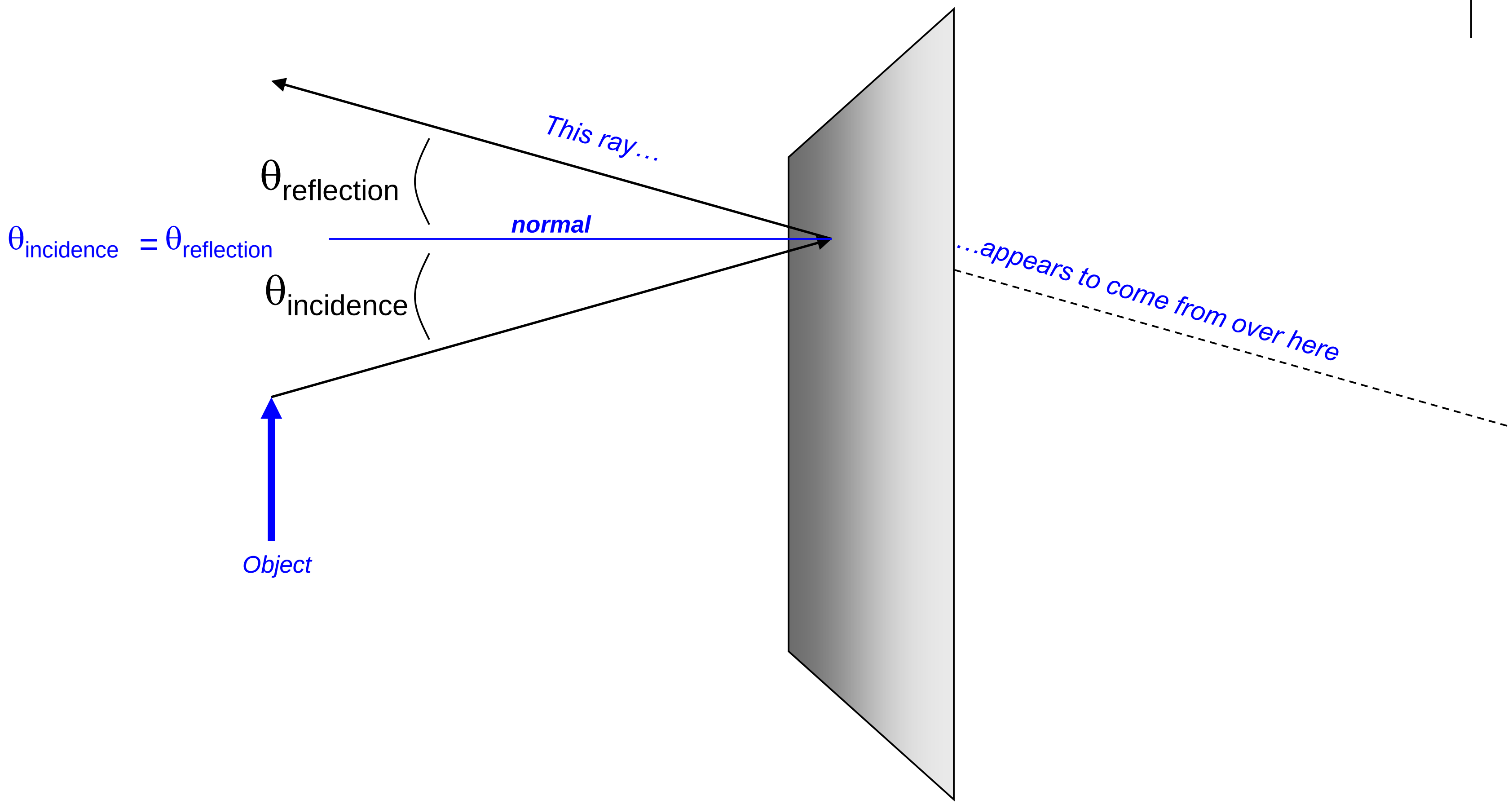
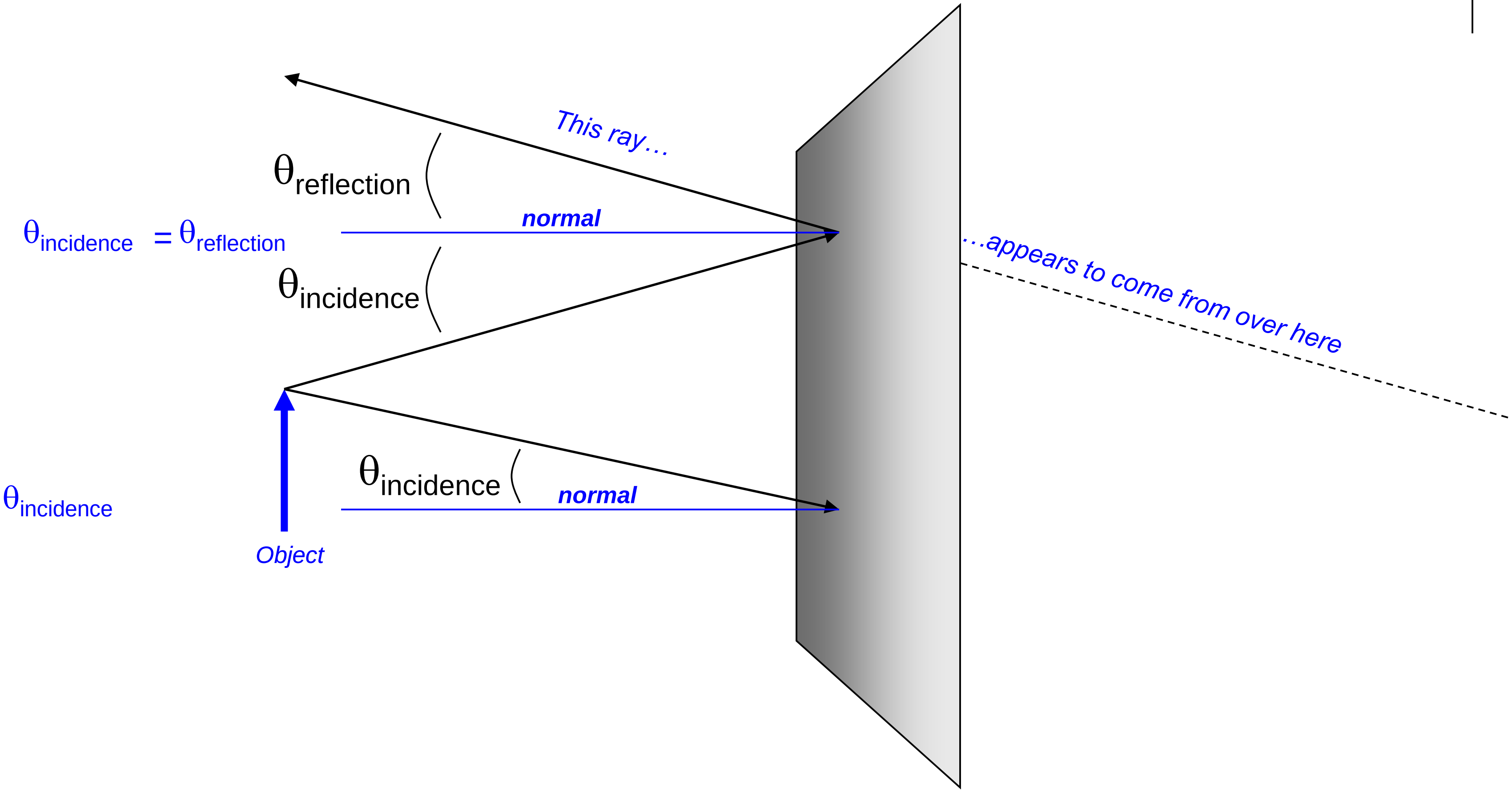
$\theta_{incidence}$
Object

Mirrors


This ray…
$\theta_{reflection}$
normal
$\theta_{incidence} = \theta_{reflection}$
$\theta_{incidence}$
…appears to come from over here
Object

Mirrors



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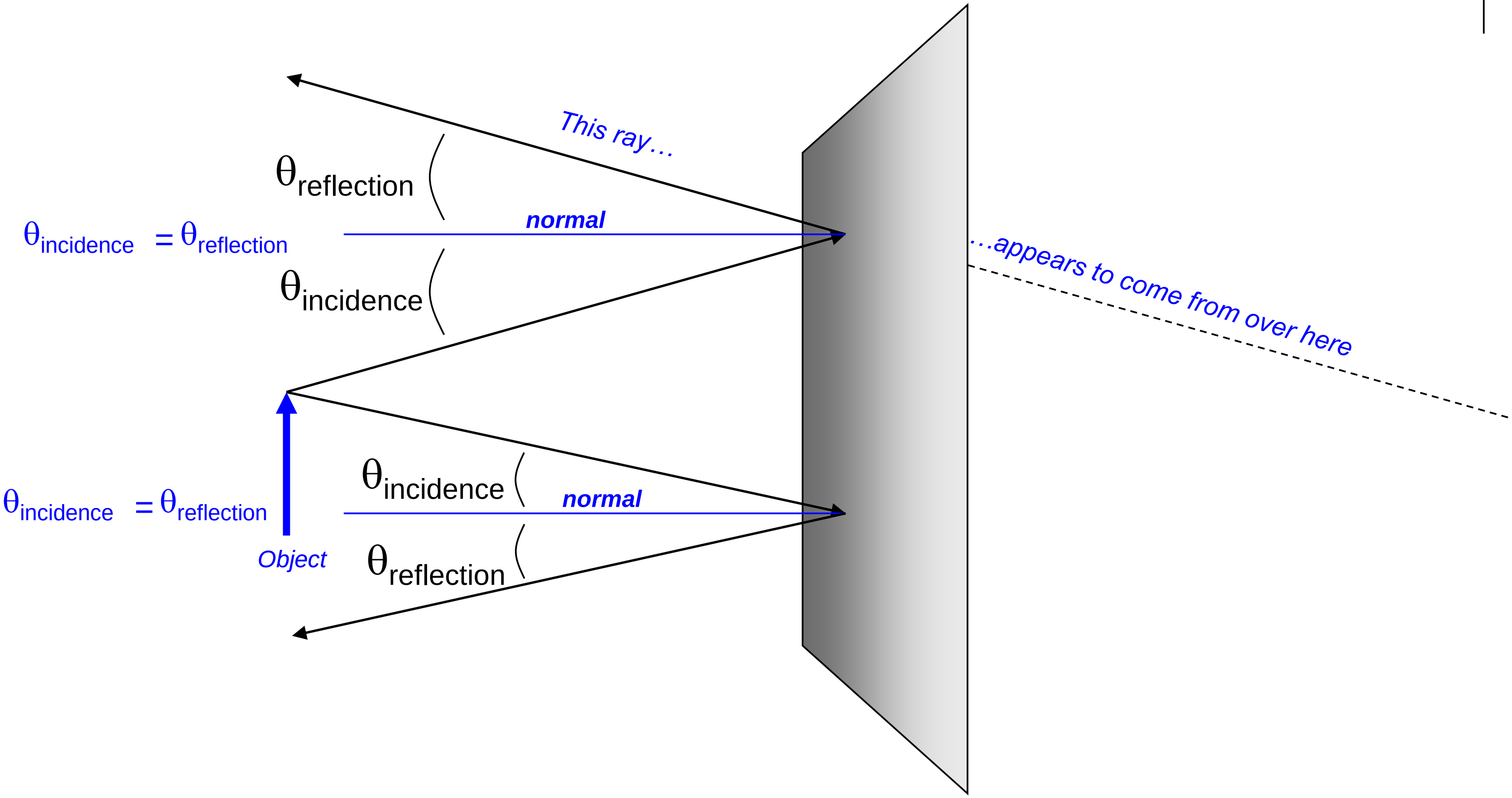

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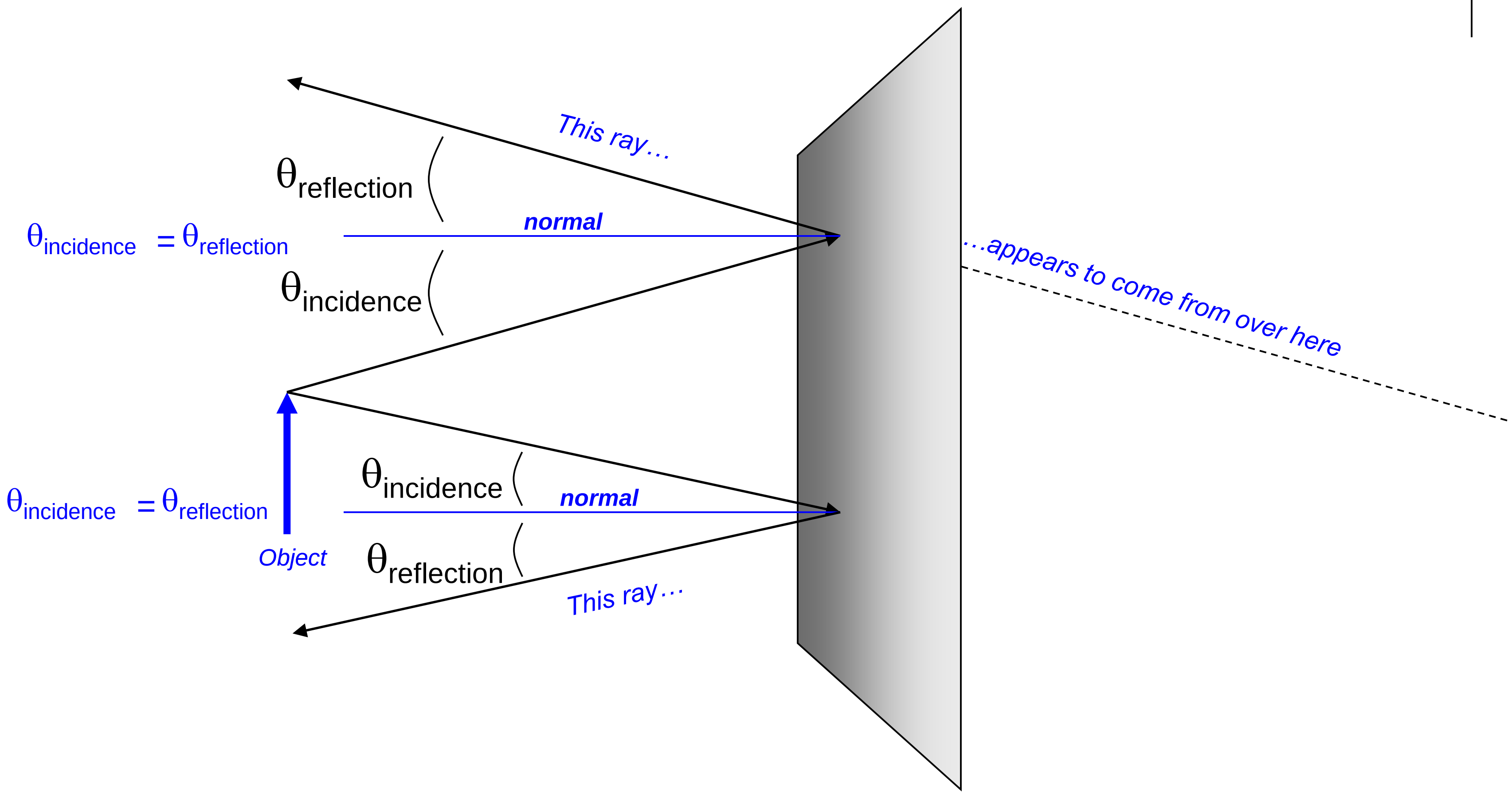

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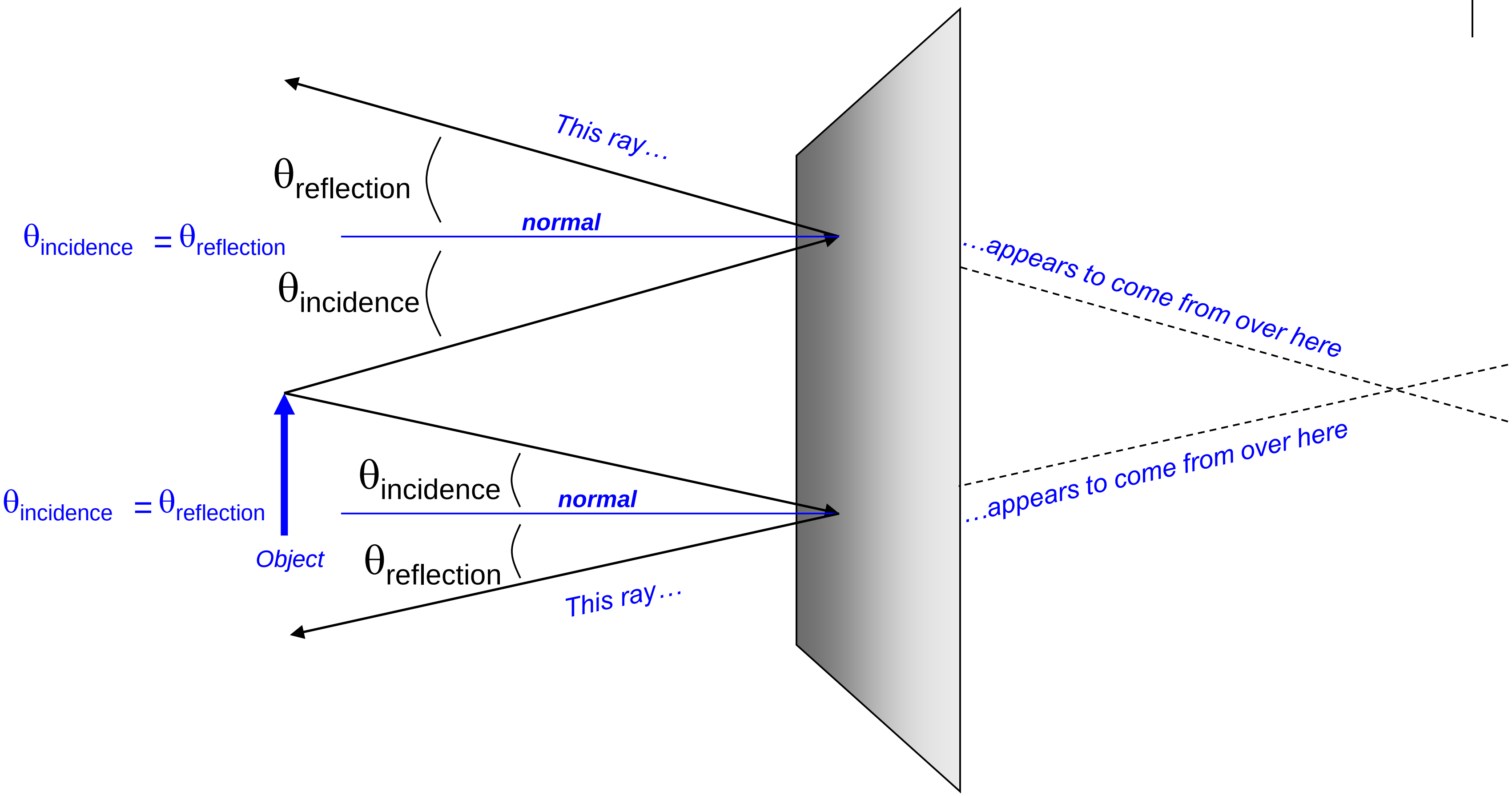
Mirrors



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This ray…
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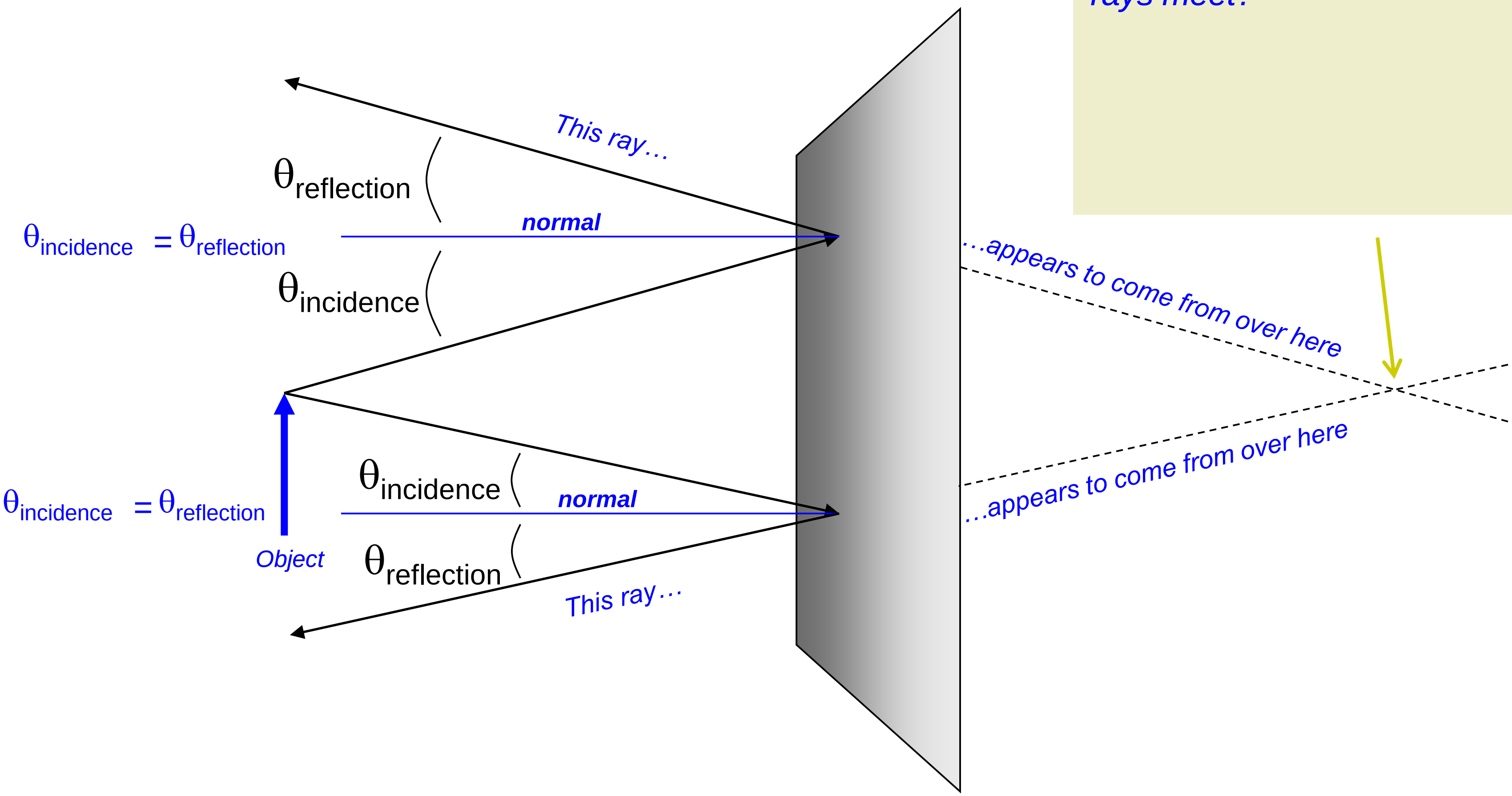
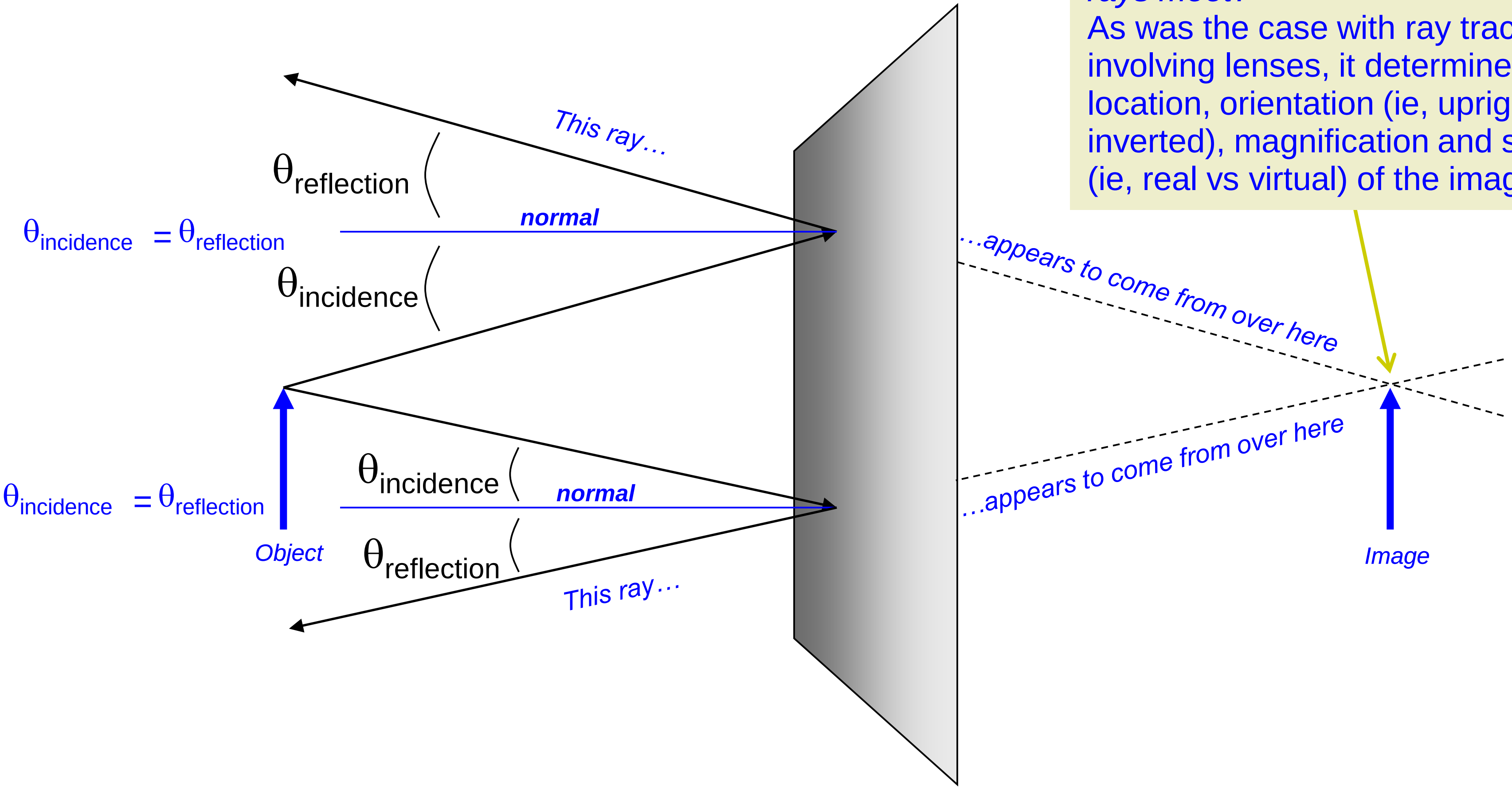
We've seen this sort of thing before… What do you suppose is significant about the point where the extended rays meet?



Mirrors

We've seen this sort of thing before… What do you suppose is significant about the point where the extended rays meet?
As was the case with ray tracing involving lenses, it determines the location, orientation (ie, upright vs inverted), magnification and status (ie, real vs virtual) of the image.



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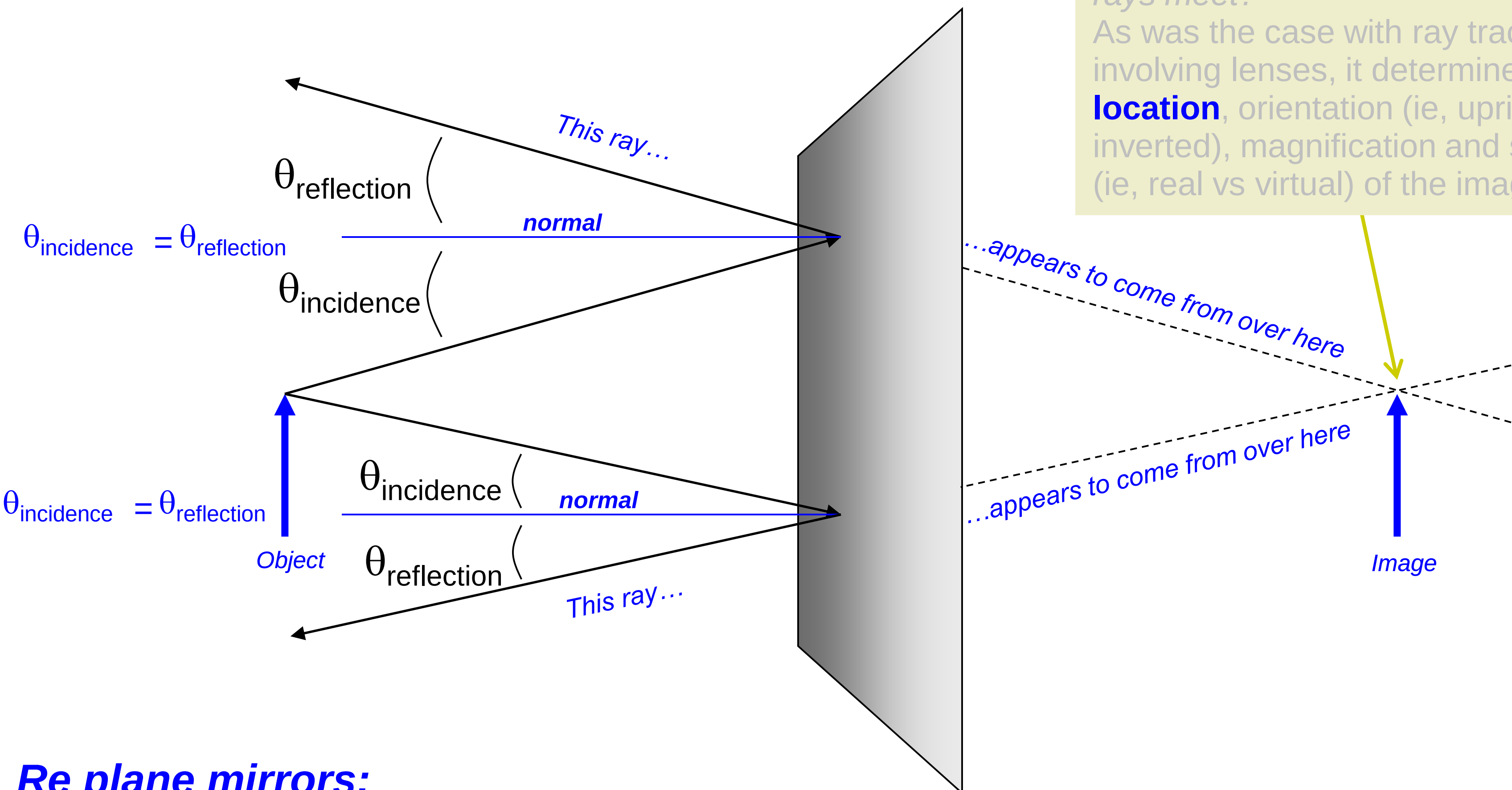

Re plane mirrors:
The image **location** is always 'behind' the mirror (ie, on the side opposite the object)

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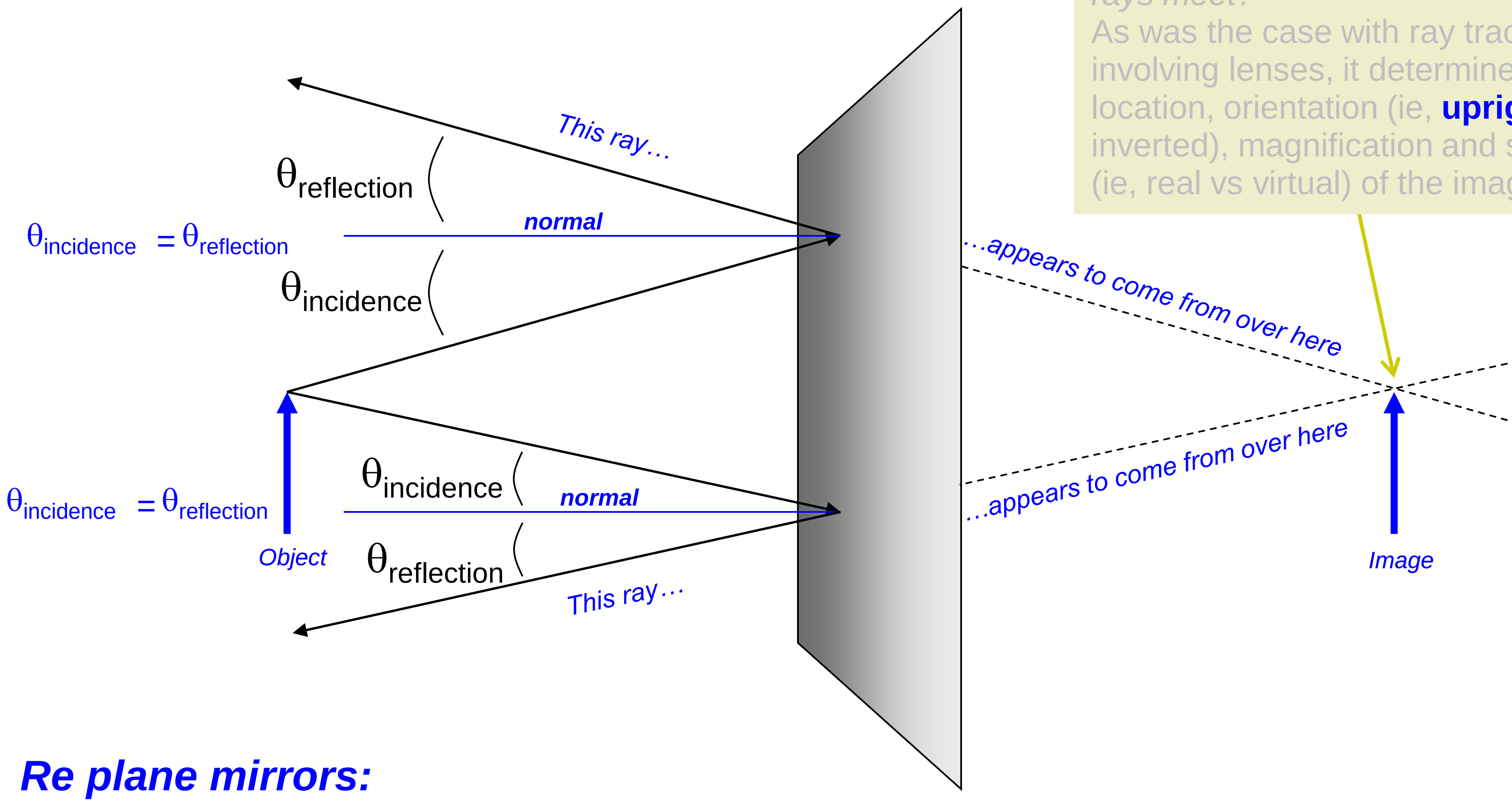

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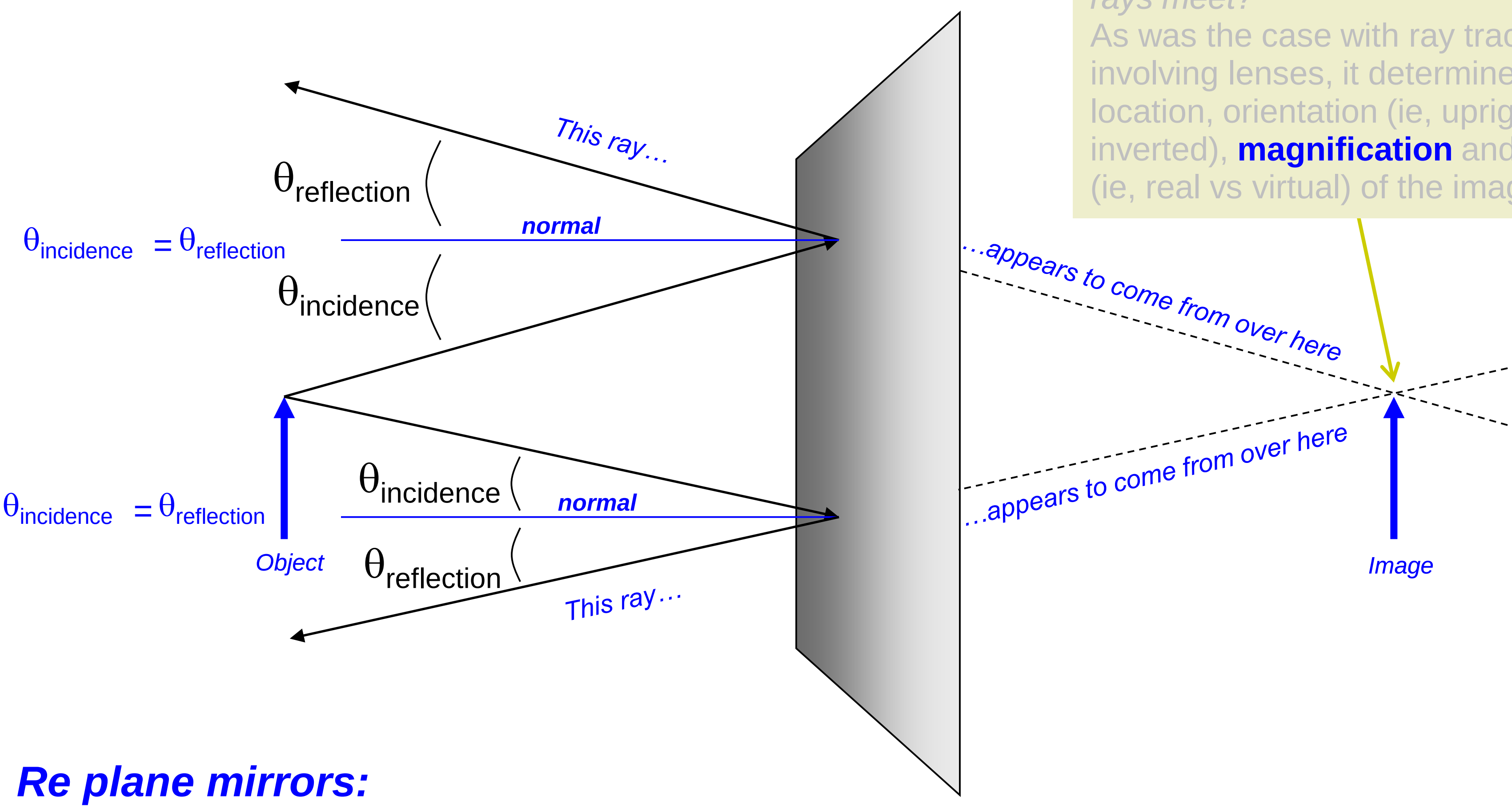
The image **location** is always 'behind' the mirror (ie, on the side opposite the object)

The image is always **upright** (Remember, *upright* means that the image has the same orientation as the object)

Mirrors



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The **magnification** is 1.0 (ie, the image is the same height as the object)

Mirrors

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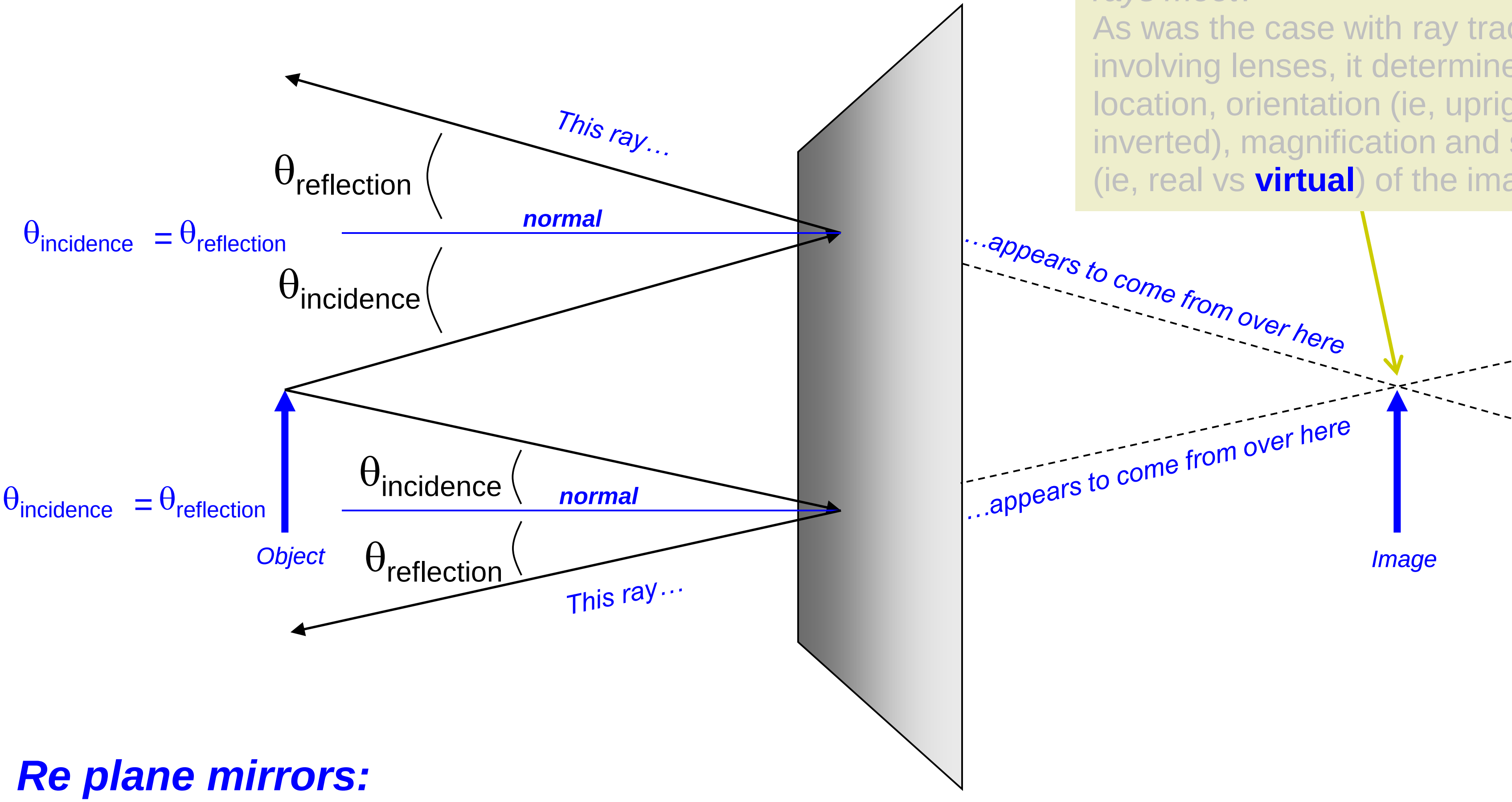


Re plane mirrors:

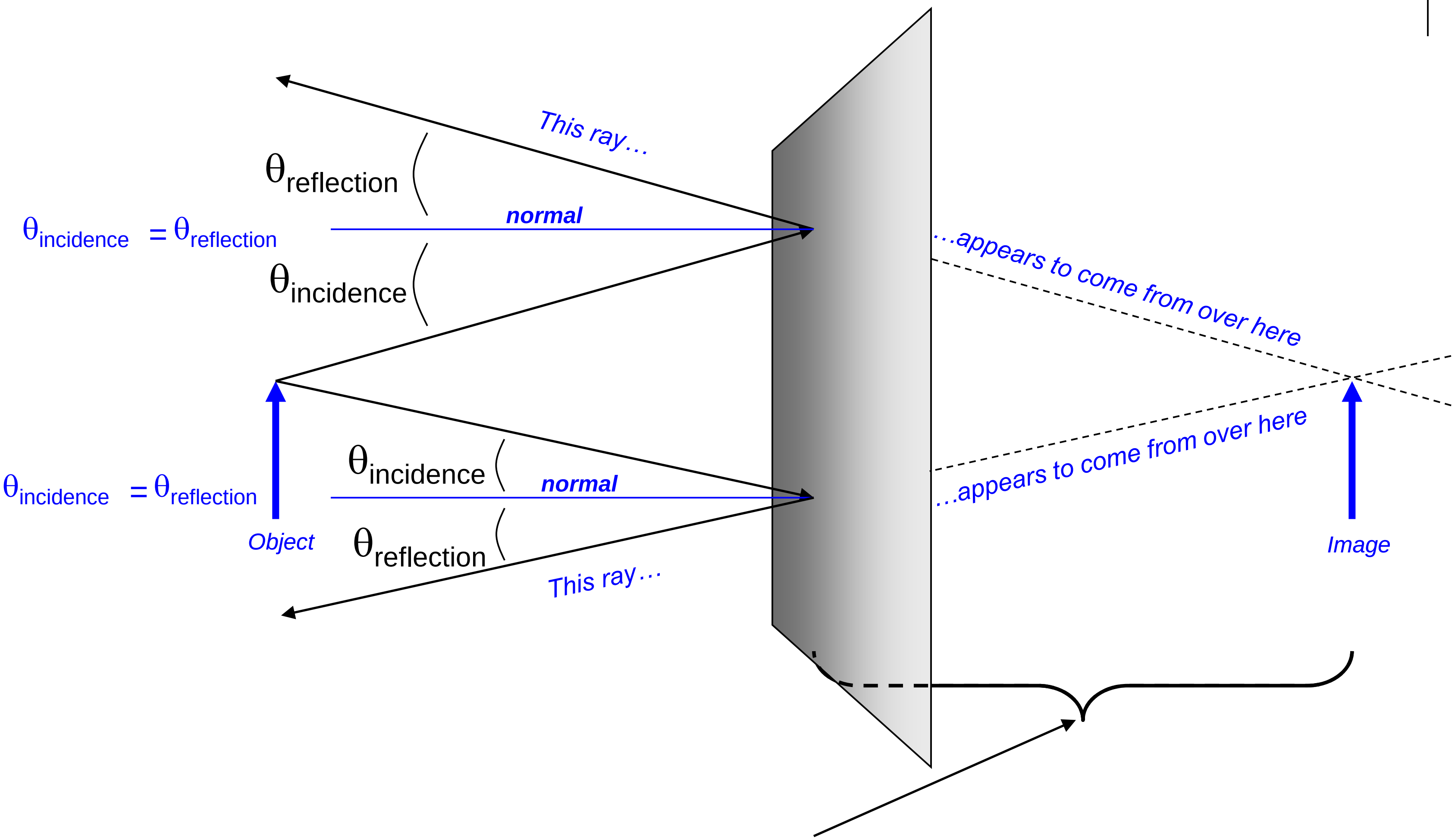
The image **location** is always 'behind' the mirror (ie, on the side opposite the object)

The image is always **upright** (Remember, *upright* means that the image has the same orientation as the object)

The **magnification** is 1.0 (ie, the image is the same height as the object)

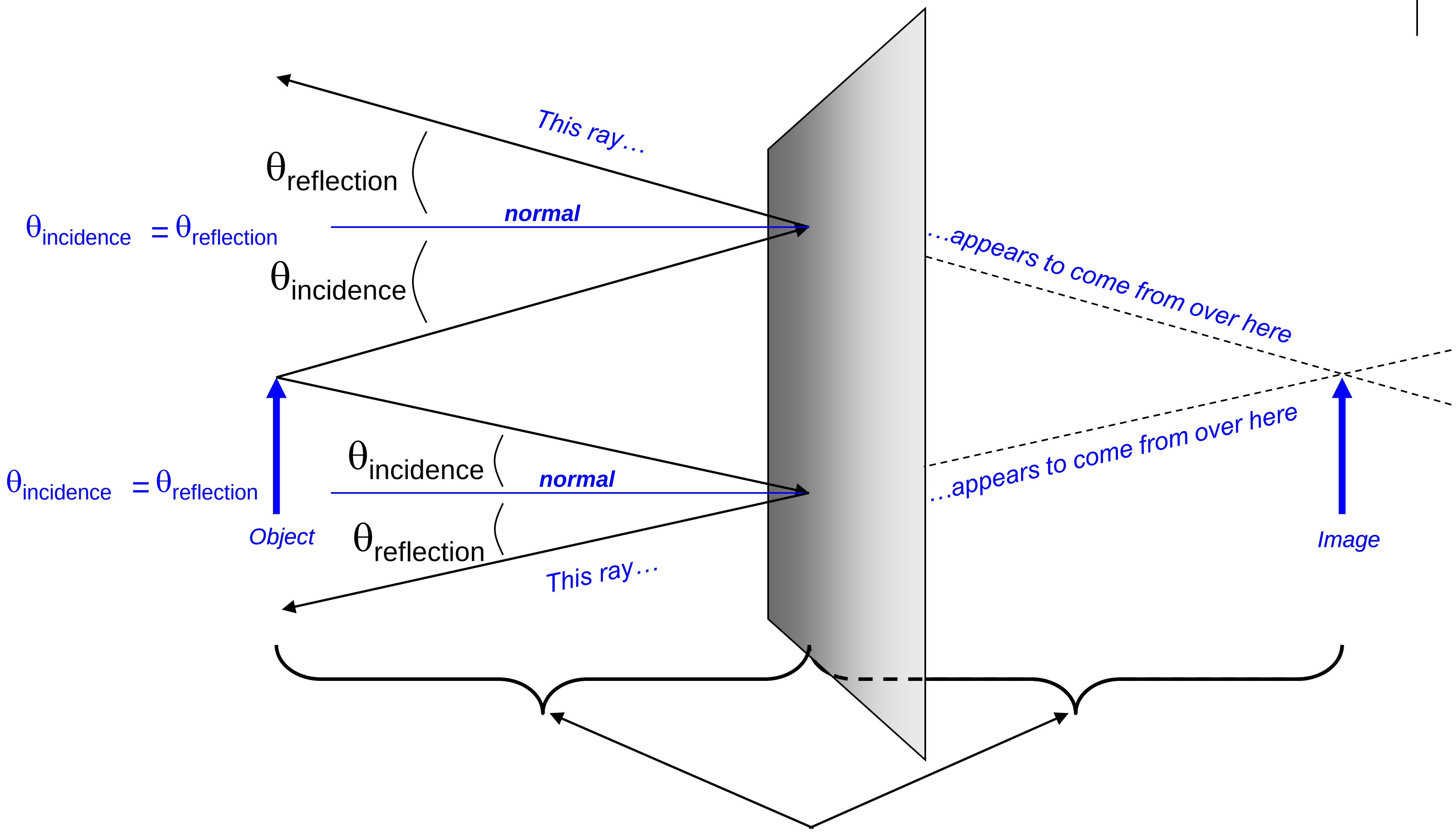
The image is always **virtual** (so you will always have to use extended 'dashed' rays to create it)

Mirrors



Additionally, for plane mirrors: **Image-to-mirror distance =**

Mirrors



Additionally, for plane mirrors: **Image-to-mirror distance = Object-to-mirror distance**

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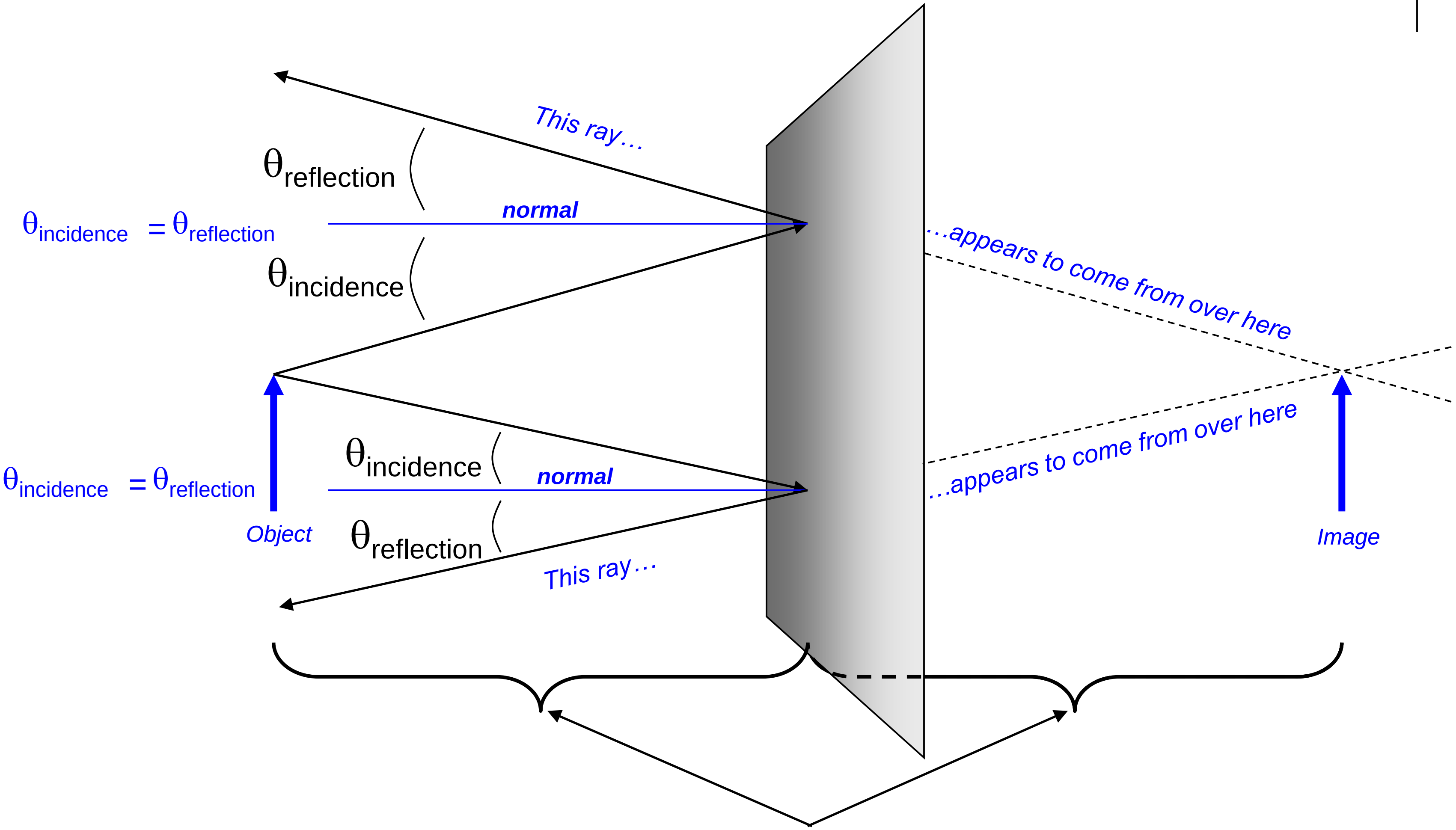


Additionally, for plane mirrors: **Image-to-mirror distance = Object-to-mirror distance**

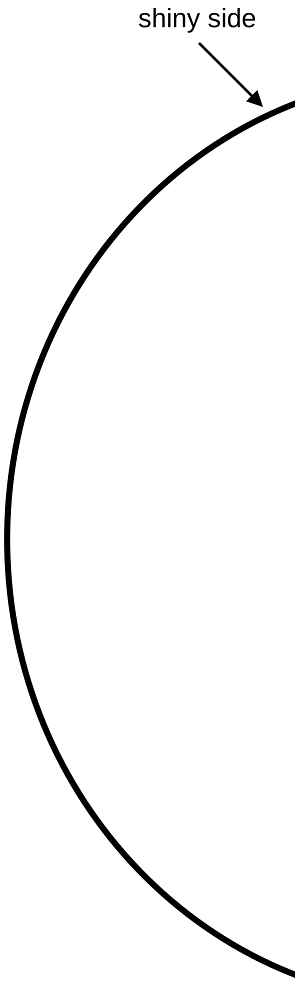
(Note that this is just another way to say **'Vergence out = Vergence in'** as mentioned previously)

Mirrors

- Concave/convex mirrors
  - Change the direction of light, but also alter its vergence
  - The rules governing reflection are equivalent to the ray-tracing rules for lenses we encountered in Chapter 19

Mirrors

The shiny side is shaped like the back of a spoon, so we know this is a *convex* mirror.



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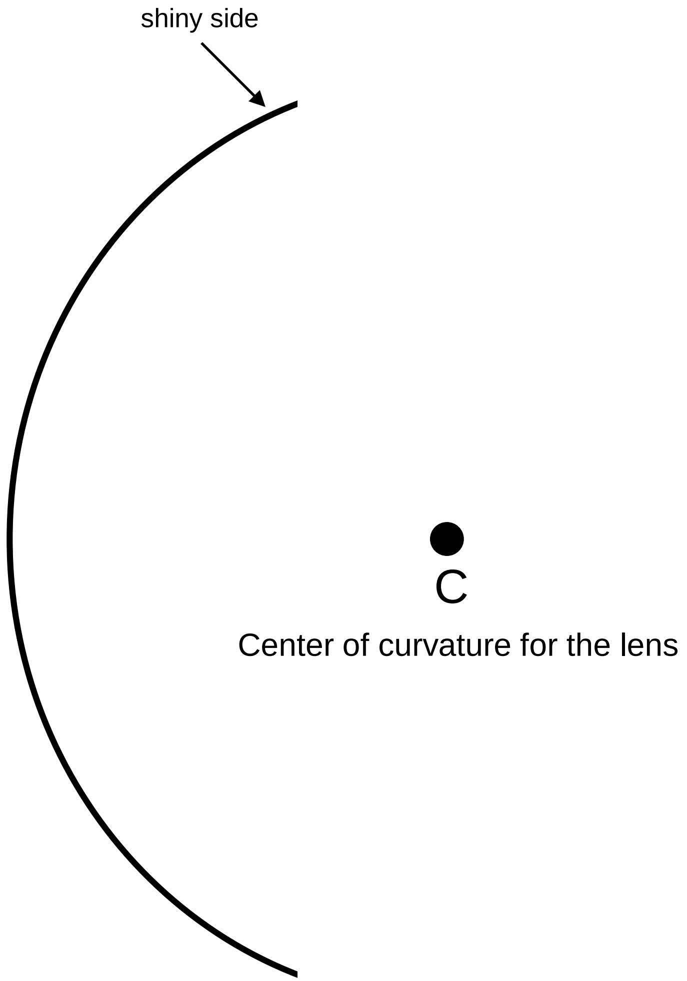
The shiny side is shaped like the back of a spoon, so we know this is a *convex* mirror.

The first aspect we should note is the *center of curvature* for the mirror. Think of it as analogous to the nodal point of a lens.



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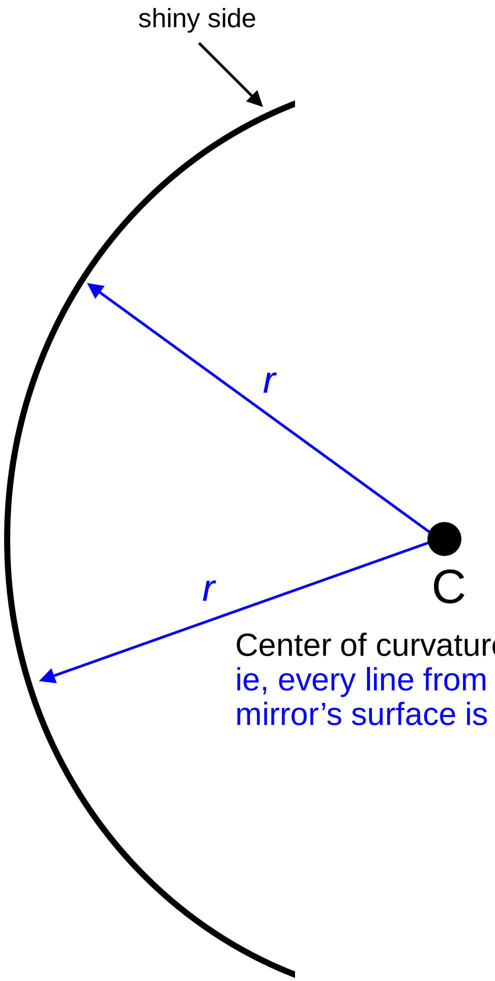

Center of curvature for the lens;
ie, every line from here to the mirror’s surface is a radius

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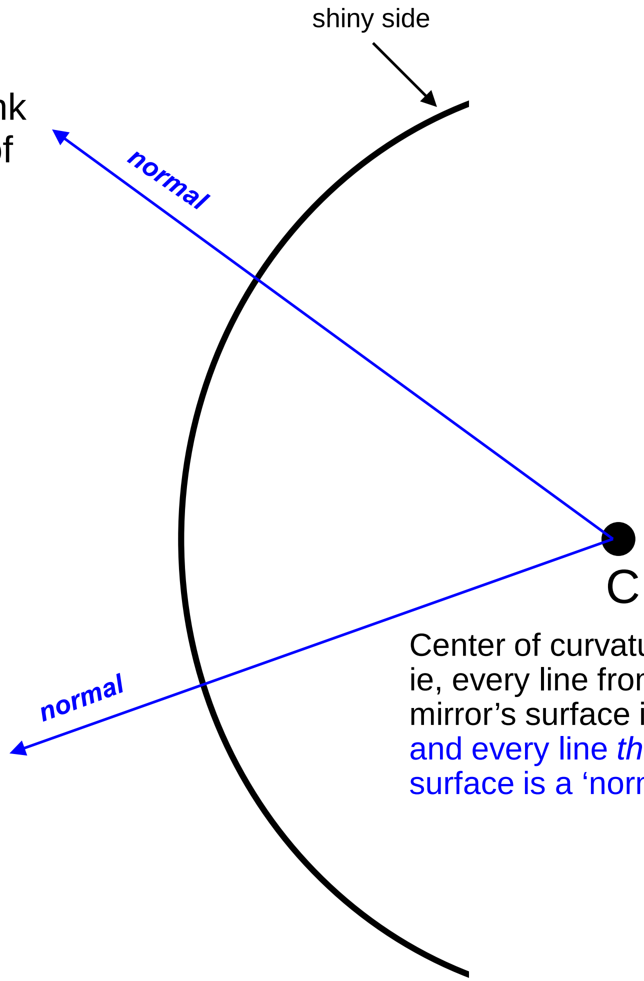

Center of curvature for the lens; ie, every line from here to the mirror's surface is a radius, and every line *through* the surface is a 'normal'

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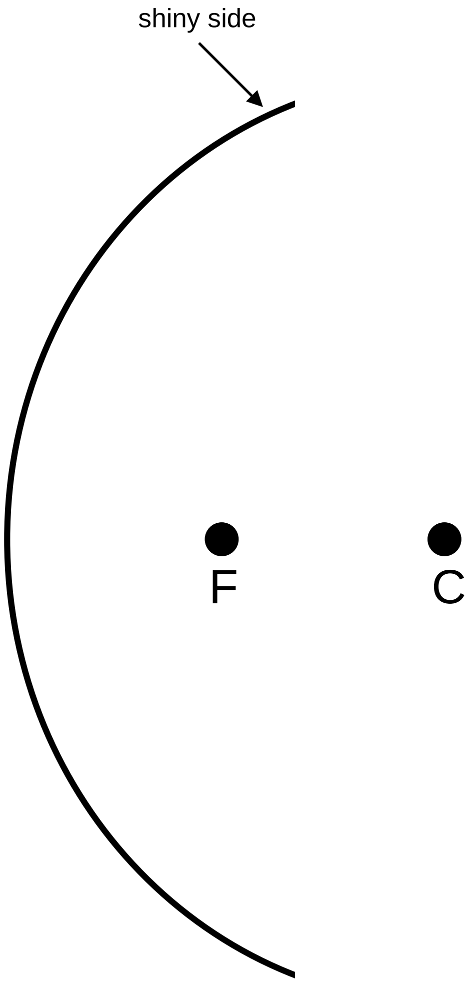
The next aspect we should note are the *focal points* of the mirror.



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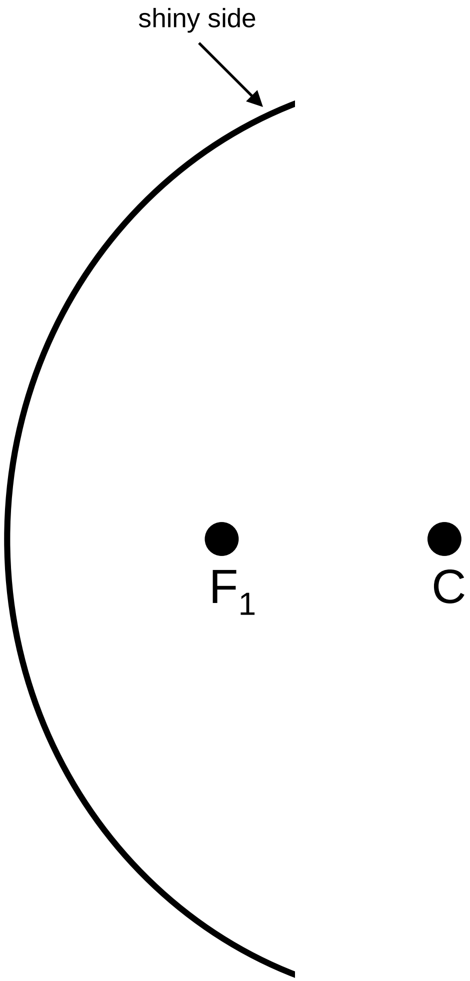
The next aspect we should note are the *focal points* of the mirror. Like a lens, a mirror has a primary focal point



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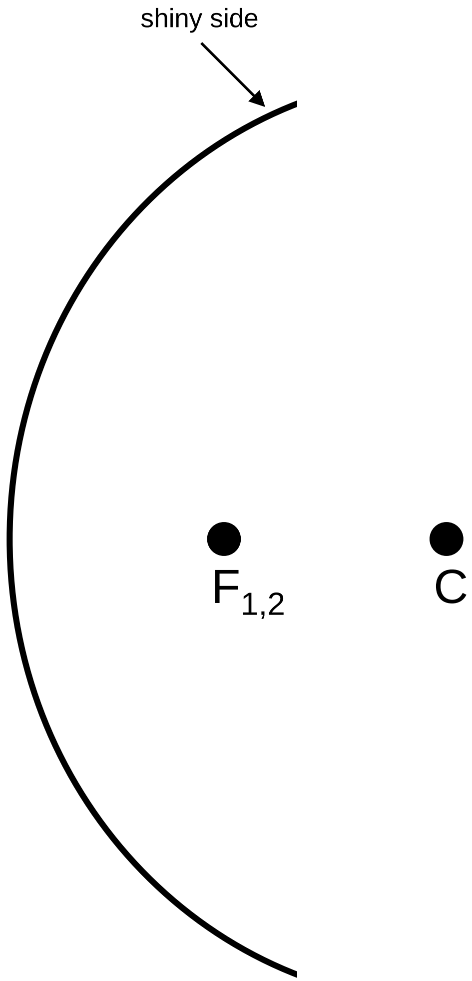

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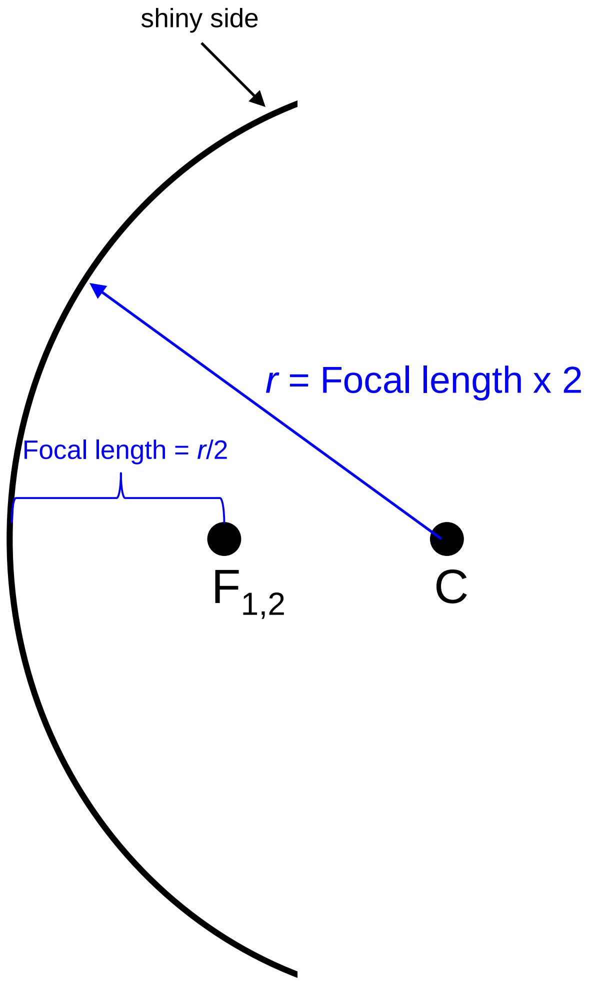

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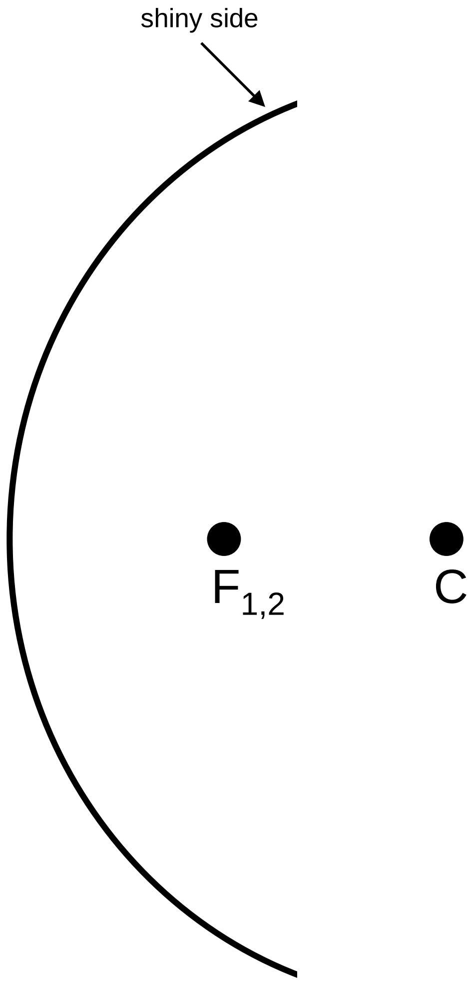
(Technically it's not the same location, in that the primary focal is located in what is known as 'object space,' whereas the secondary focal point is located in 'image space.')



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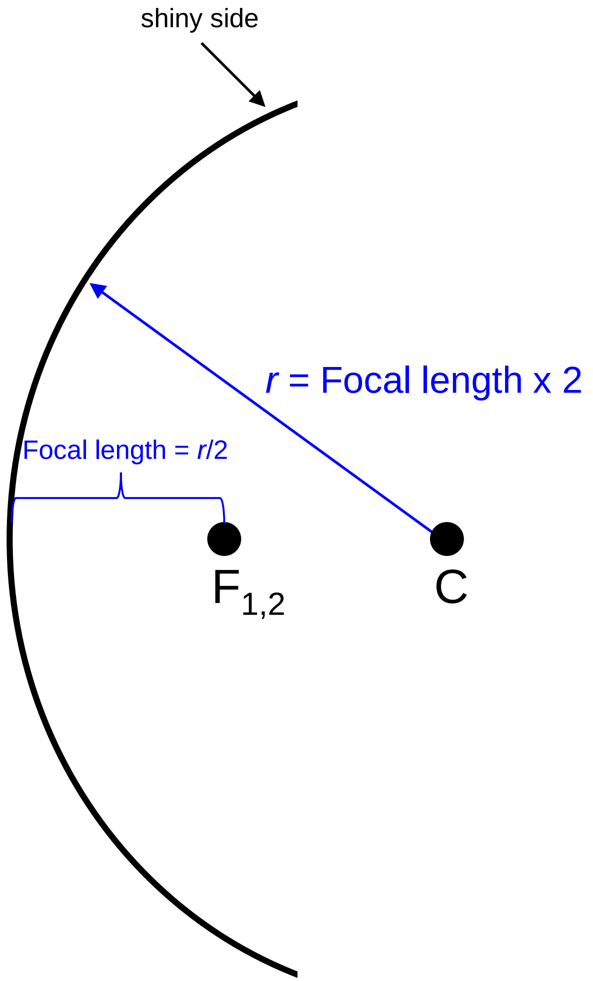
Thus, if you know the location of either the center of curvature or the focal point(s), you can determine the location of the other.



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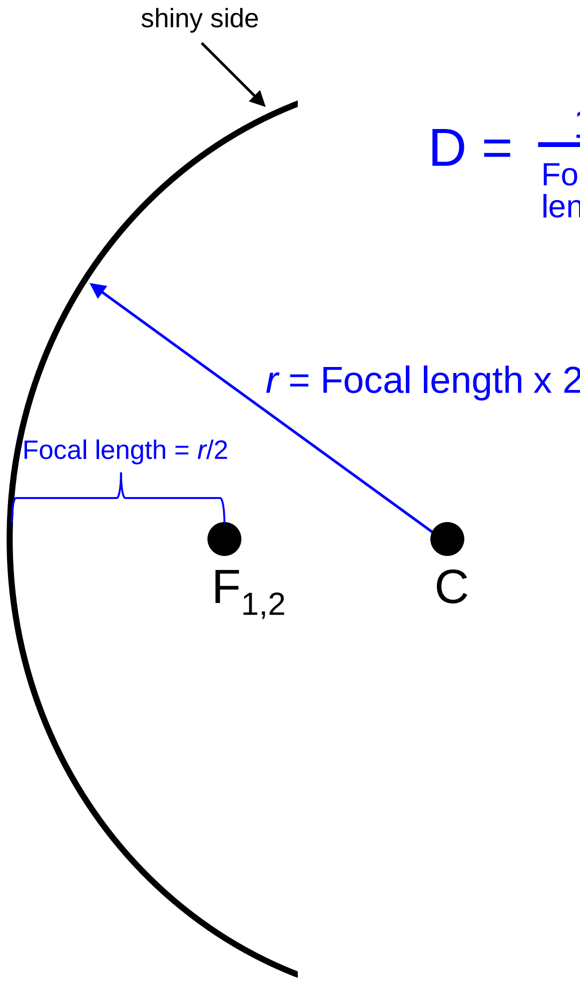
Thus, if you know the location of either the center of curvature or the focal point(s), you can determine the location of the other. Likewise, because the distance from the focal point(s) to the mirror (ie, the *focal length*) is the reciprocal of the converging power of the mirror in diopters, you can also determine the power of the mirror.

(The '2' simply reflects the fact that the radius is exactly twice as large as the focal length)

$$D = \frac{1}{\text{Focal length}} = \frac{2}{r}$$



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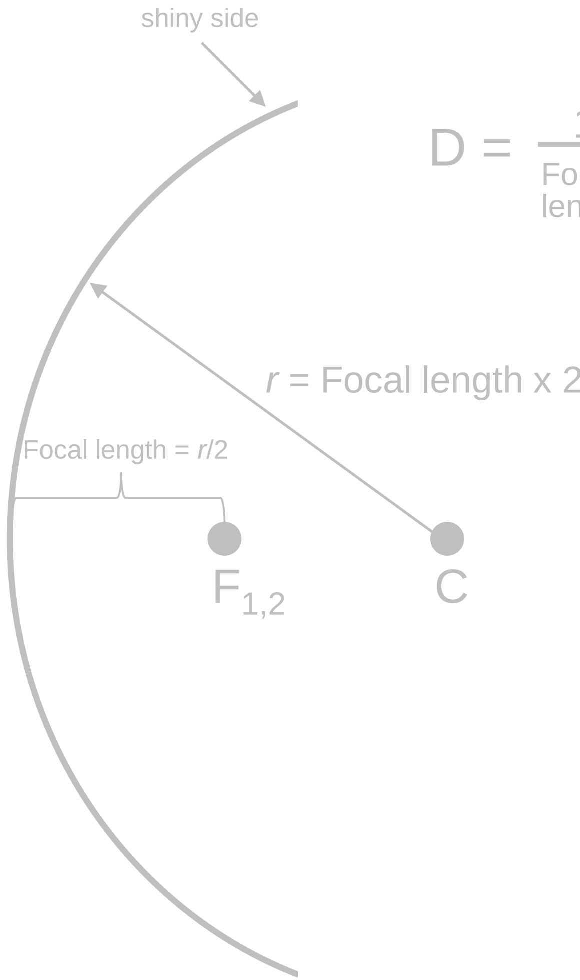
*Note: Because mirrors always reverse the direction of light, you may see the power expressed thusly, with a **minus sign**:*

$$D = \frac{1}{\text{Focal length}} = -\frac{2}{r}$$



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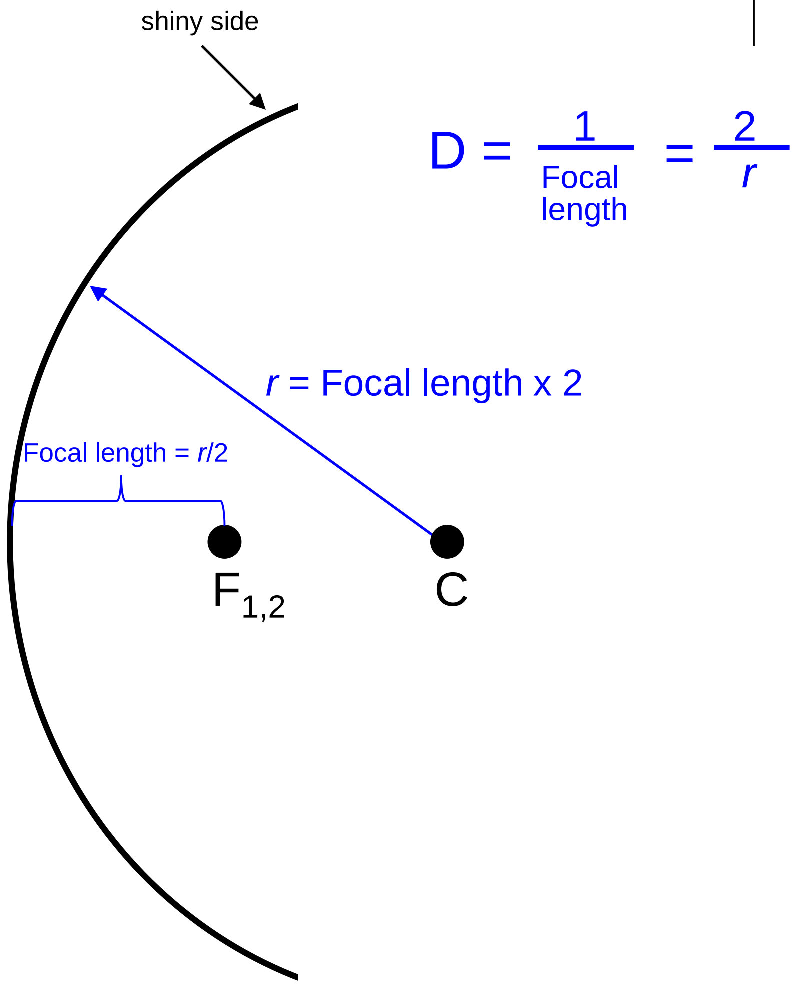
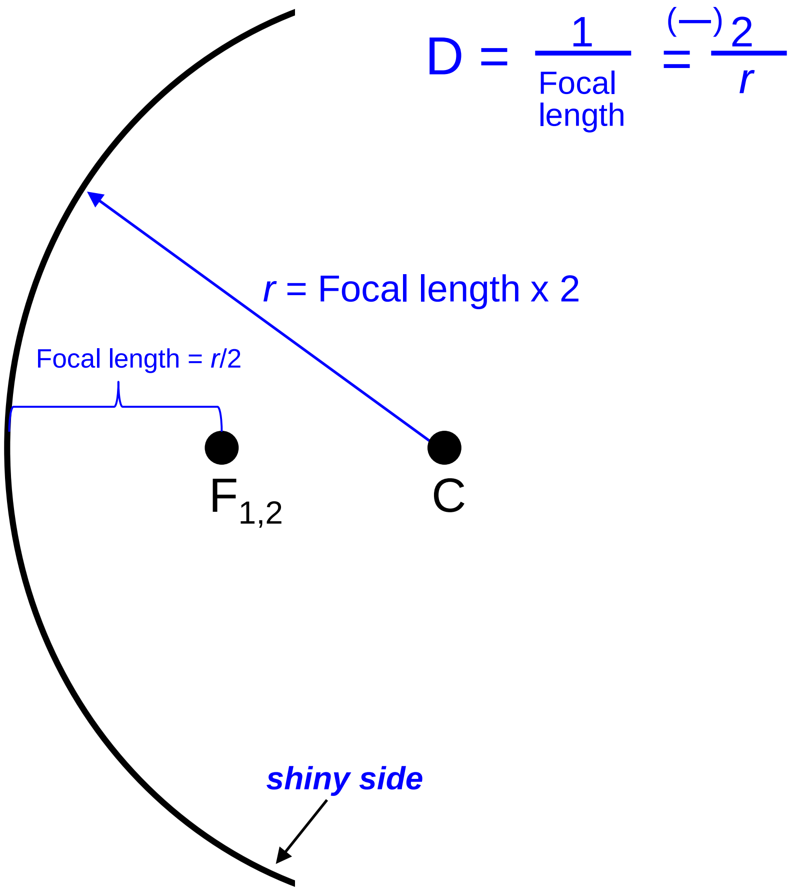


Note that the same facts hold true for both convex…

Mirrors



The shiny side is shaped like the front of a spoon, so we know this is a ***concave*** mirror.

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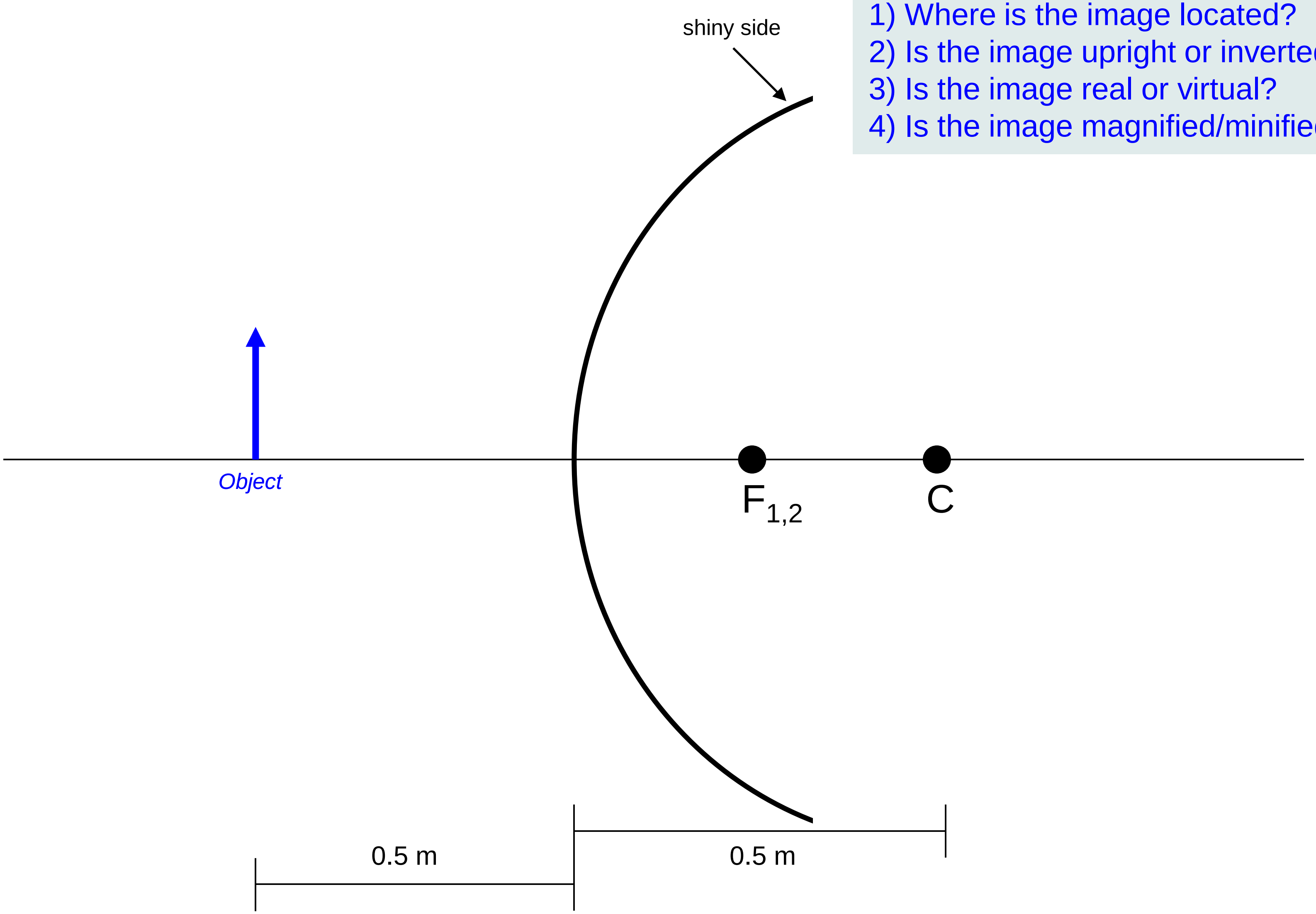
Note that the same facts hold true for both convex…and *concave* mirrors

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



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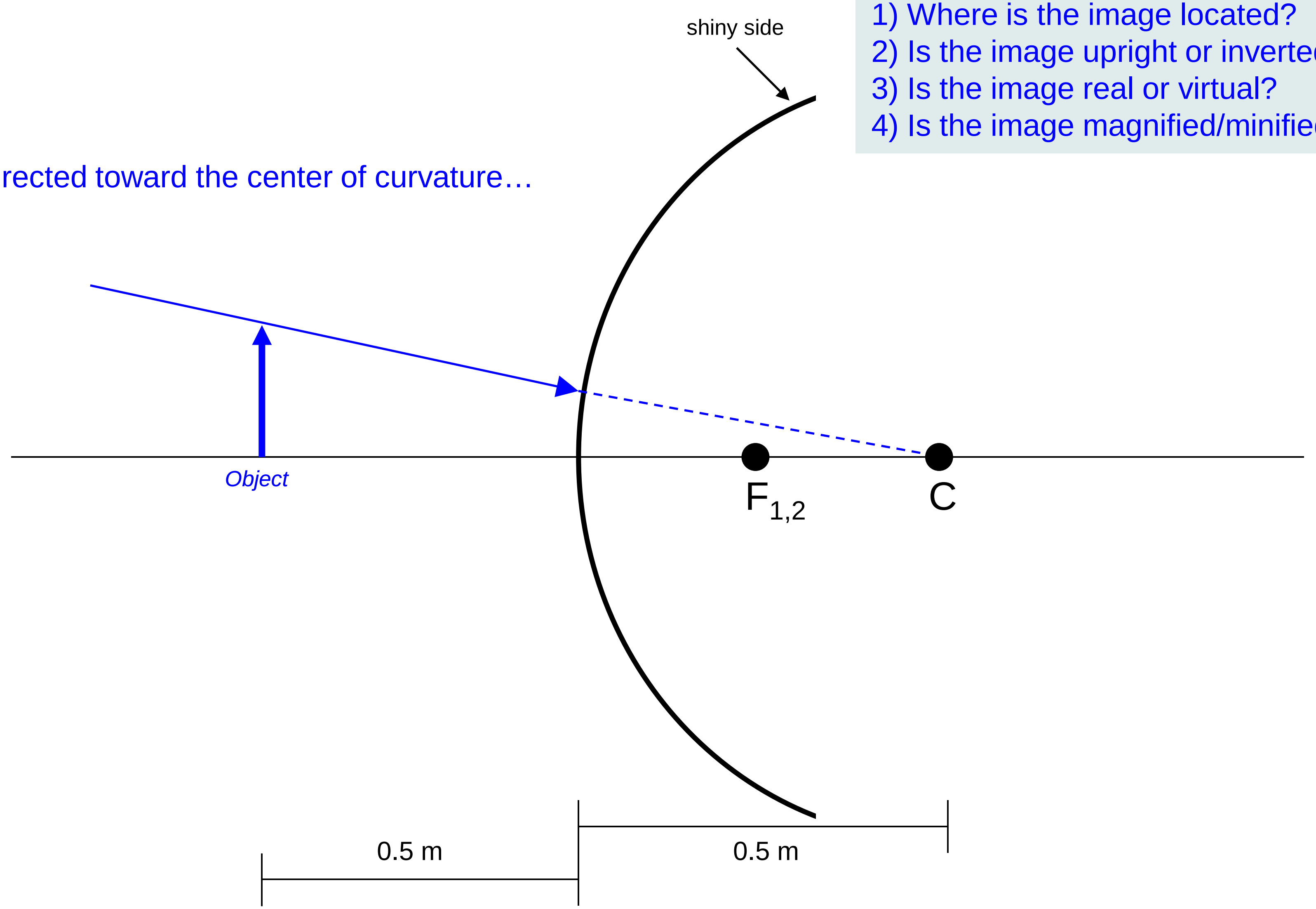
A ray directed toward the center of curvature…



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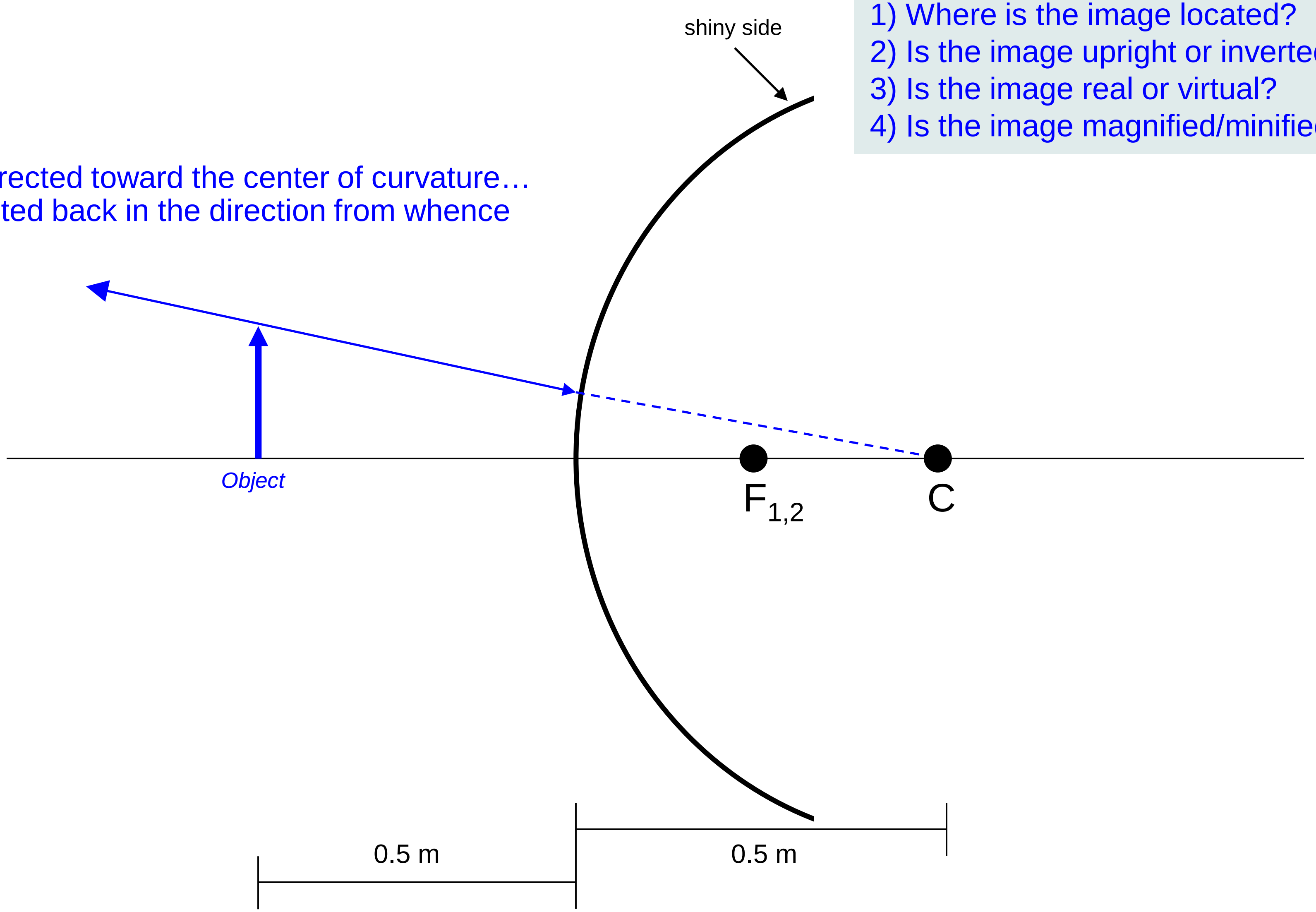
A ray directed toward the center of curvature… is reflected back in the direction from whence it came.



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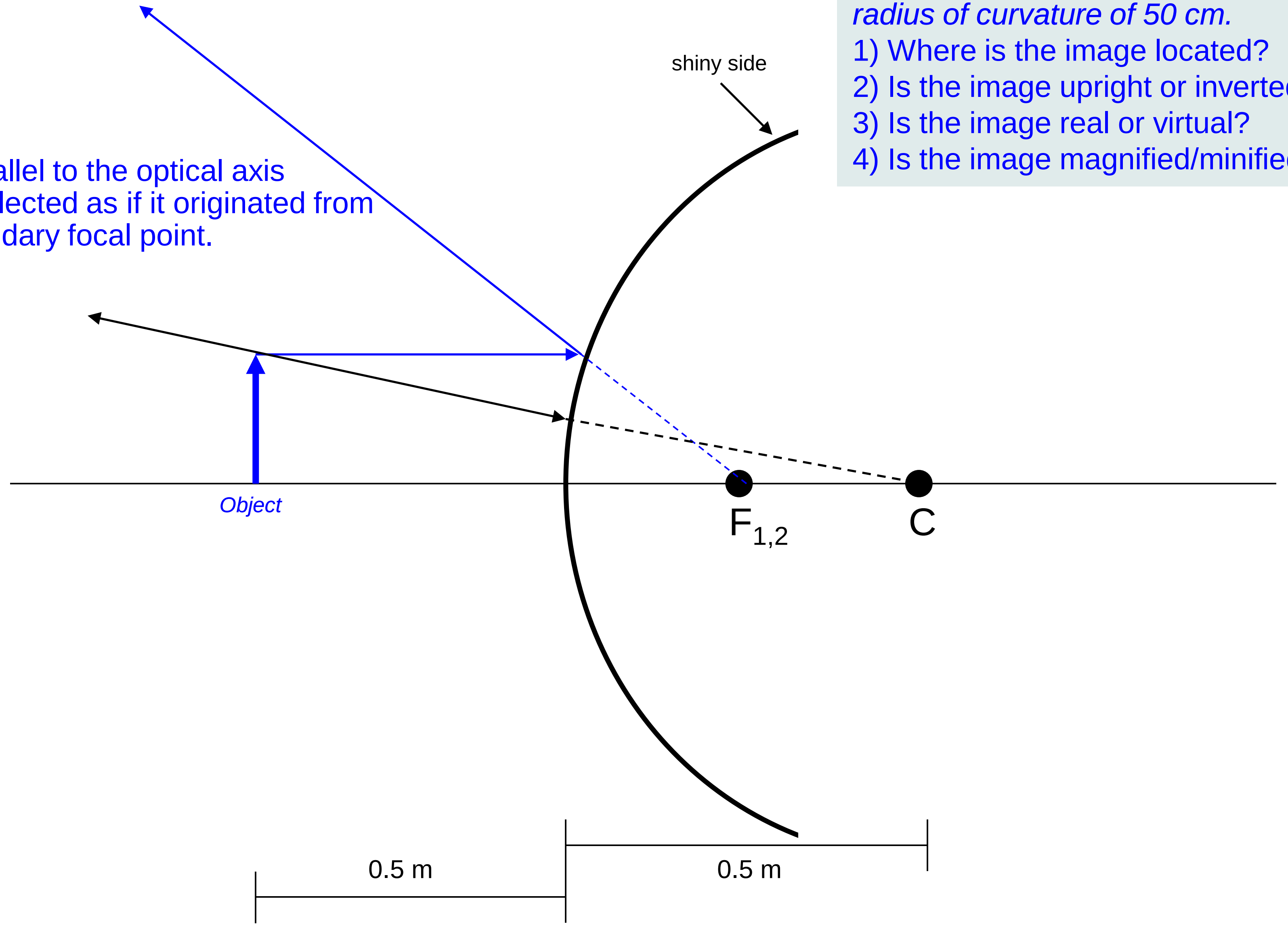
A ray parallel to the optical axis will be reflected as if it originated from the secondary focal point.



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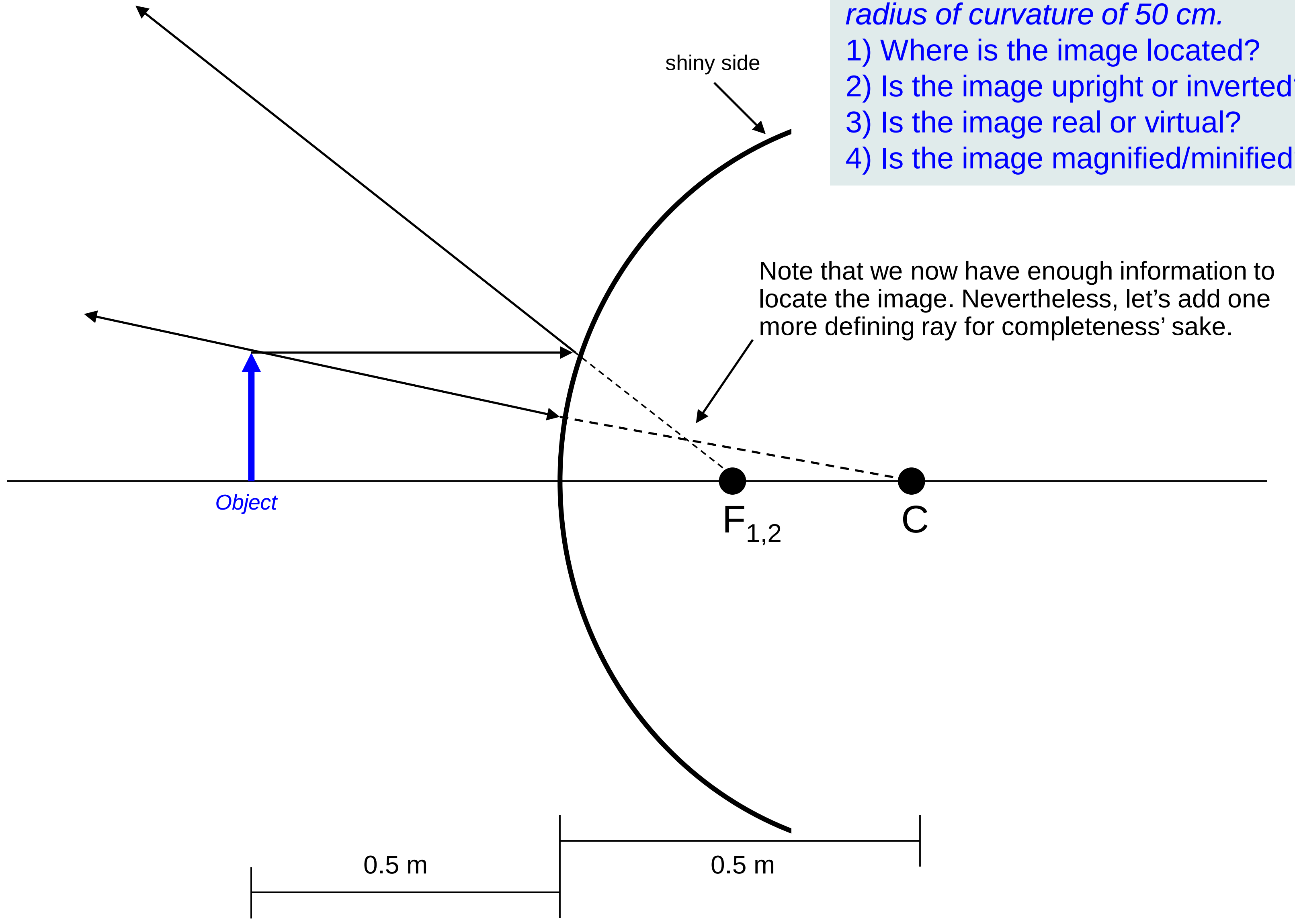
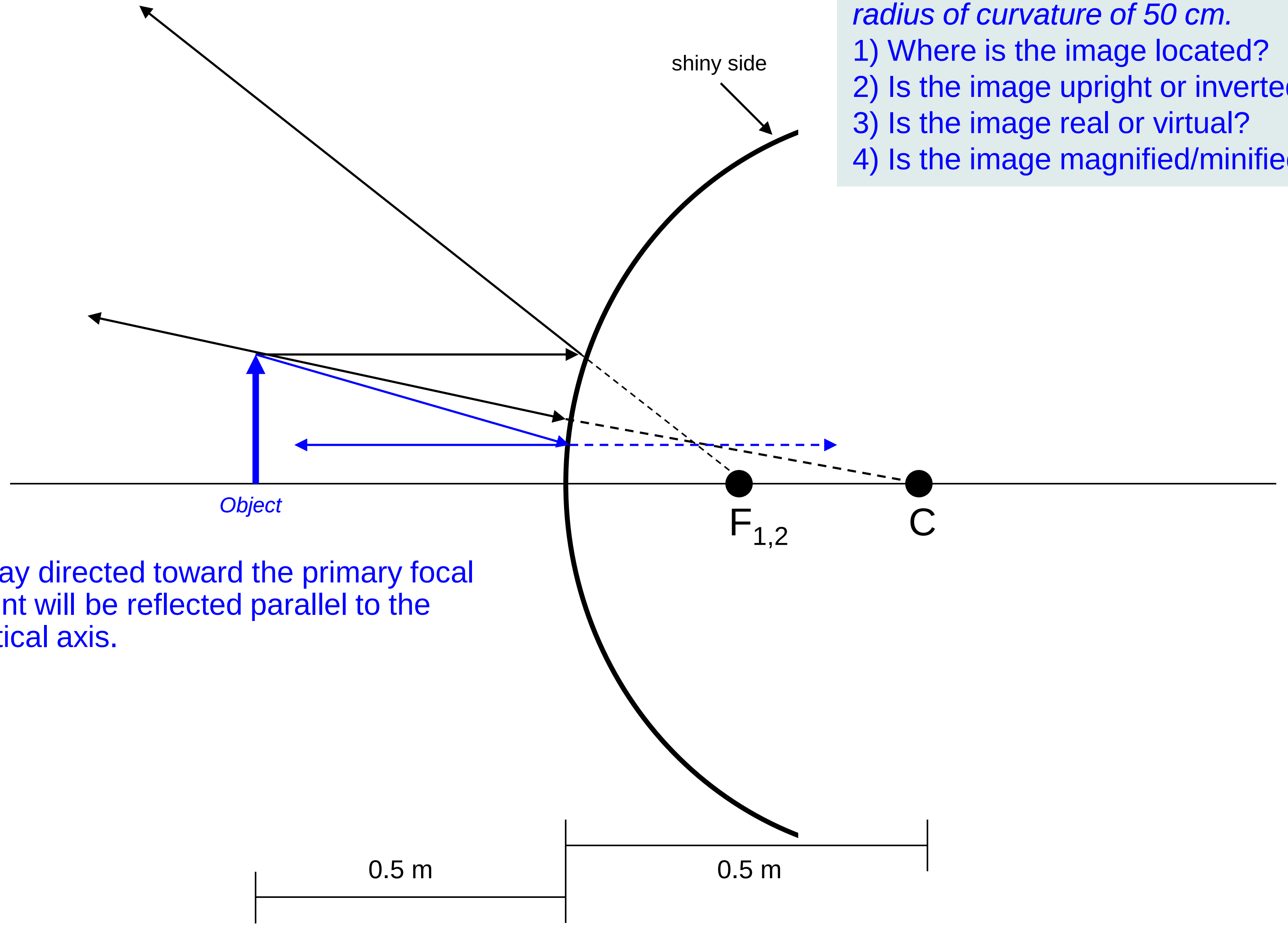


Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

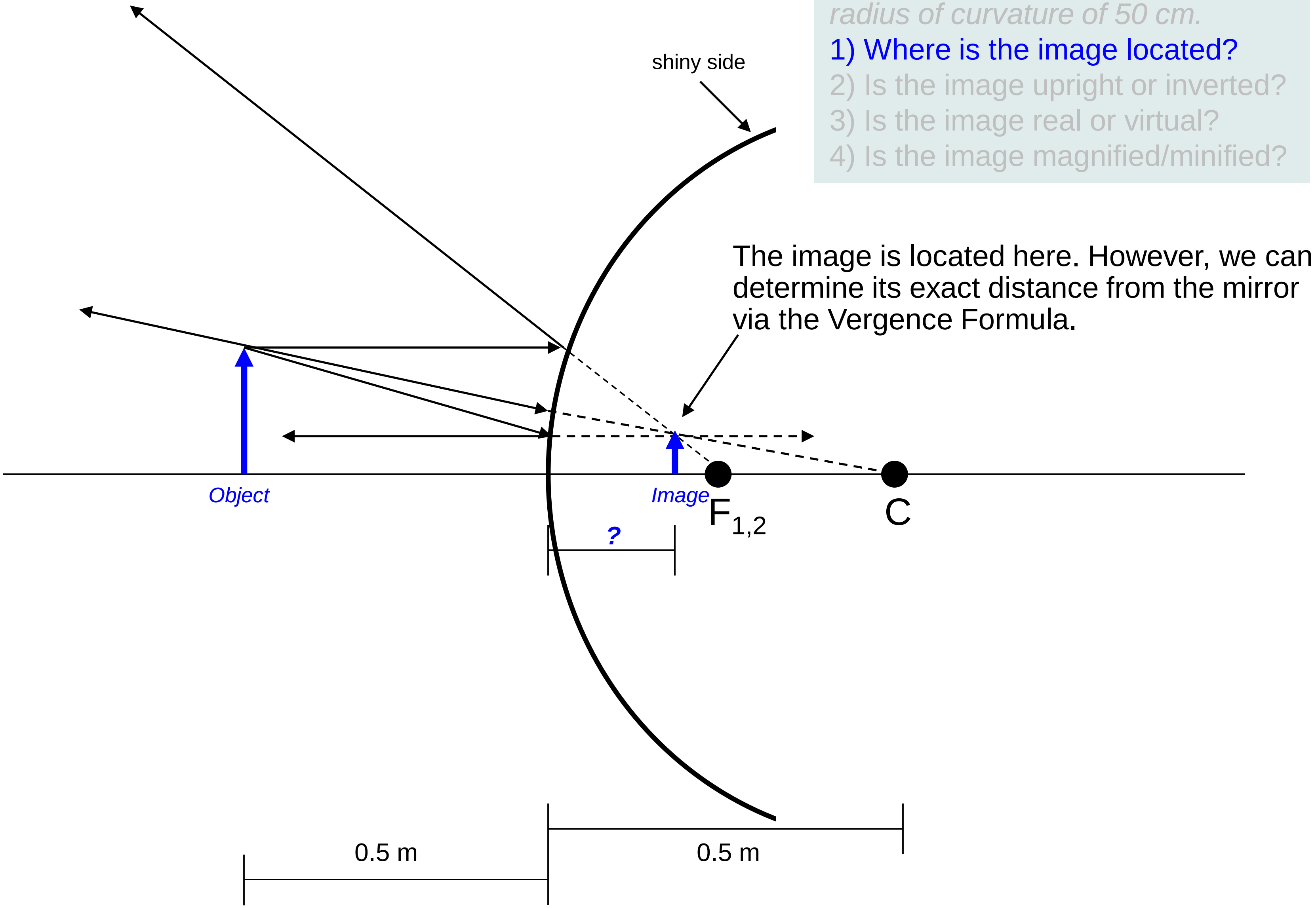


A ray directed toward the primary focal point will be reflected parallel to the optical axis.

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

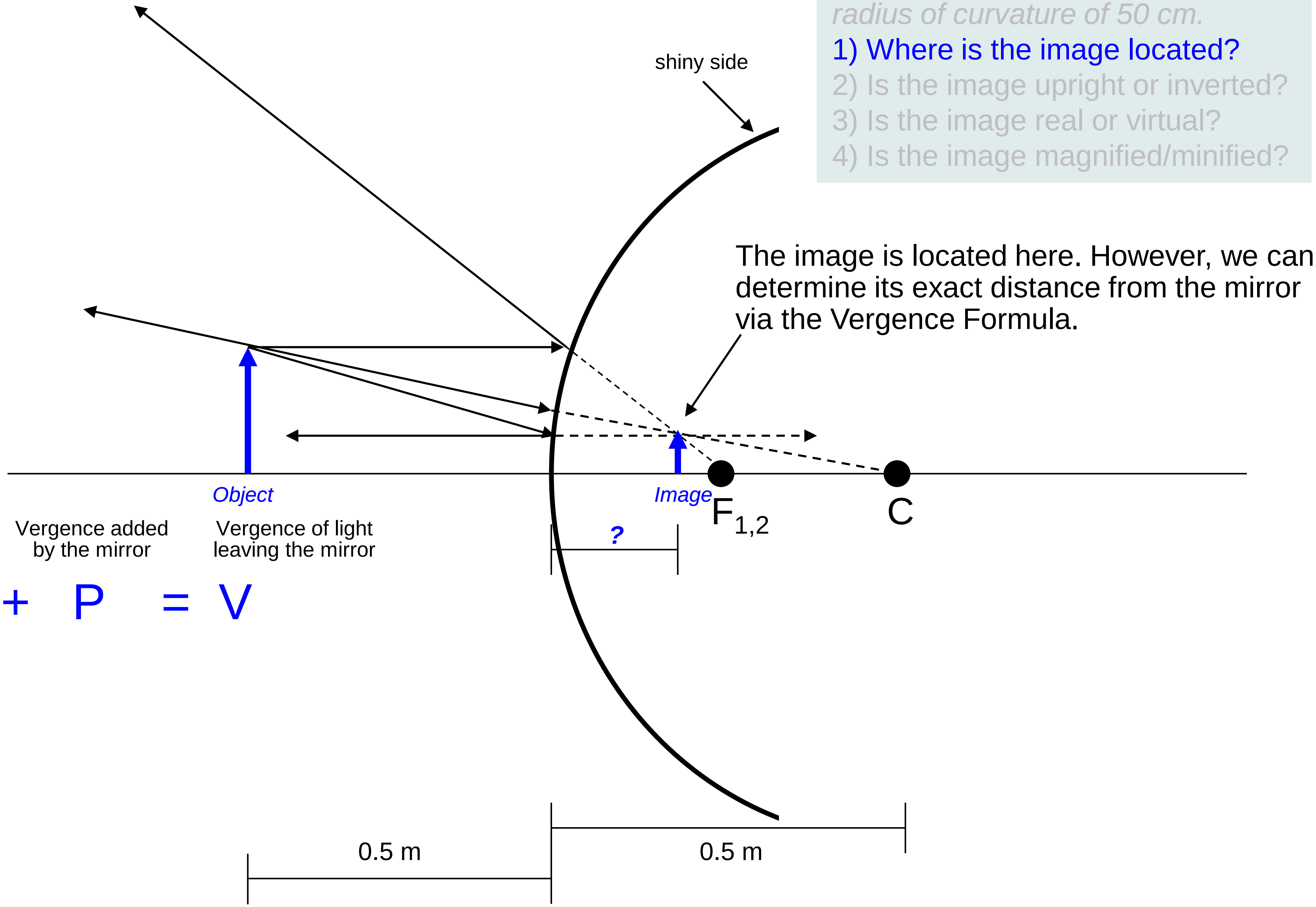
1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

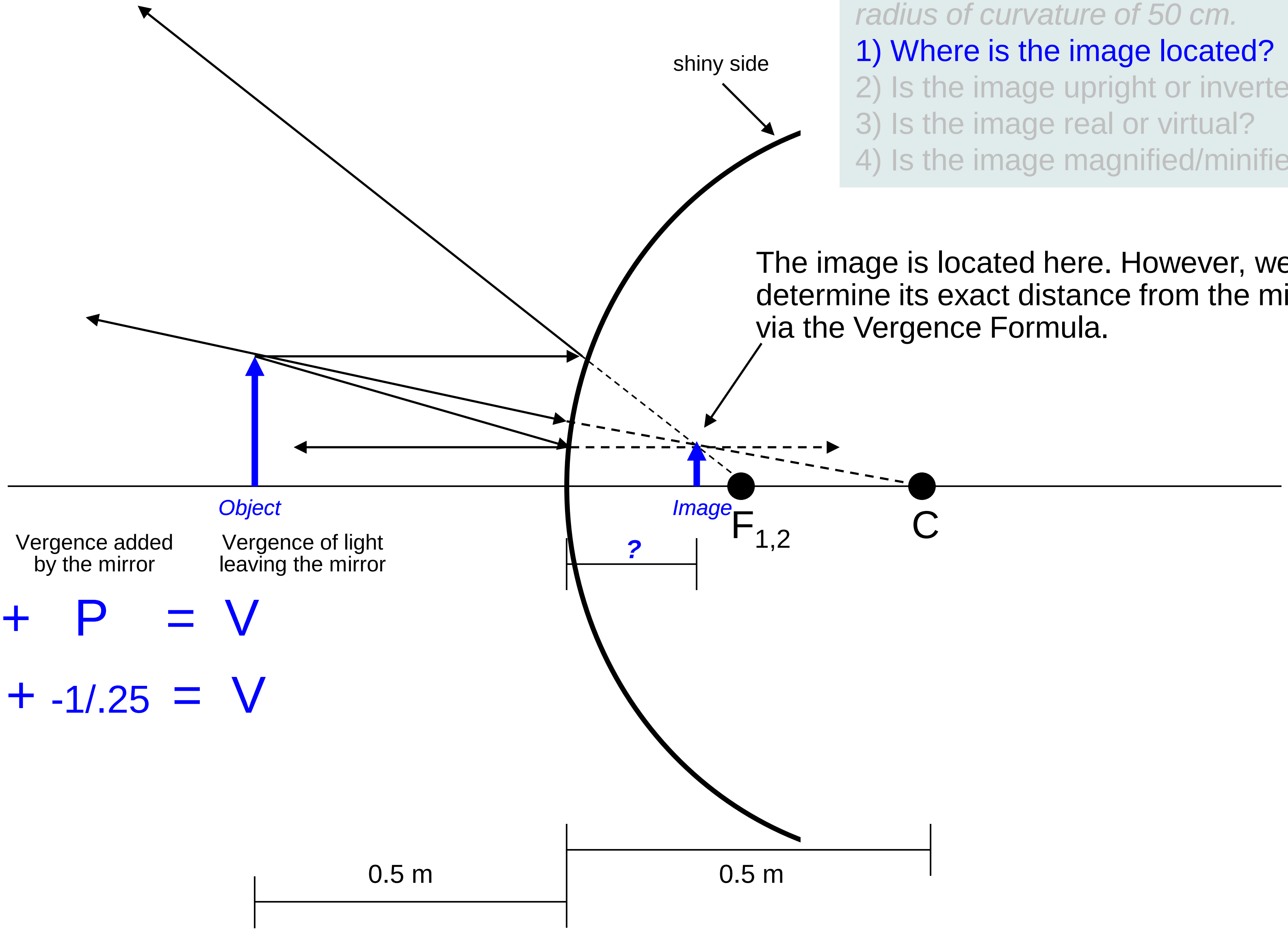


Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



Vergence of incoming light | Vergence added by the mirror | Vergence of light leaving the mirror

$$U + P = V$$

$$-1/.5 + -1/.25 = V$$

Mirrors

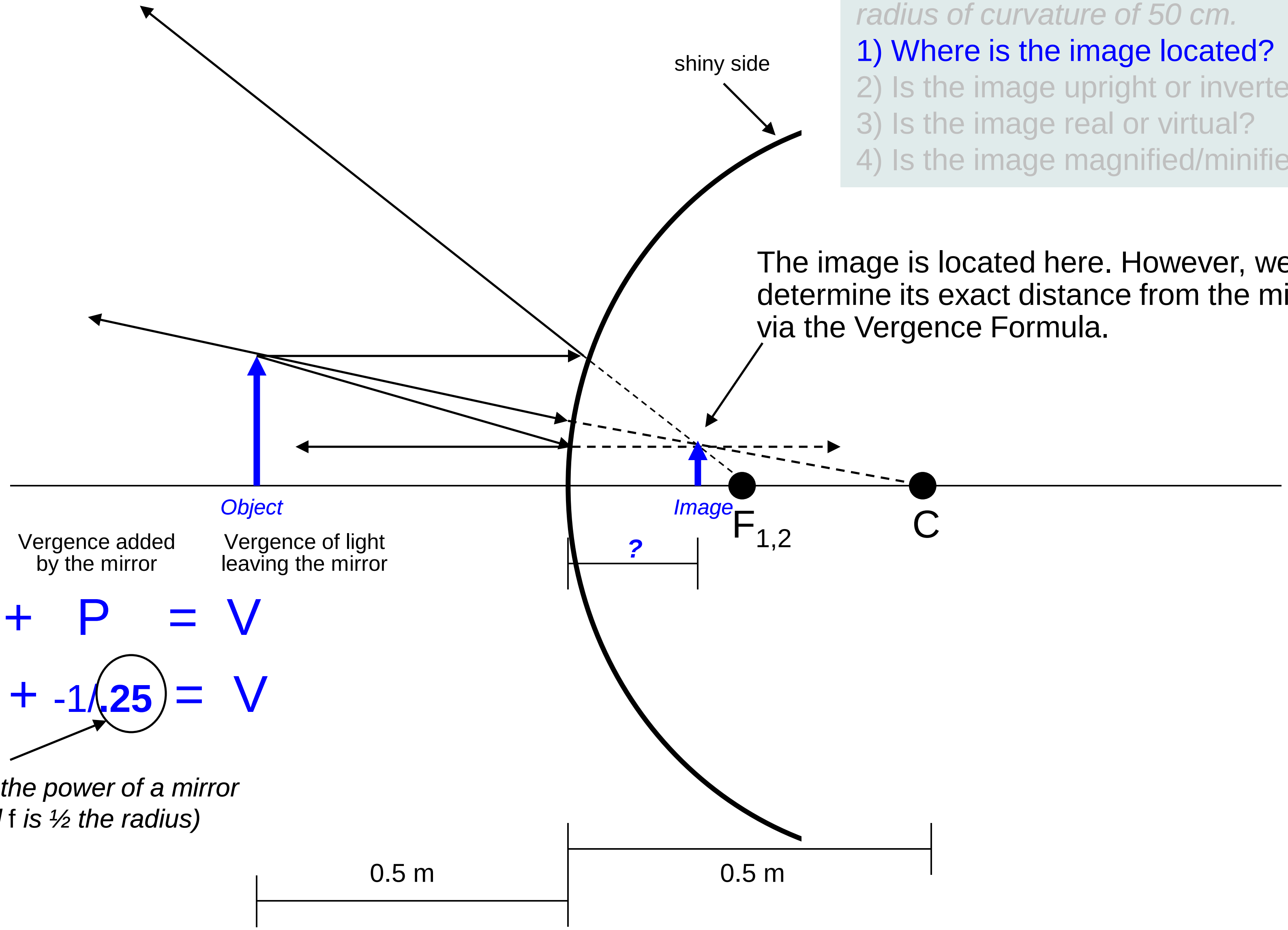
An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?

2) Is the image upright or inverted?

3) Is the image real or virtual?

4) Is the image magnified/minified?



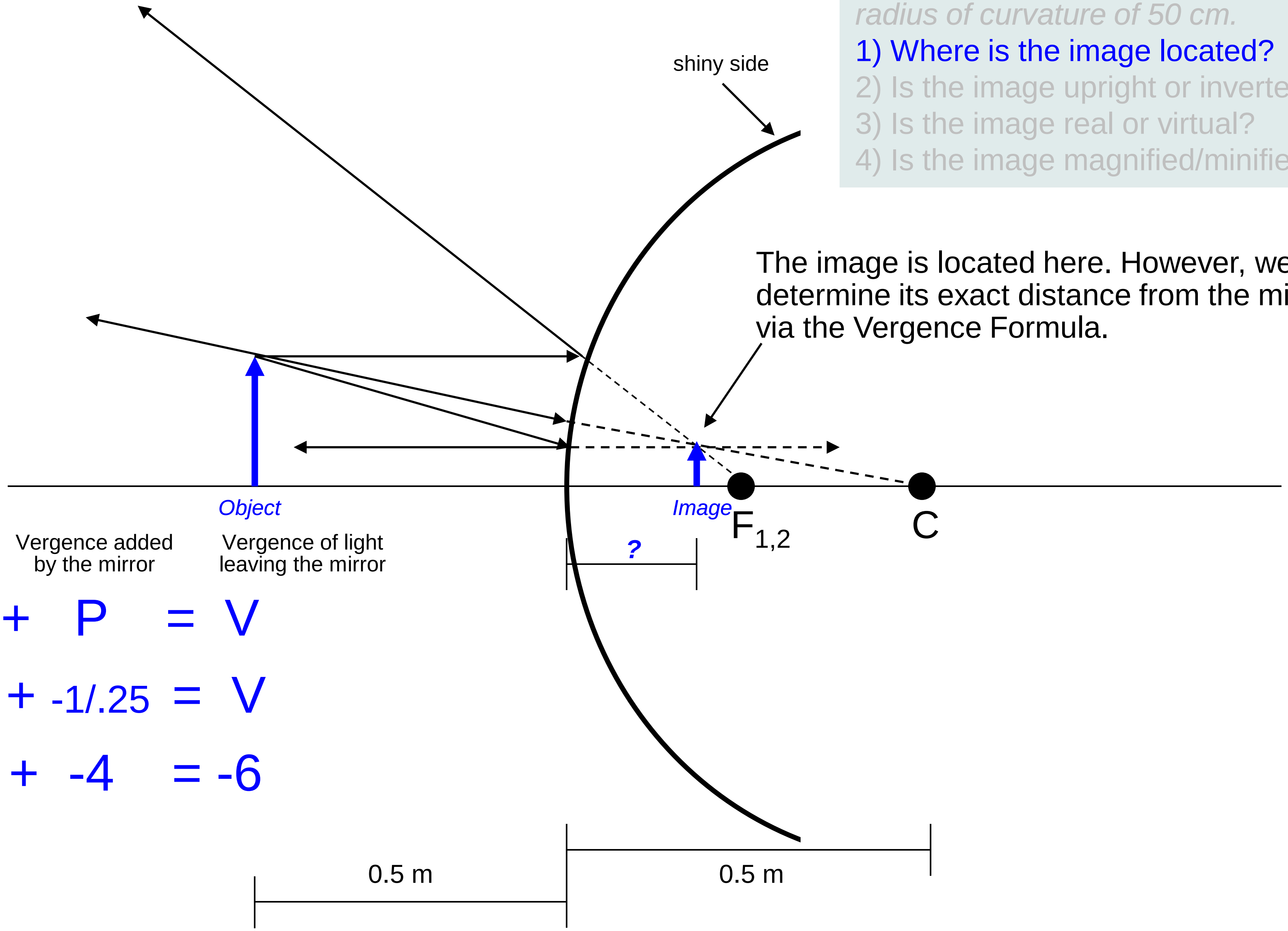
The image is located here. However, we can determine its exact distance from the mirror via the Vergence Formula.

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/**.25**	=	V

*(Remember, the power of a mirror is 1/*f*, and* f *is ½ the radius)*

Mirrors

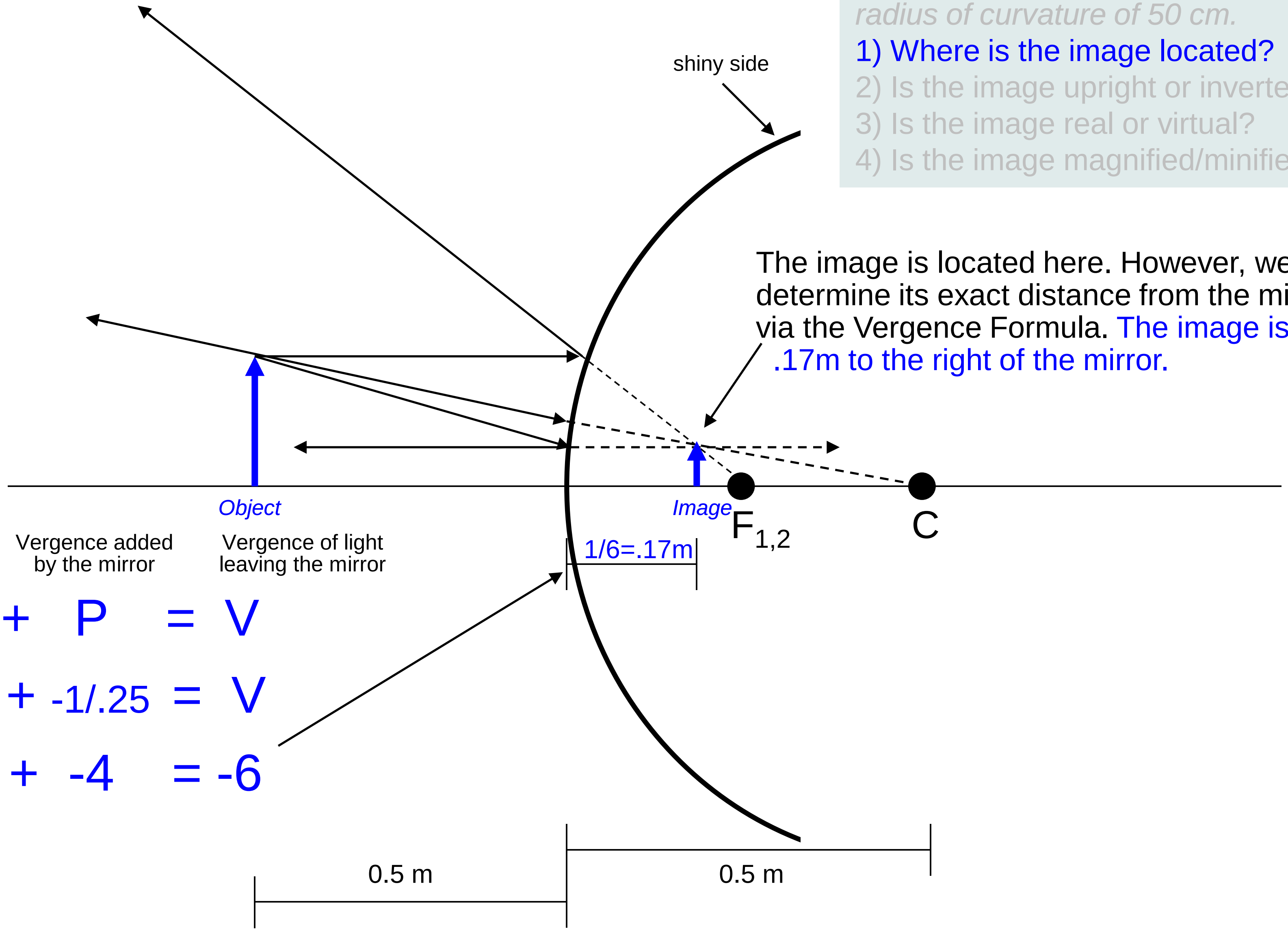
An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.
1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.
1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



The image is located here. However, we can determine its exact distance from the mirror via the Vergence Formula. The image is .17m to the right of the mirror.

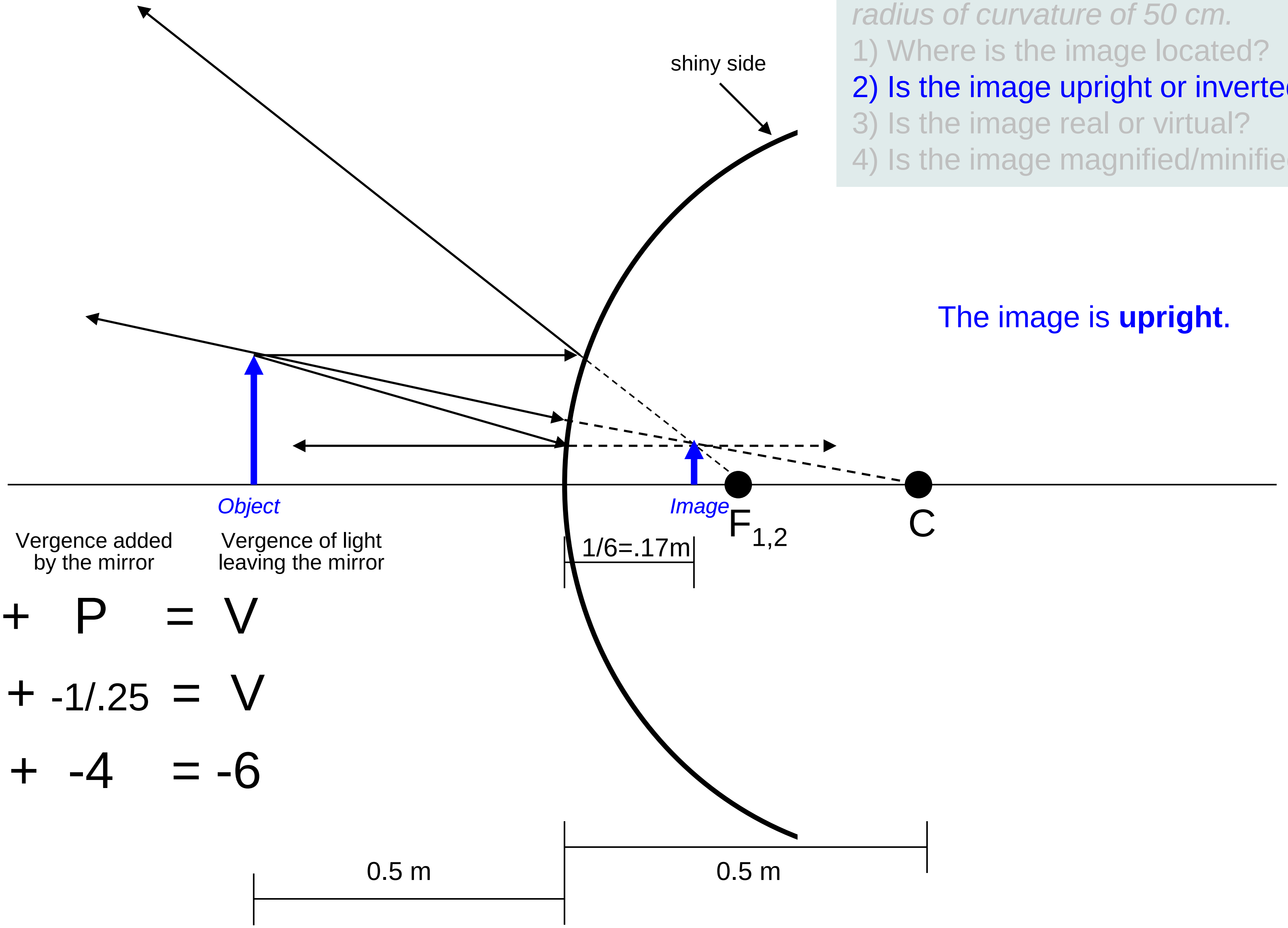
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

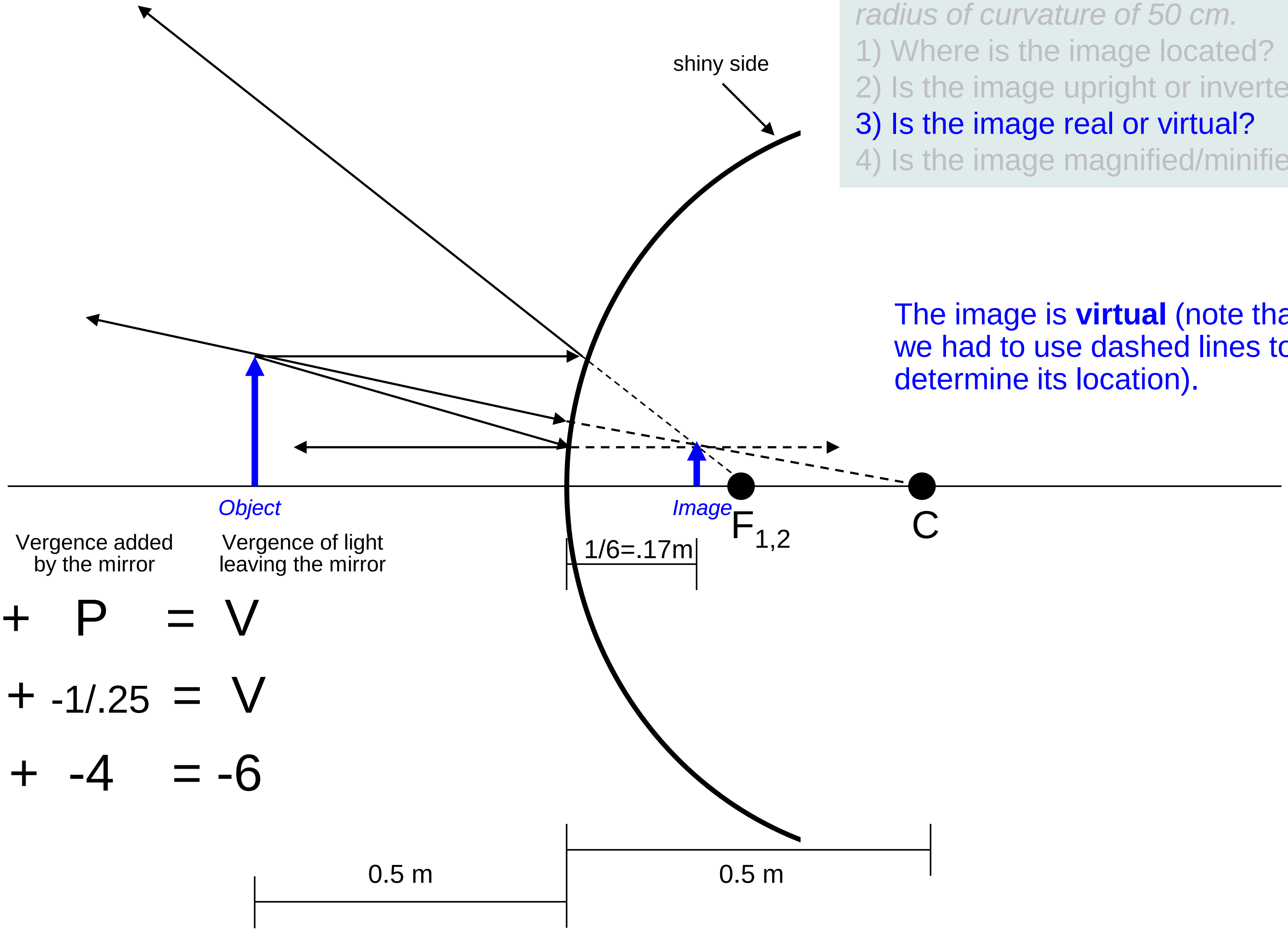
1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is **upright**.



Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors



An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

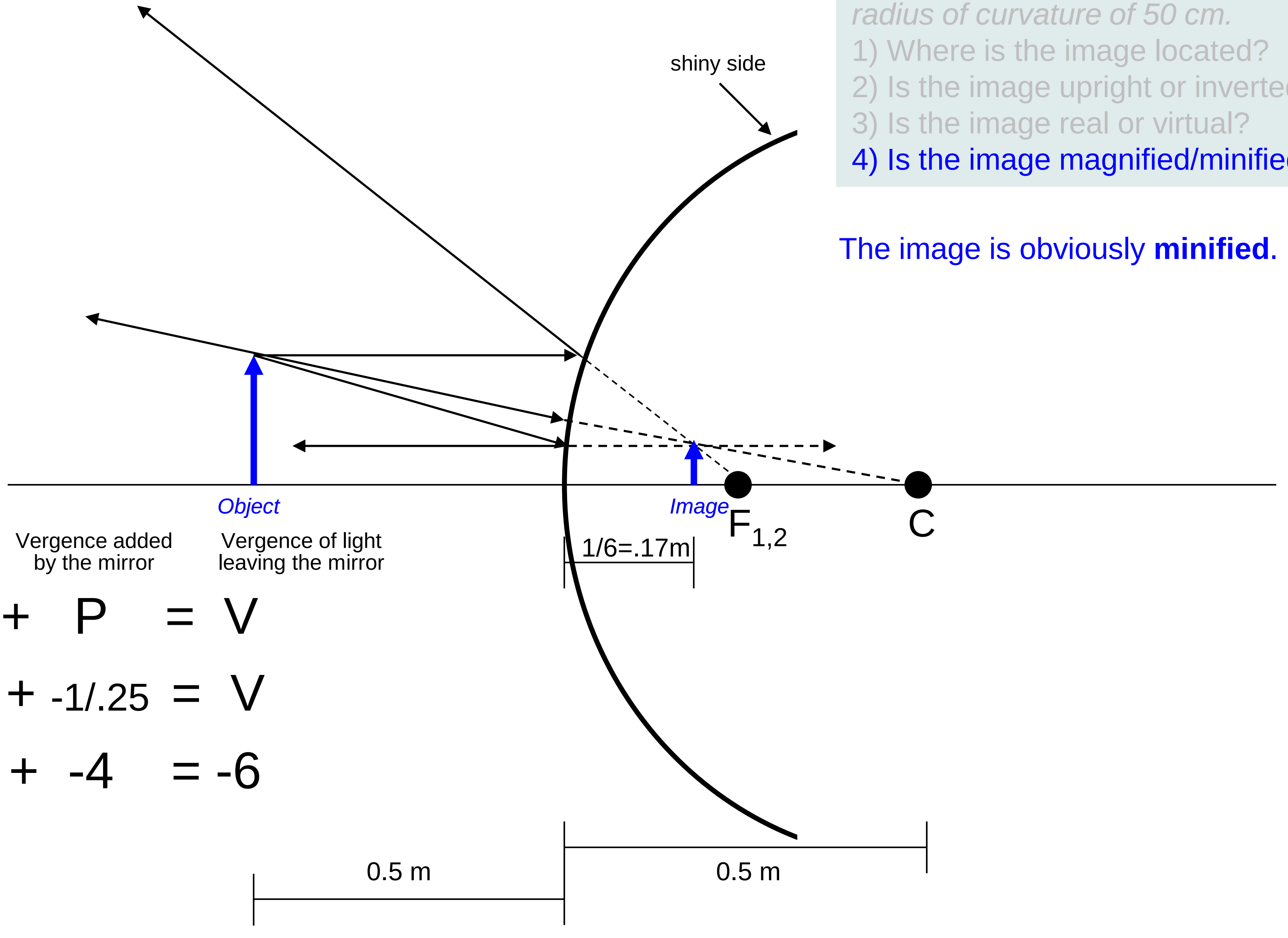
The image is **virtual** (note that we had to use dashed lines to determine its location).

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.
1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is obviously **minified**.



Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

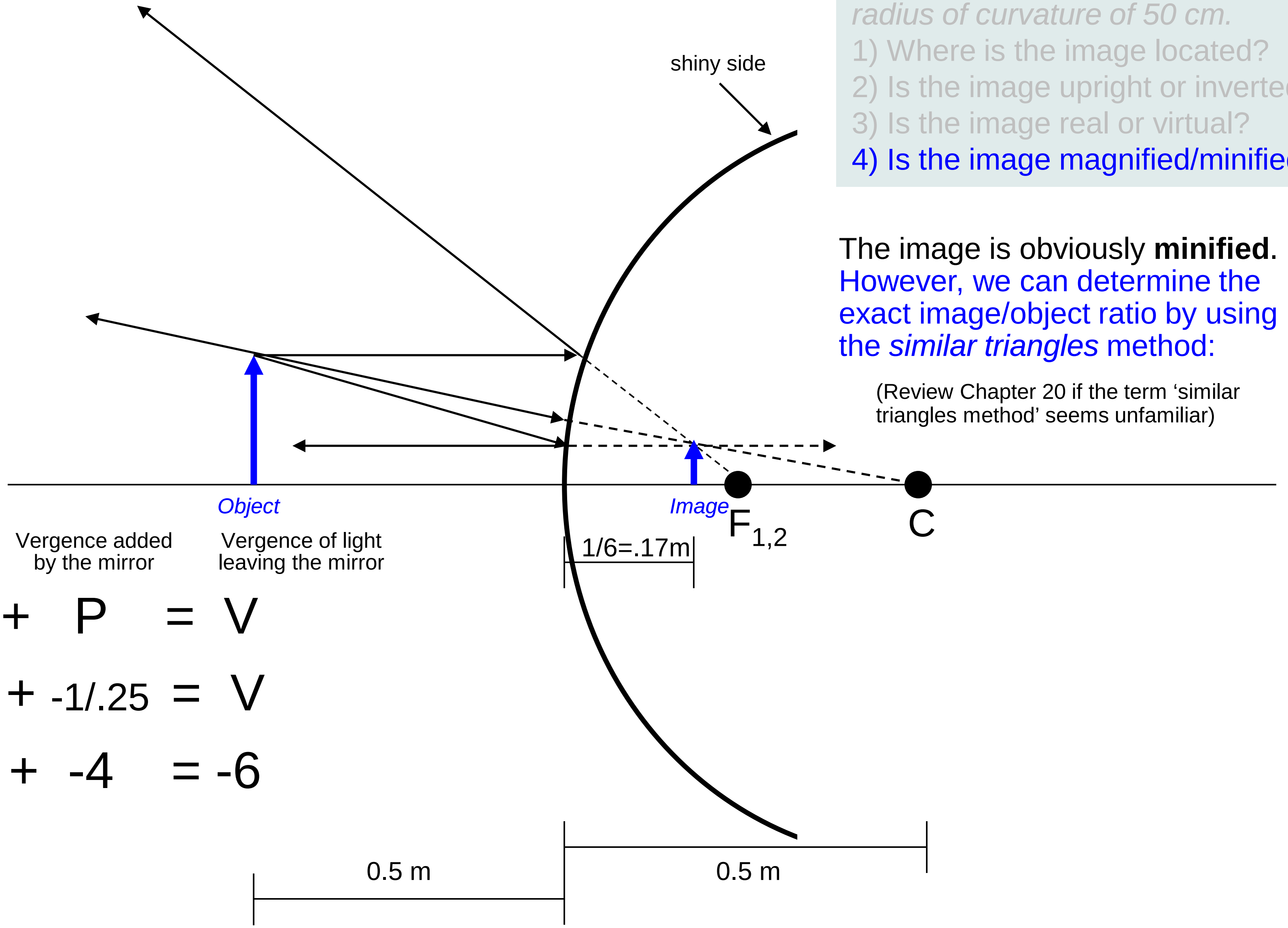
Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is obviously **minified**. However, we can determine the exact image/object ratio by using the *similar triangles* method:

(Review Chapter 20 if the term 'similar triangles method' seems unfamiliar)

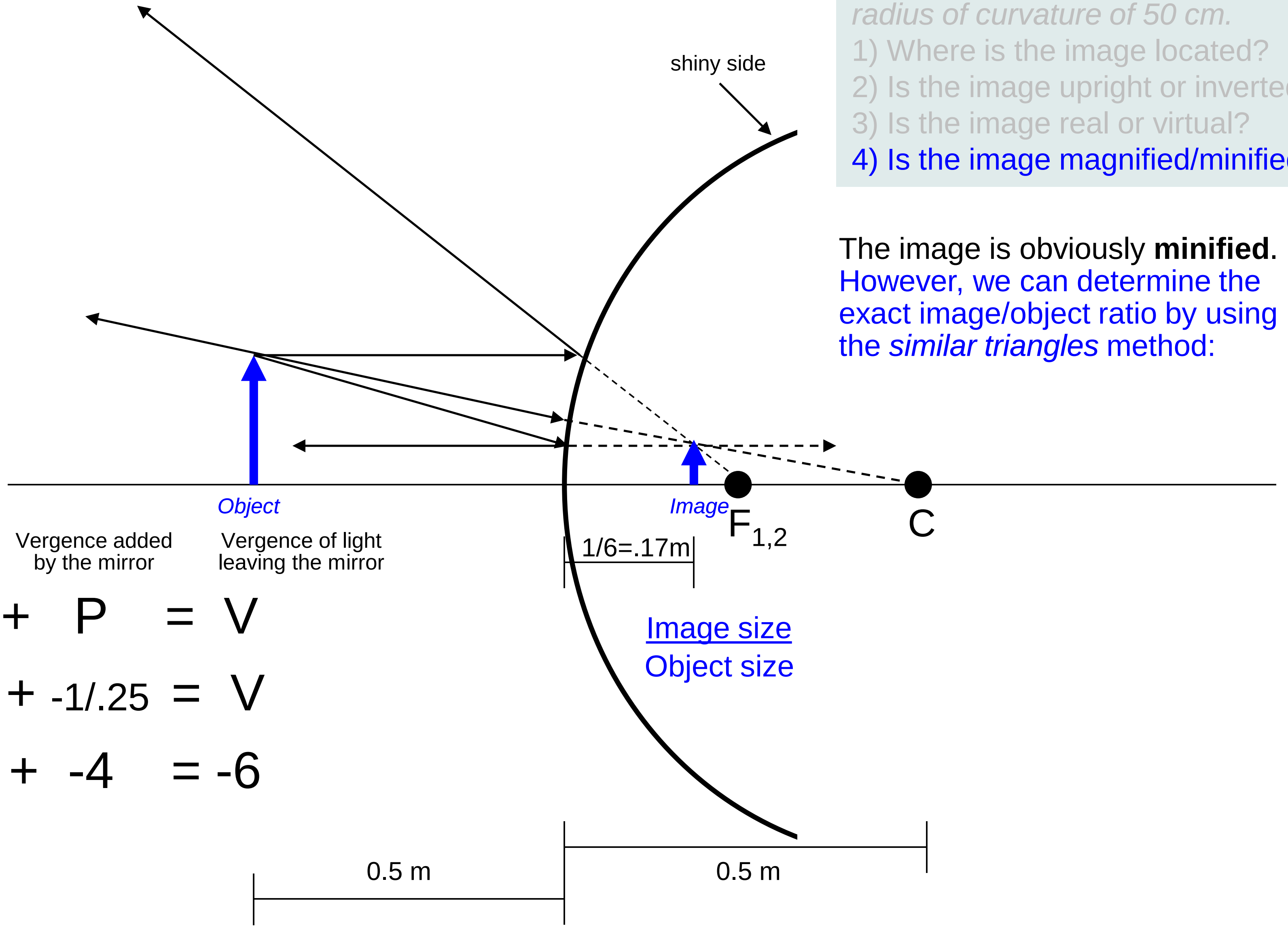


Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



The image is obviously **minified**. However, we can determine the exact image/object ratio by using the *similar triangles* method:

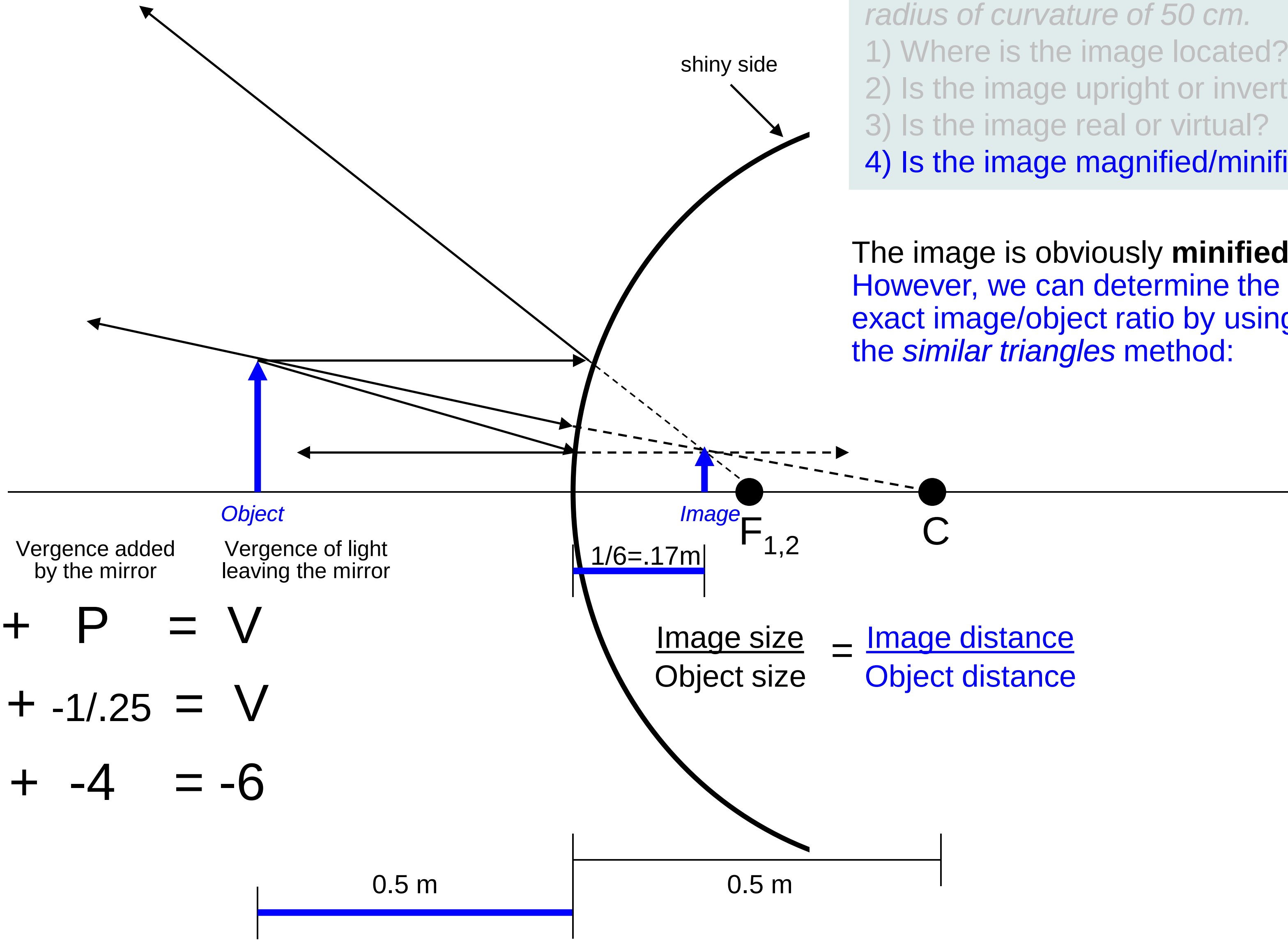
Image size
Object size

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



The image is obviously **minified**. However, we can determine the exact image/object ratio by using the *similar triangles* method:

$$\frac{\text{Image size}}{\text{Object size}} = \frac{\text{Image distance}}{\text{Object distance}}$$

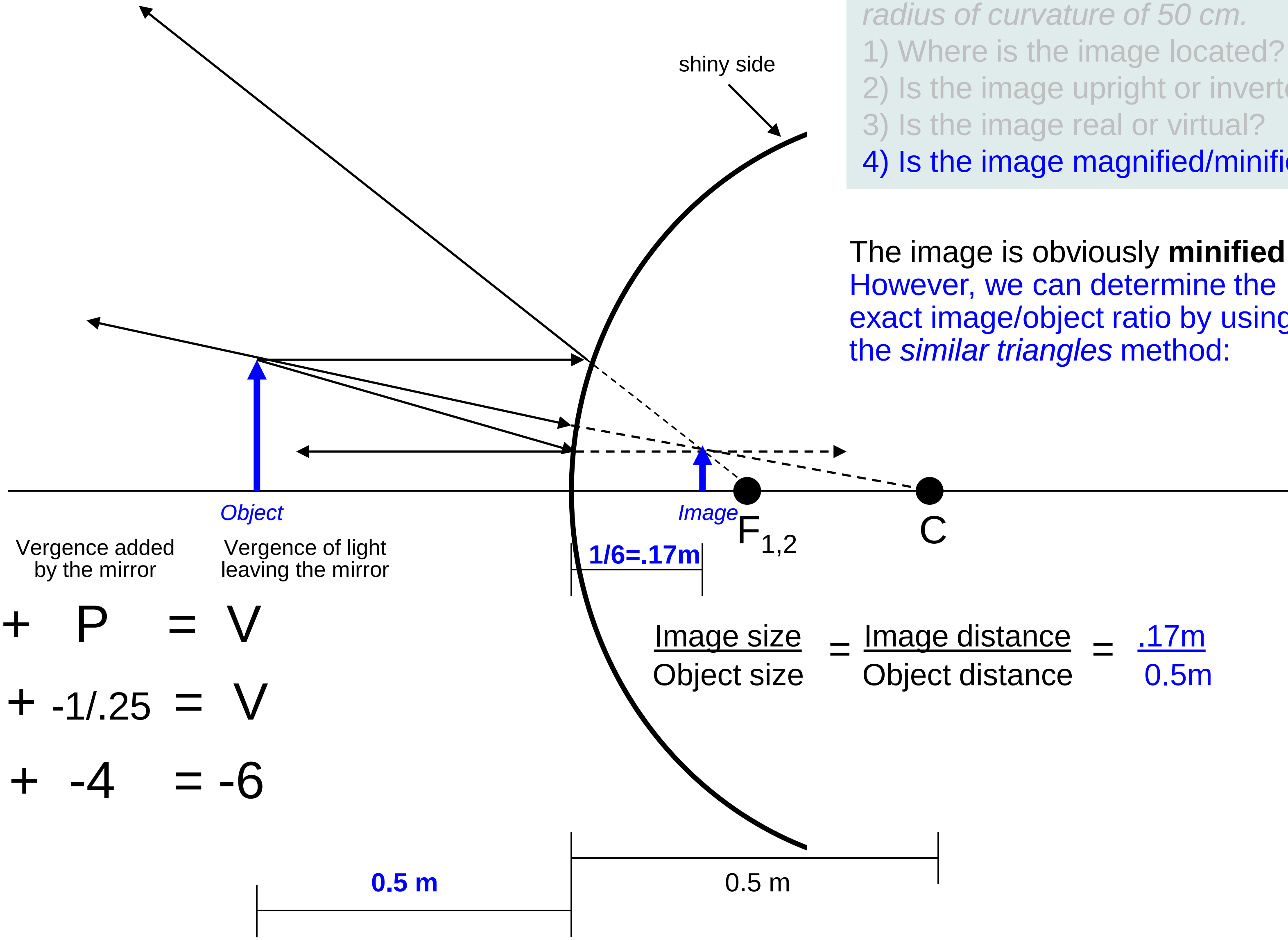
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is obviously **minified**. However, we can determine the exact image/object ratio by using the *similar triangles* method:



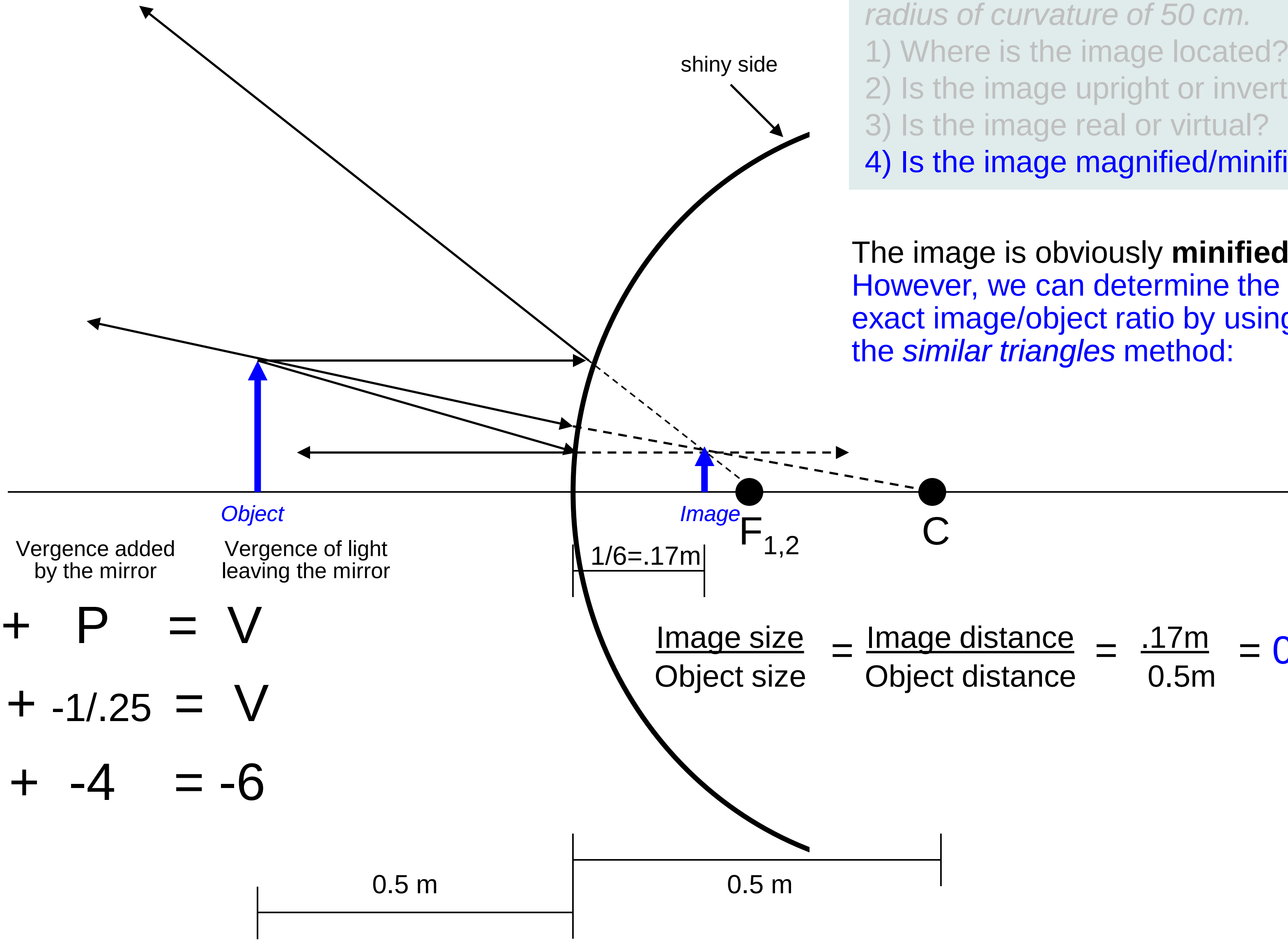
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

$$\frac{\text{Image size}}{\text{Object size}} = \frac{\text{Image distance}}{\text{Object distance}} = \frac{.17\text{m}}{0.5\text{m}}$$

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



The image is obviously **minified**.
However, we can determine the exact image/object ratio by using the *similar triangles* method:

$$\frac{\text{Image size}}{\text{Object size}} = \frac{\text{Image distance}}{\text{Object distance}} = \frac{.17\text{m}}{0.5\text{m}} = 0.33$$

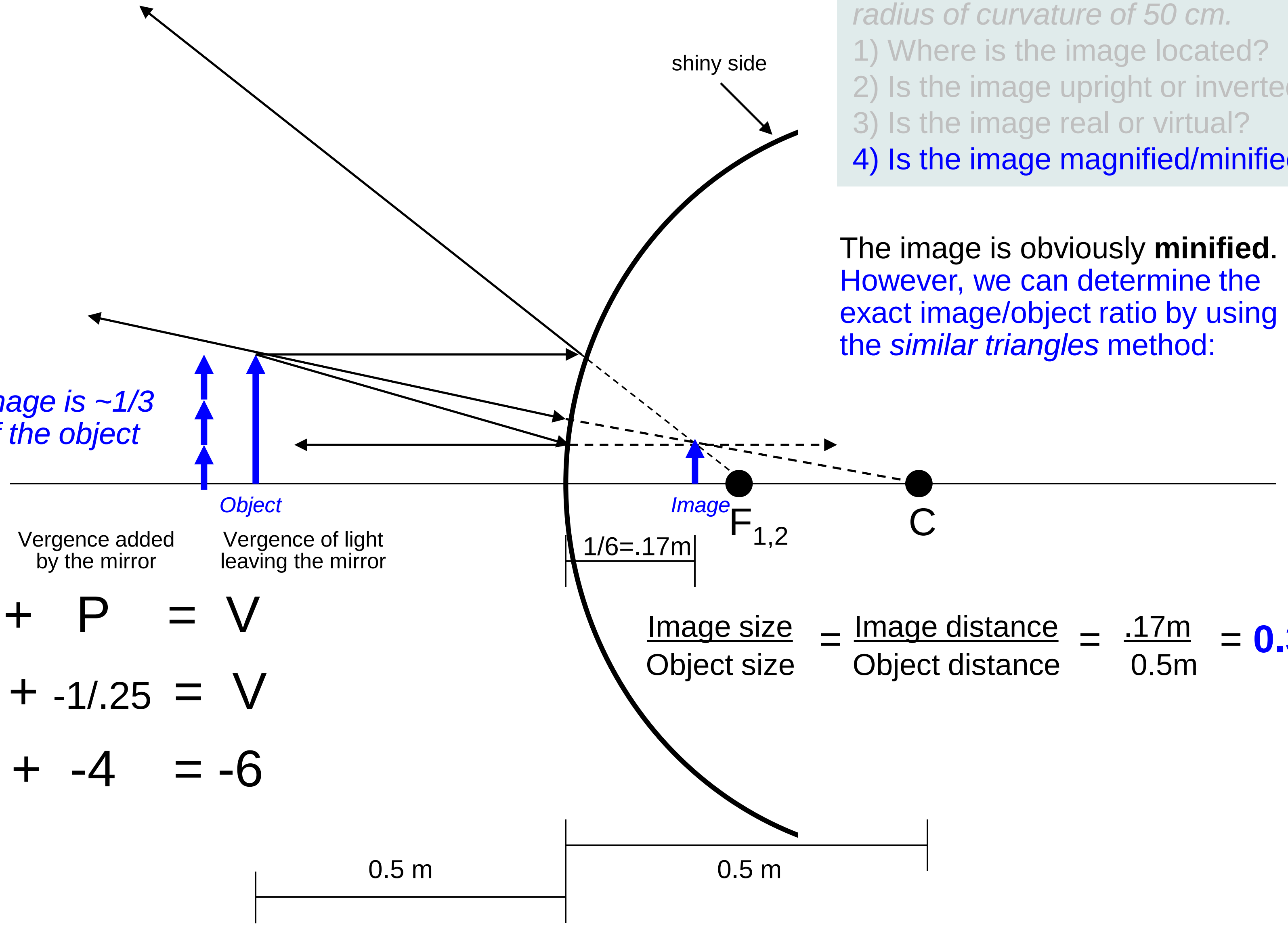
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

Mirrors

An object is located 50 cm from the surface of a convex mirror with a radius of curvature of 50 cm.
1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is obviously **minified**. However, we can determine the exact image/object ratio by using the *similar triangles* method:

Thus the image is ~1/3 the size of the object



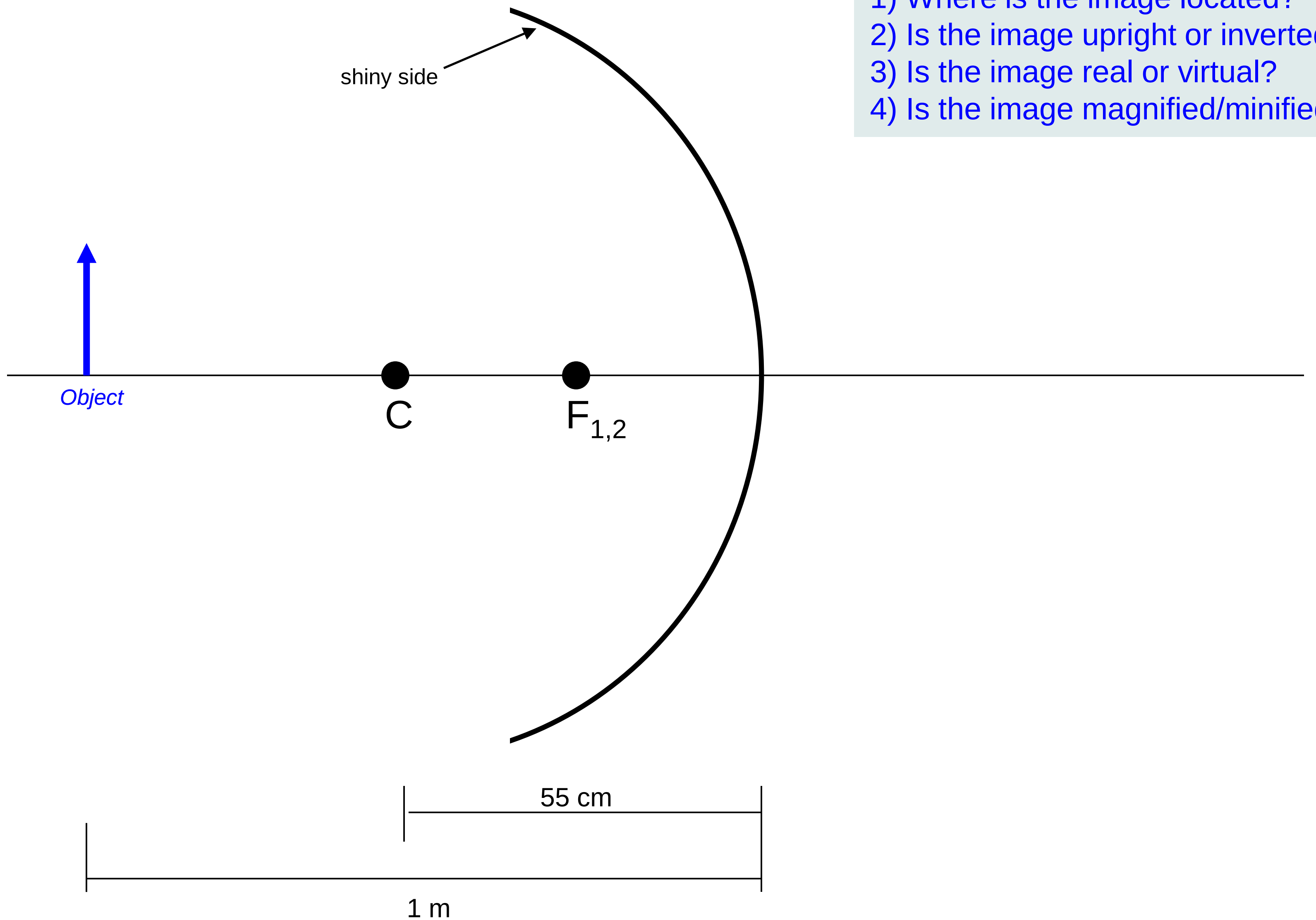
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.5	+	-1/.25	=	V
-2	+	-4	=	-6

$$\frac{\text{Image size}}{\text{Object size}} = \frac{\text{Image distance}}{\text{Object distance}} = \frac{.17\text{m}}{0.5\text{m}} = \mathbf{0.33}$$

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

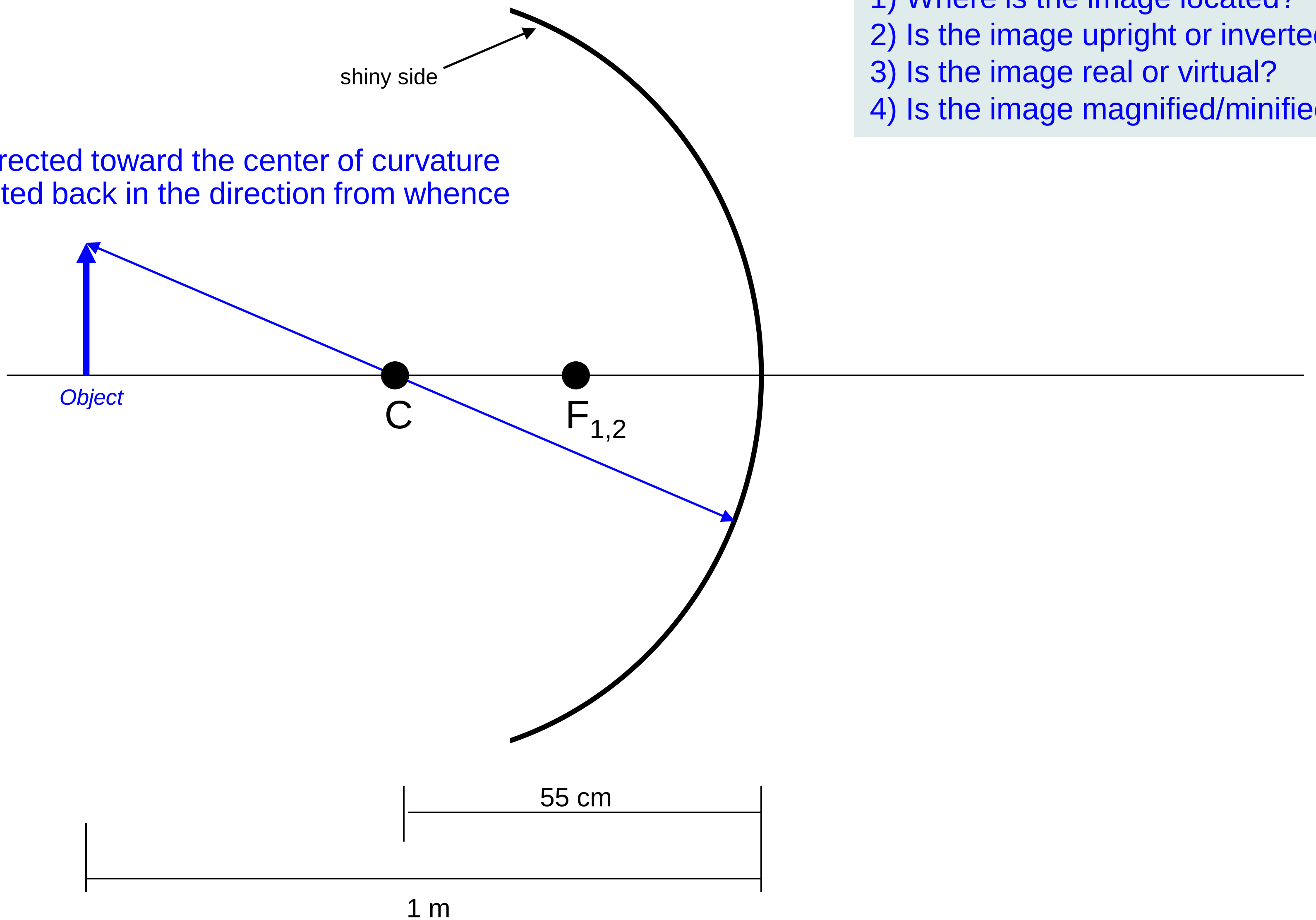


Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

A ray directed toward the center of curvature is reflected back in the direction from whence it came.

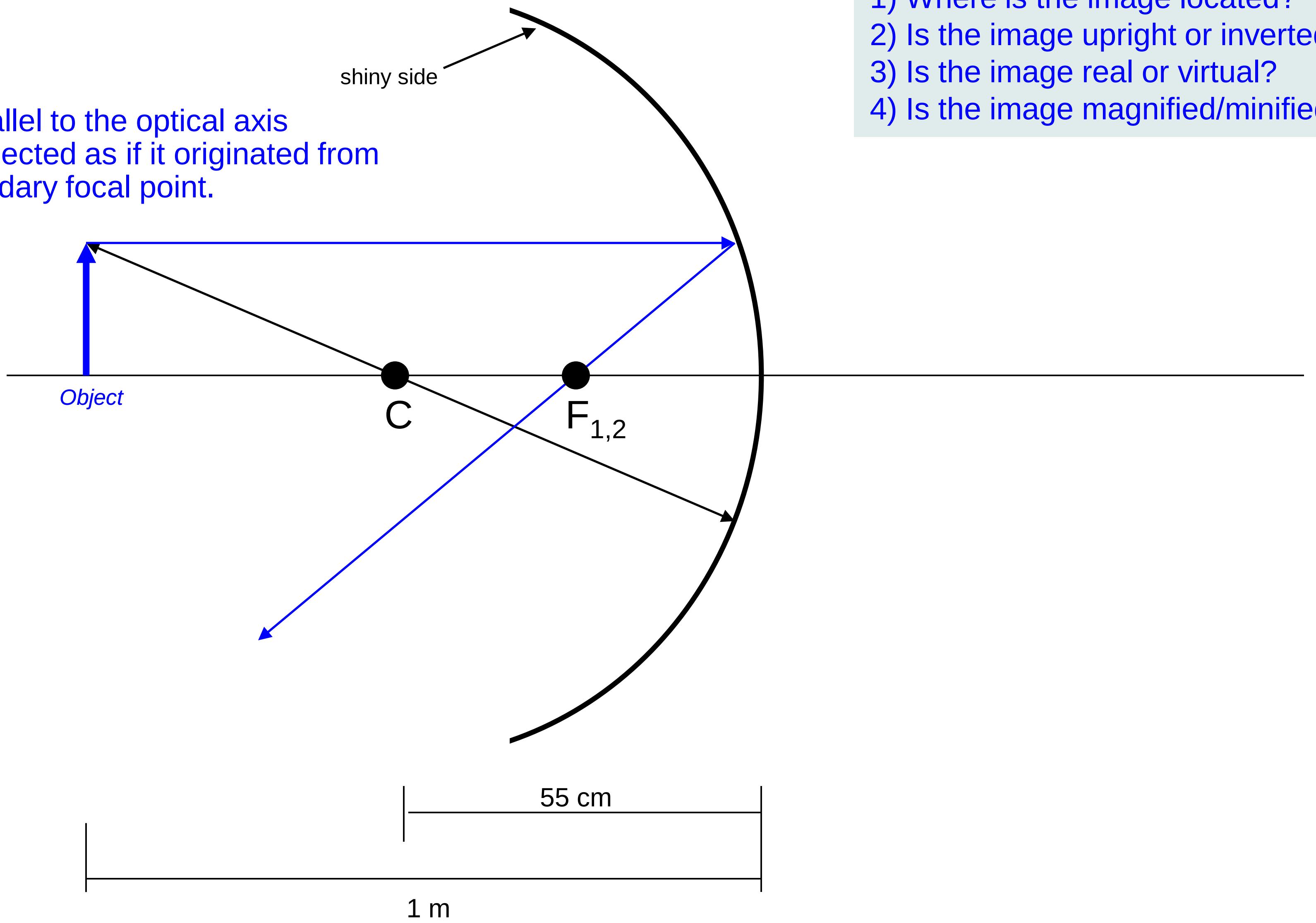


Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

A ray parallel to the optical axis will be reflected as if it originated from the secondary focal point.

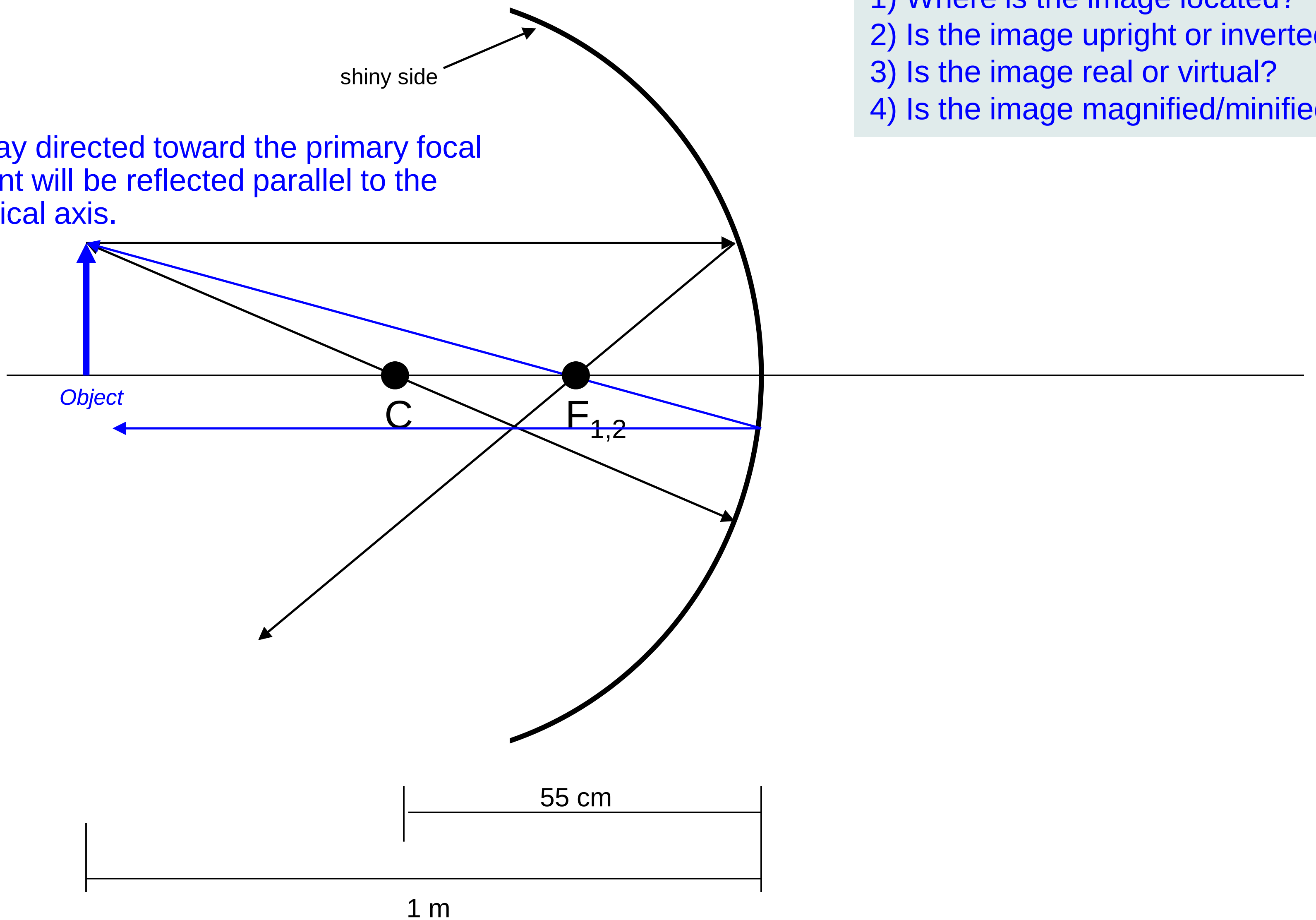


Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

A ray directed toward the primary focal point will be reflected parallel to the optical axis.

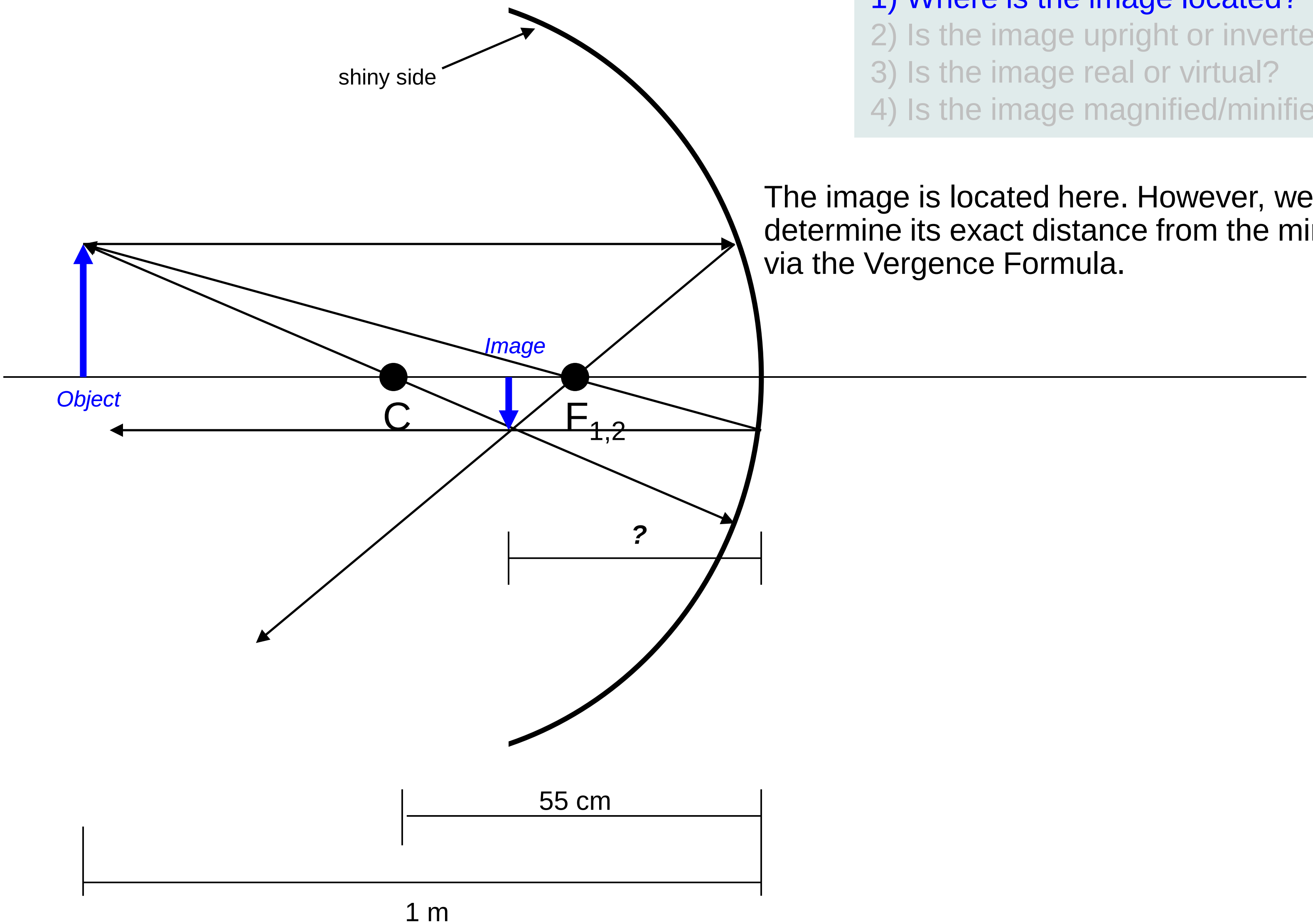


Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is located here. However, we can determine its exact distance from the mirror via the Vergence Formula.

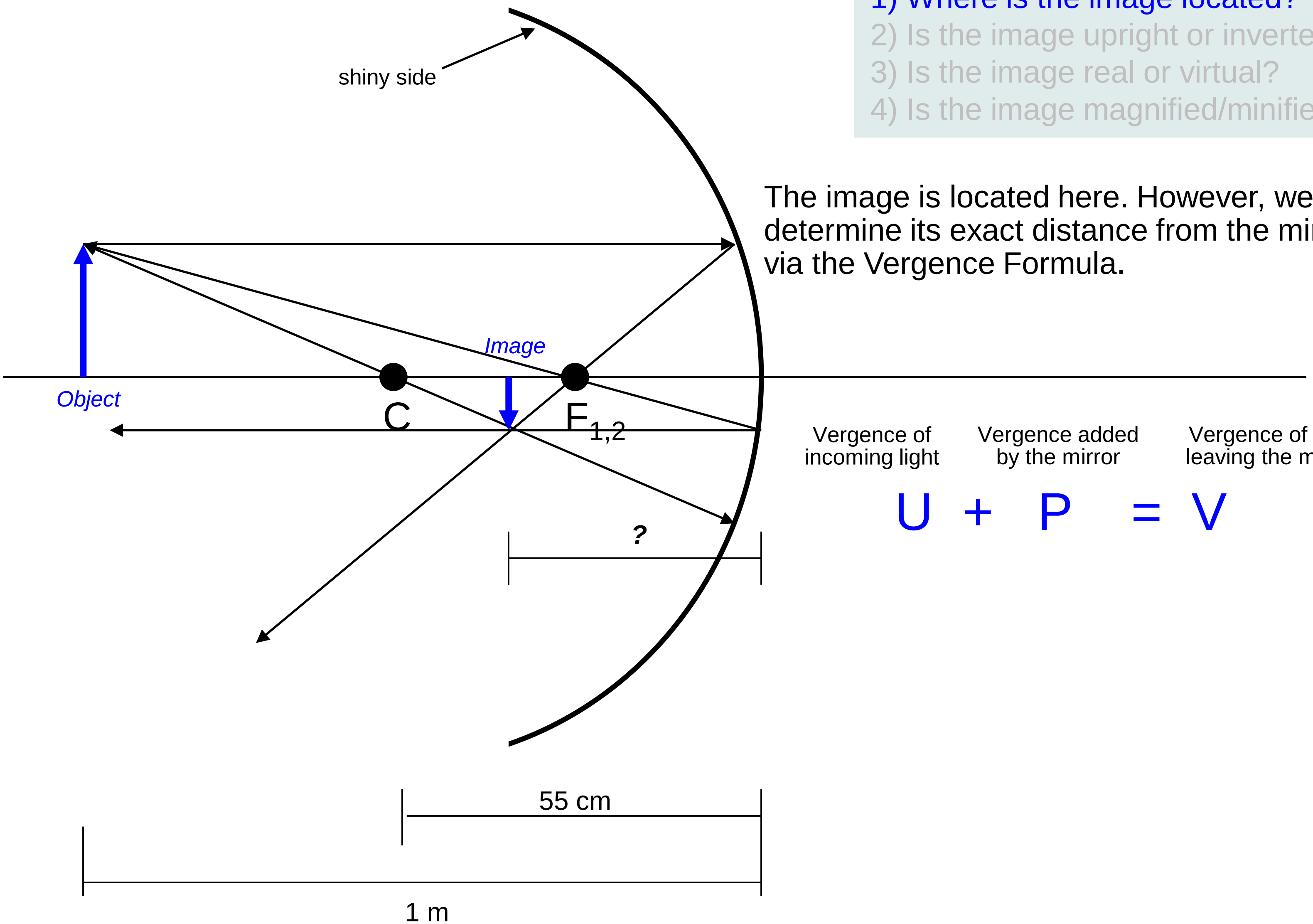


Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is located here. However, we can determine its exact distance from the mirror via the Vergence Formula.

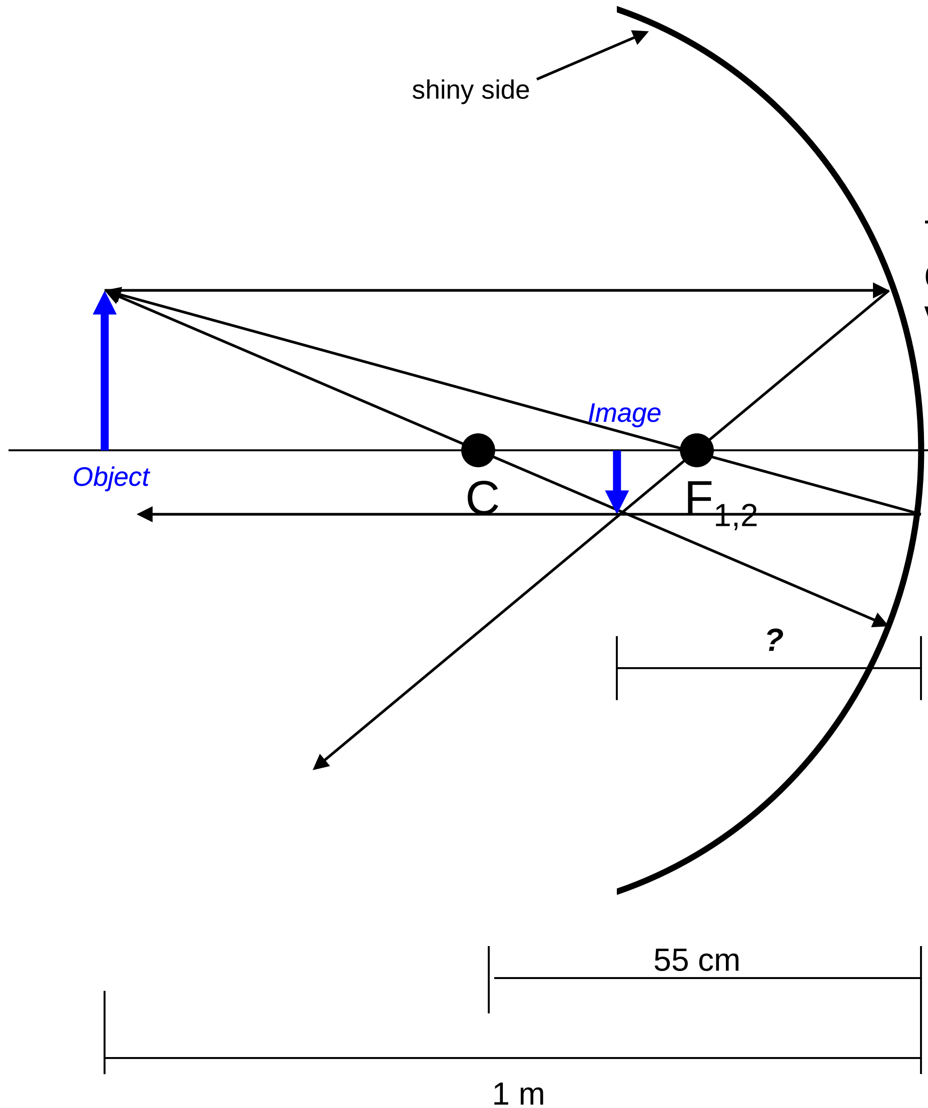


Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



The image is located here. However, we can determine its exact distance from the mirror via the Vergence Formula.

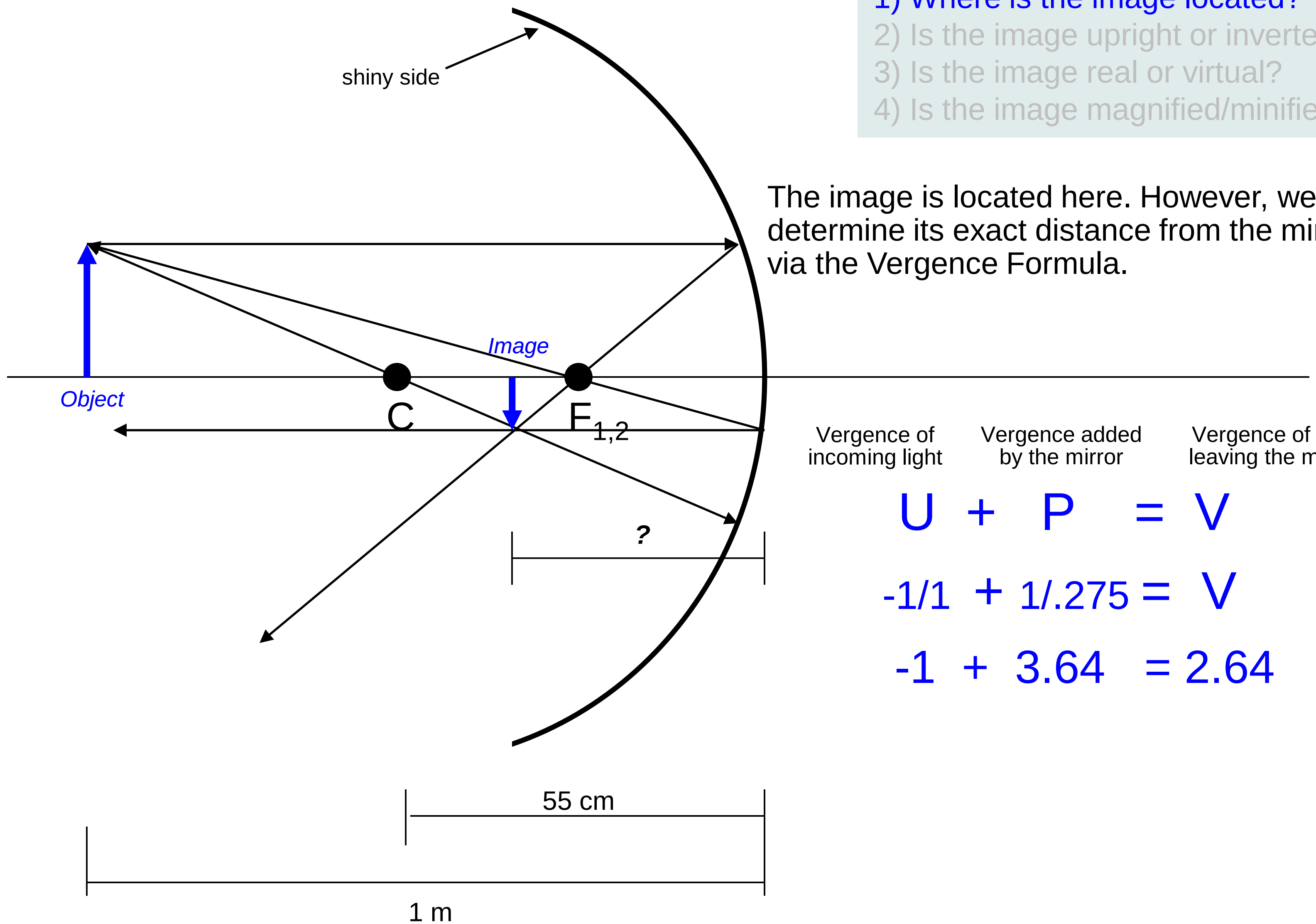
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/1	+	1/.275	=	V

*(Again, the power of a mirror is 1/*f*, and* f *is ½ the radius)*

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



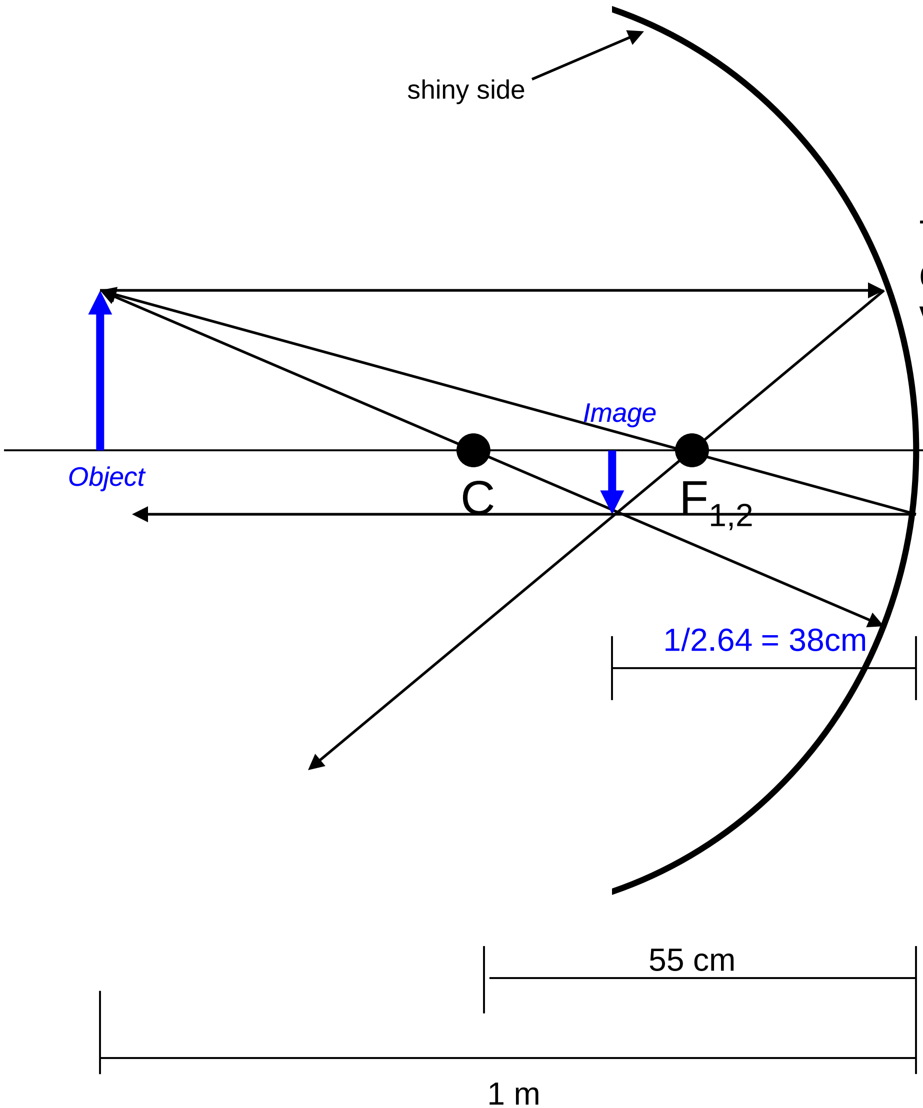
The image is located here. However, we can determine its exact distance from the mirror via the Vergence Formula.

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/1	+	1/.275	=	V
-1	+	3.64	=	2.64

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?



The image is located here. However, we can determine its exact distance from the mirror via the Vergence Formula. The image is .38m (38 cm) to the left of the mirror.

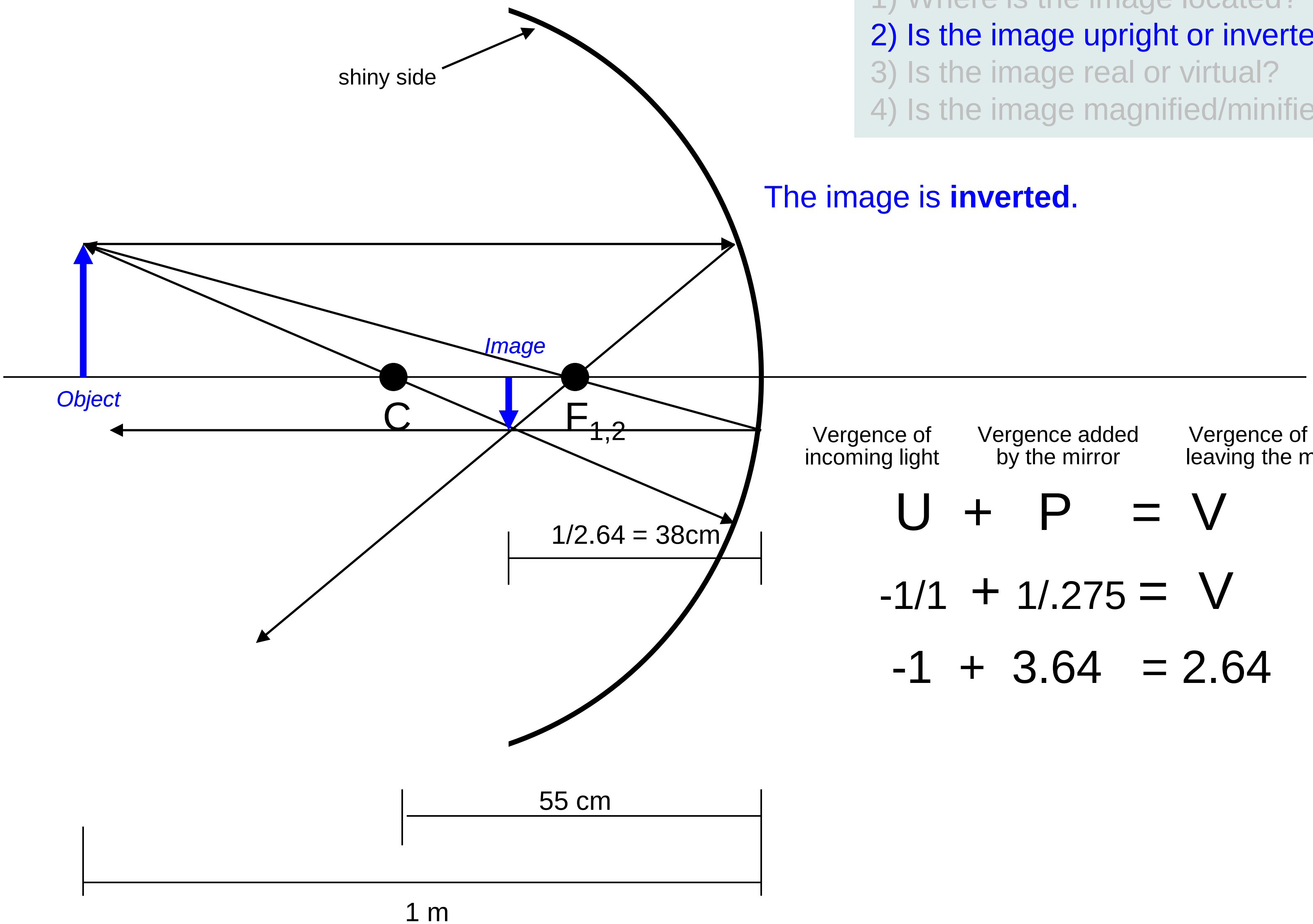
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/1	+	1/.275	=	V
-1	+	3.64	=	2.64

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is **inverted**.



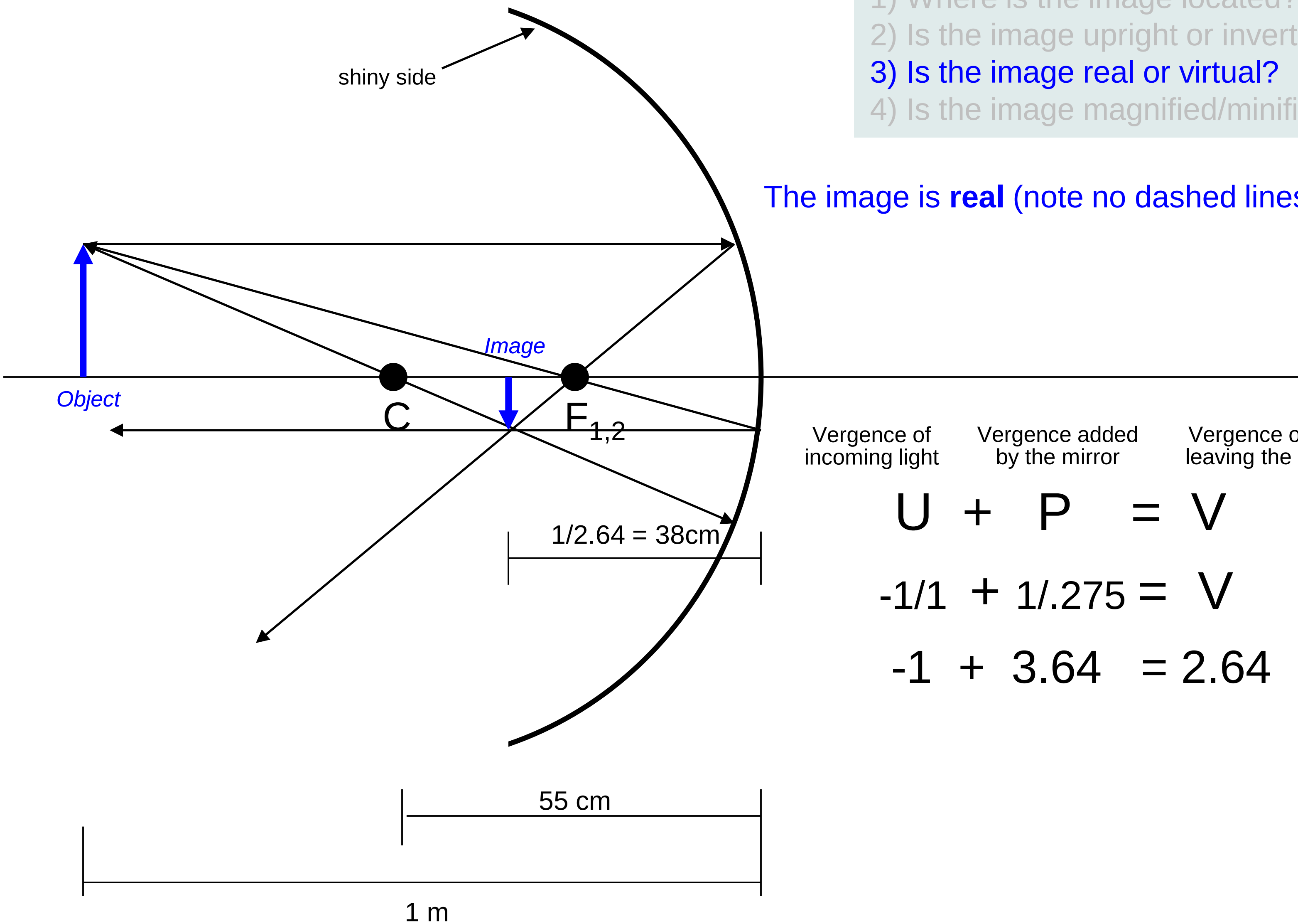
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/1	+	1/.275	=	V
-1	+	3.64	=	2.64

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is **real** (note no dashed lines).



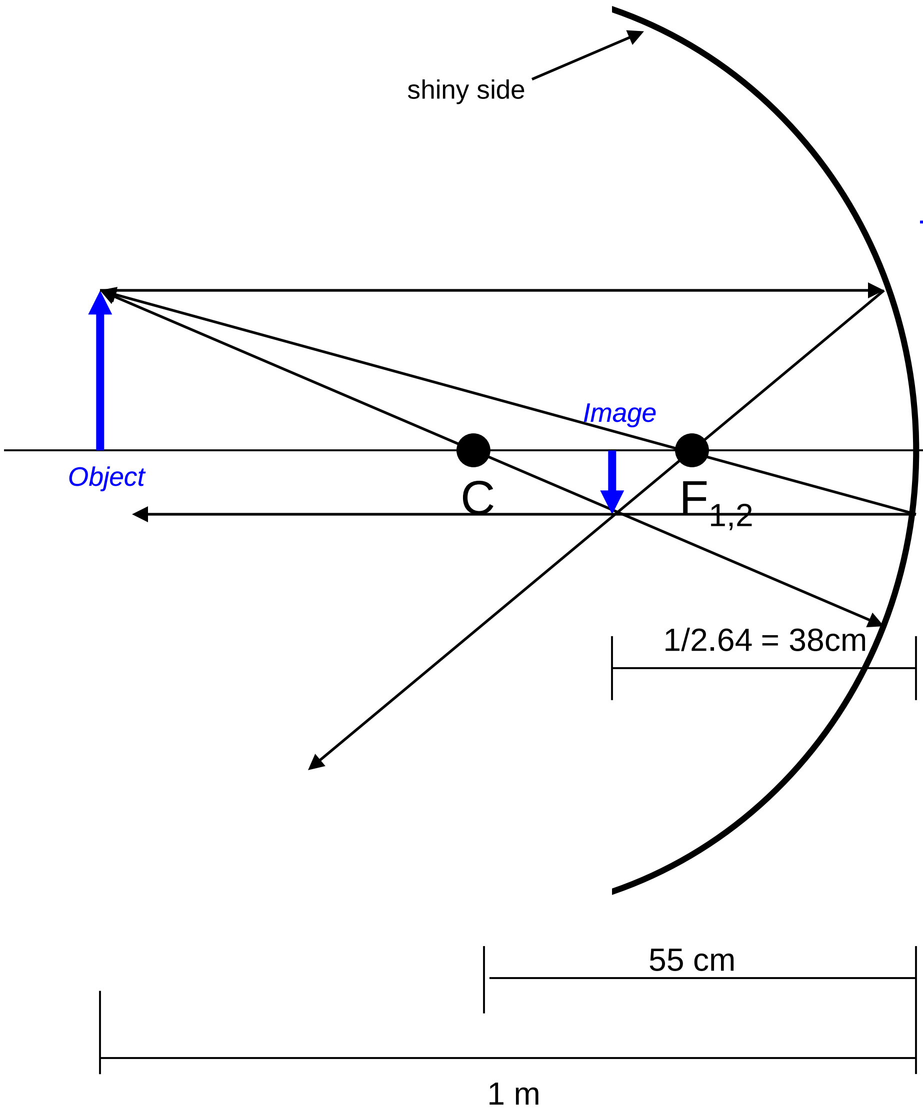
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/1	+	1/.275	=	V
-1	+	3.64	=	2.64

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is **minified**.



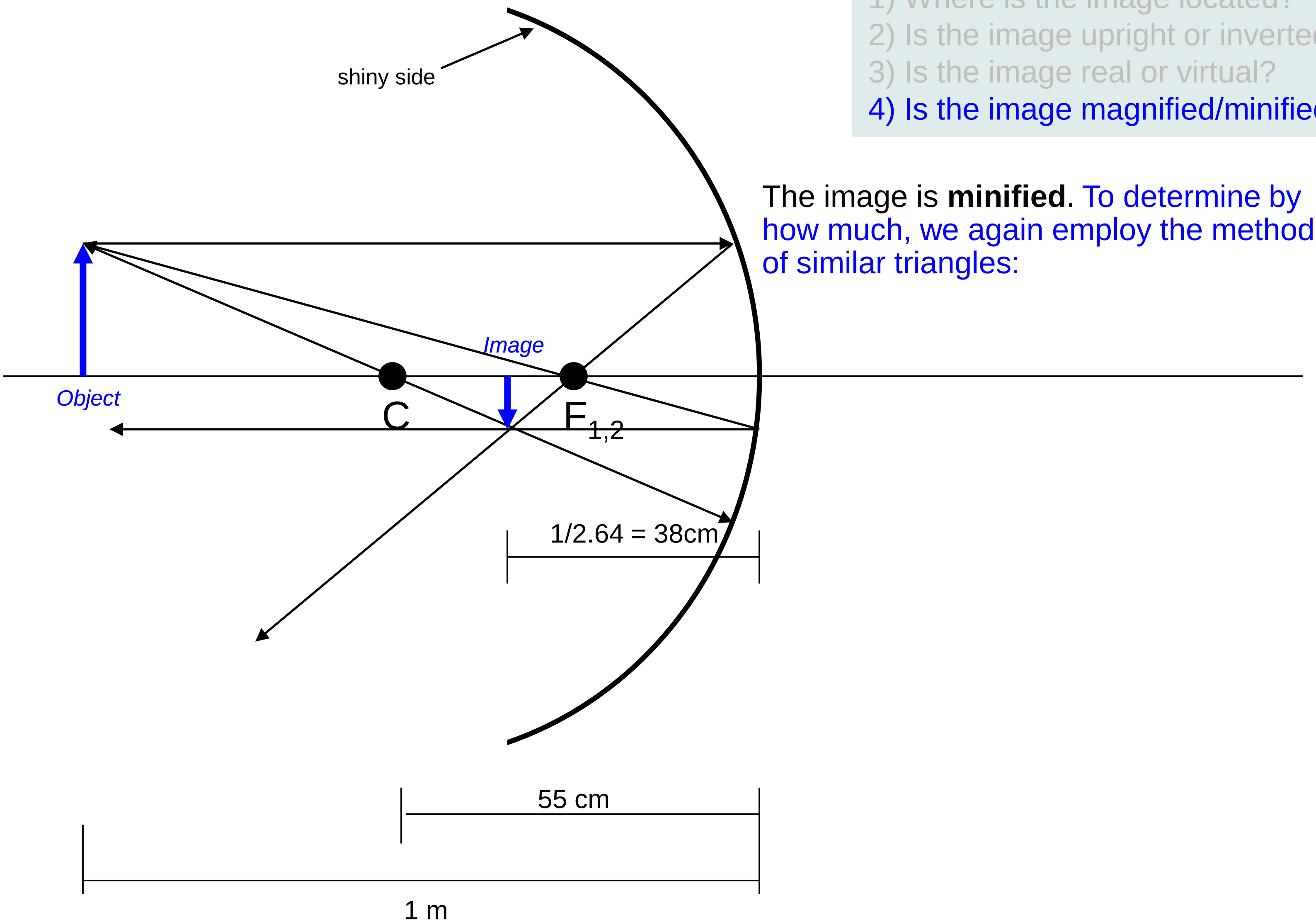
Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/1	+	1/.275	=	V
-1	+	3.64	=	2.64

Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is **minified**. To determine by how much, we again employ the method of similar triangles:

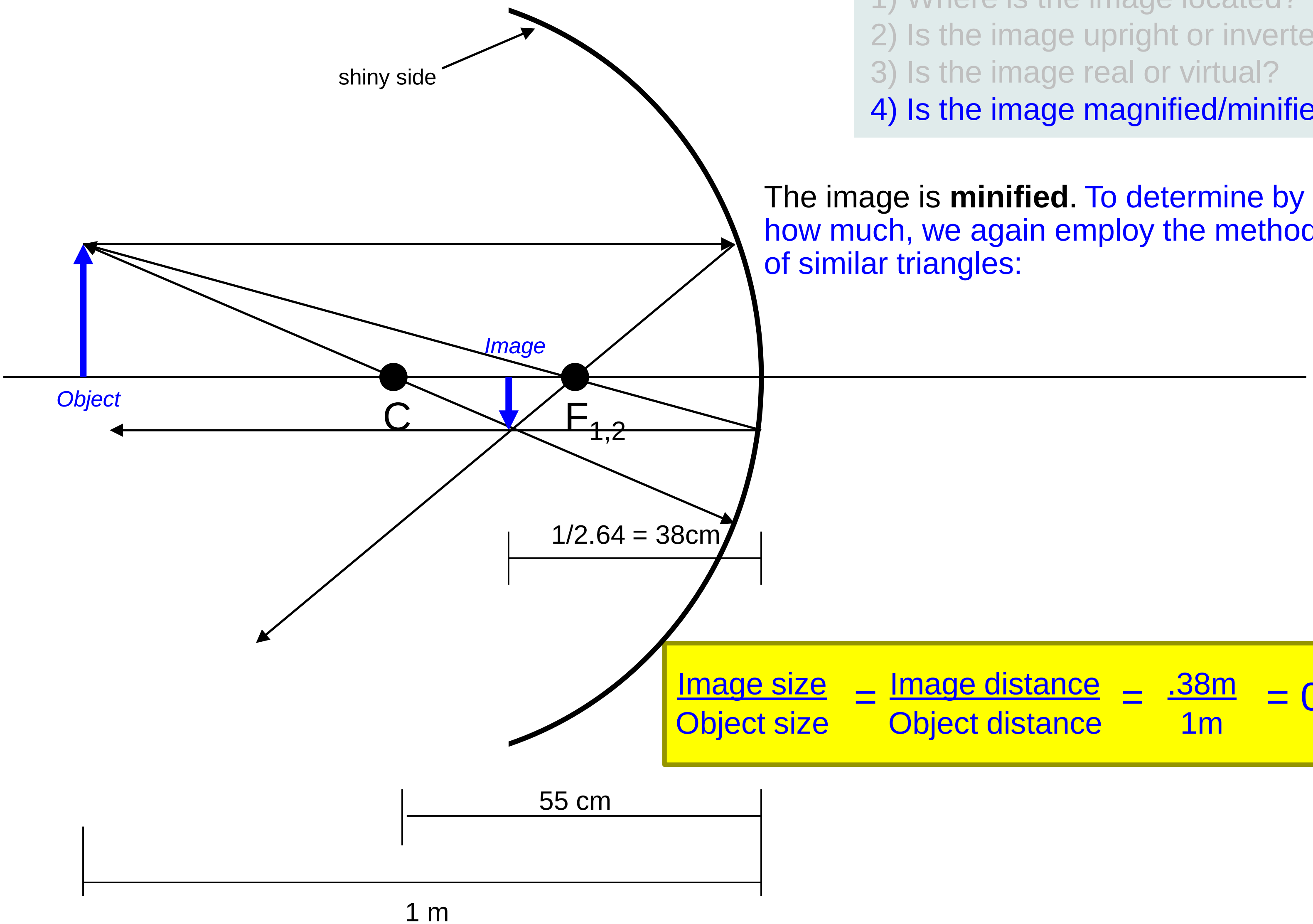


Mirrors

An object is located 1 m from the surface of a concave mirror with a radius of curvature of 55 cm.

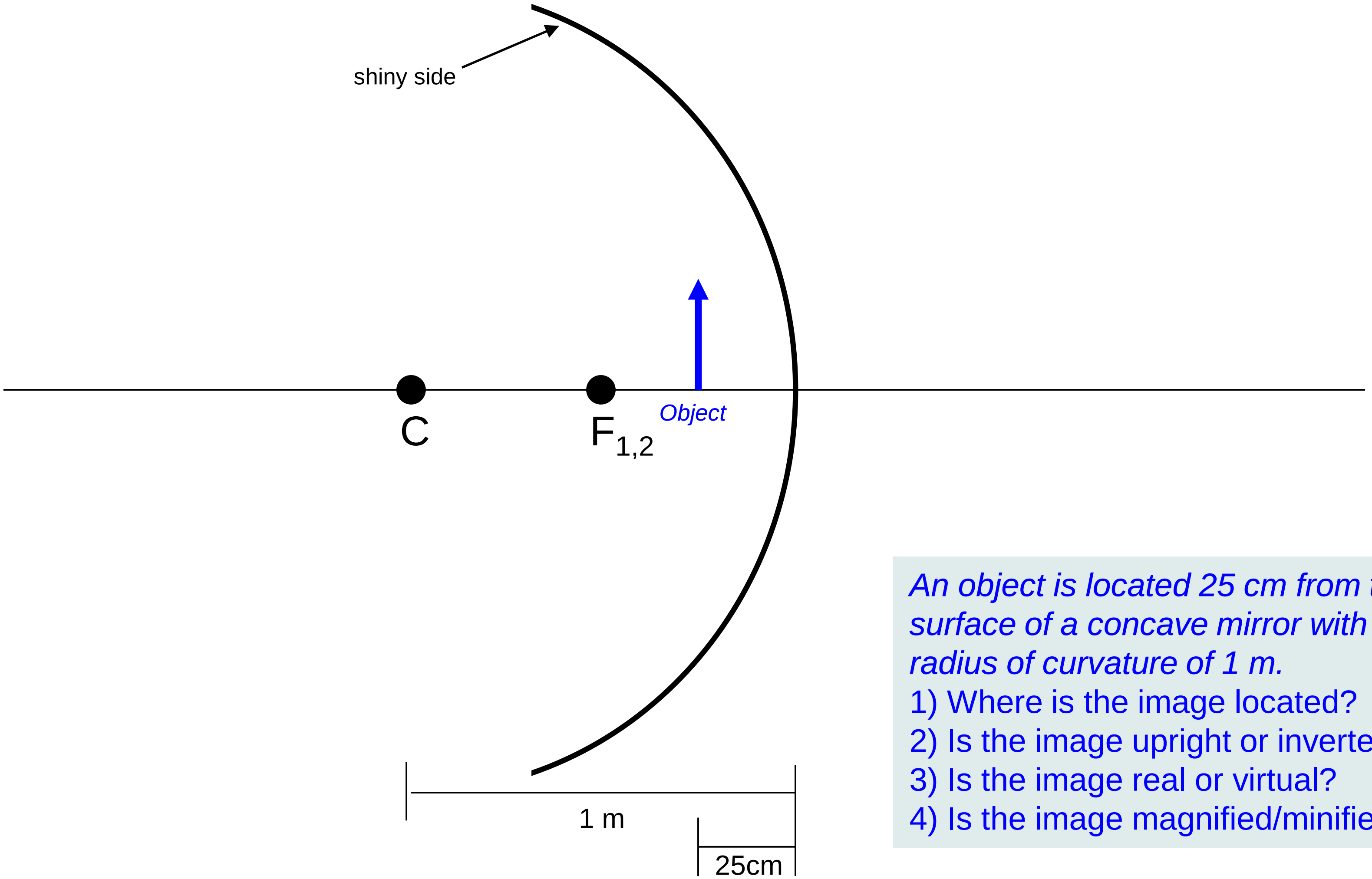
1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

The image is **minified**. To determine by how much, we again employ the method of similar triangles:



$$\frac{\text{Image size}}{\text{Object size}} = \frac{\text{Image distance}}{\text{Object distance}} = \frac{.38\text{m}}{1\text{m}} = 0.38$$

Mirrors

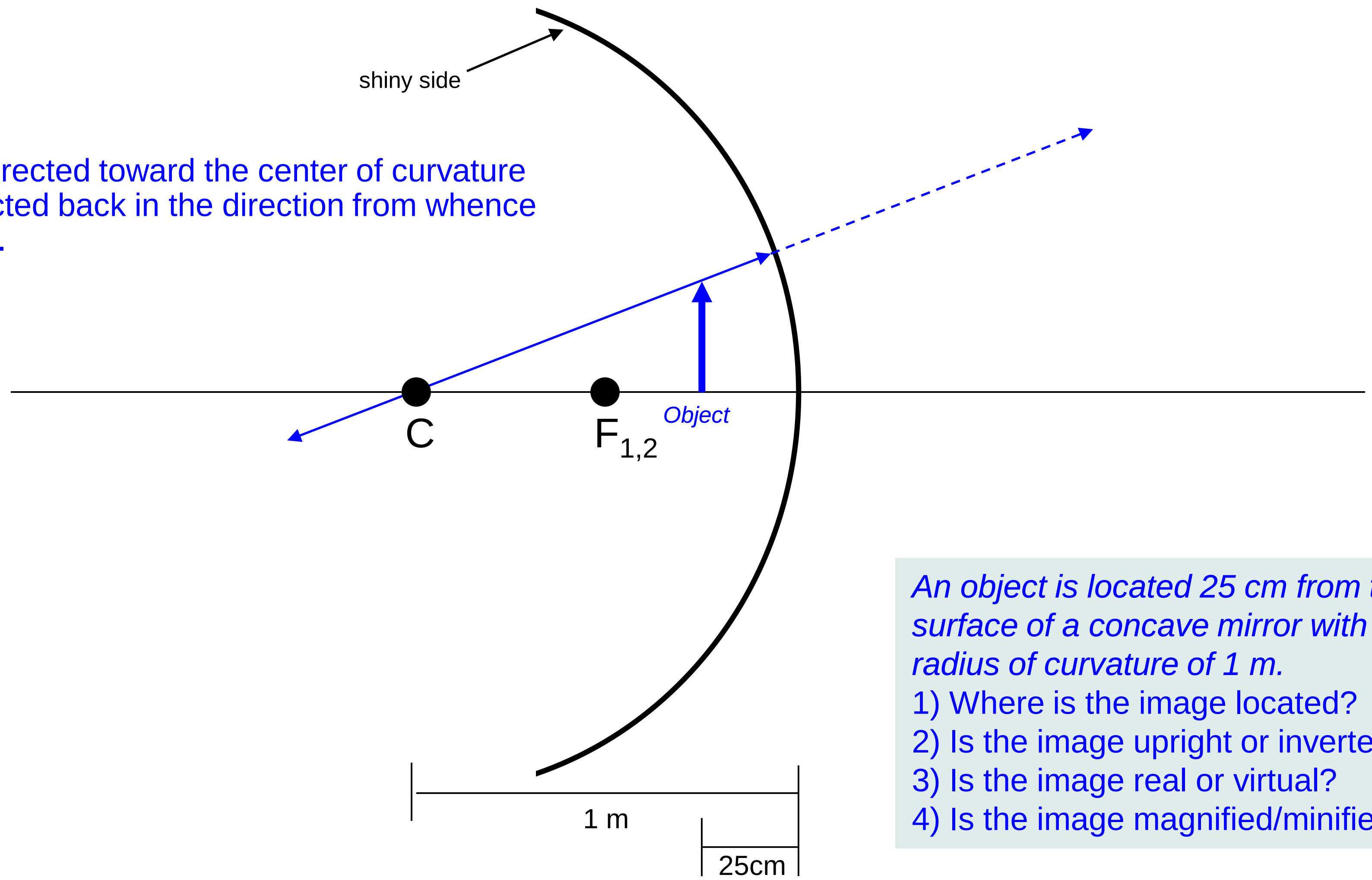


An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

A ray directed toward the center of curvature is reflected back in the direction from whence it came.

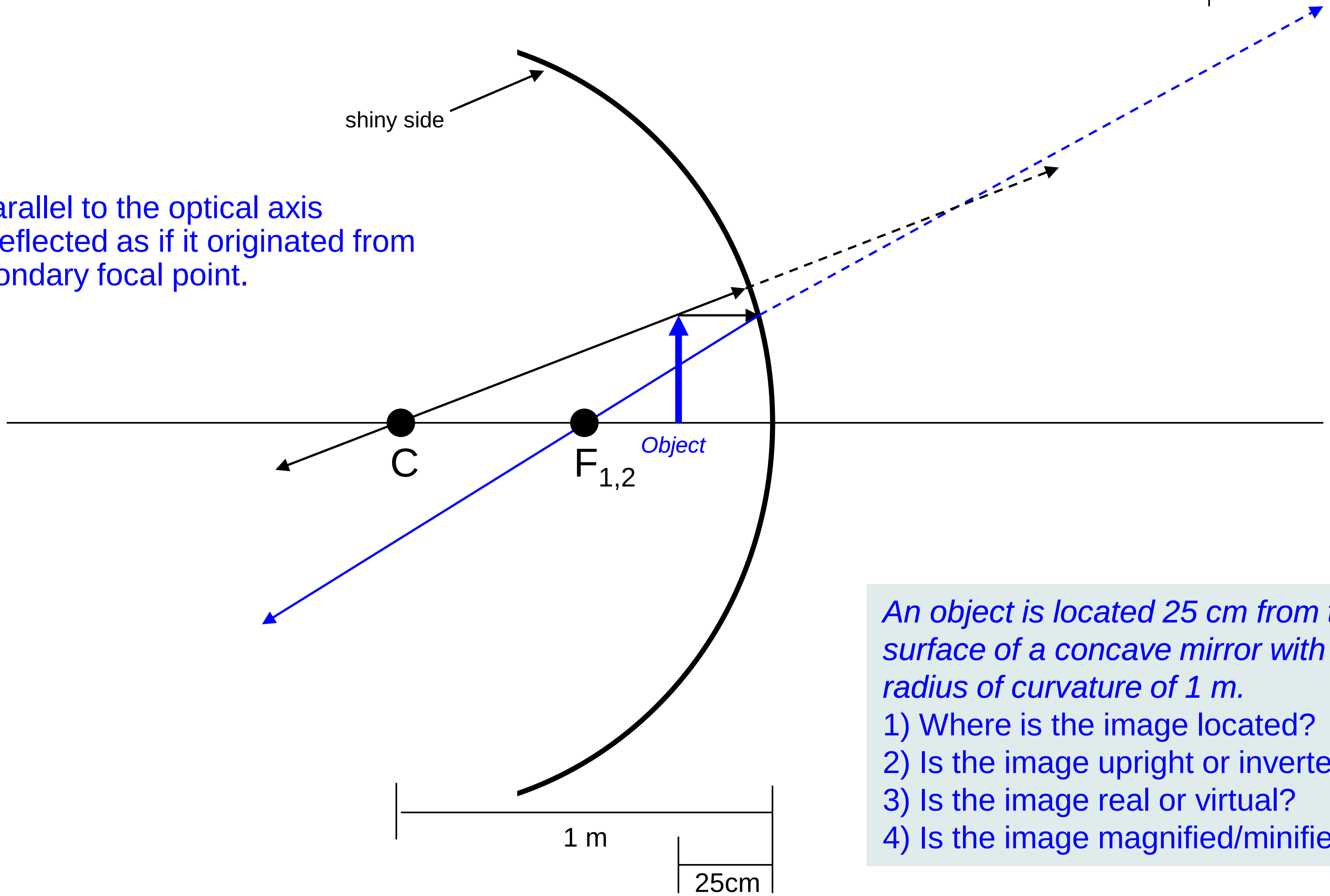


An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

A ray parallel to the optical axis
will be reflected as if it originated from
the secondary focal point.

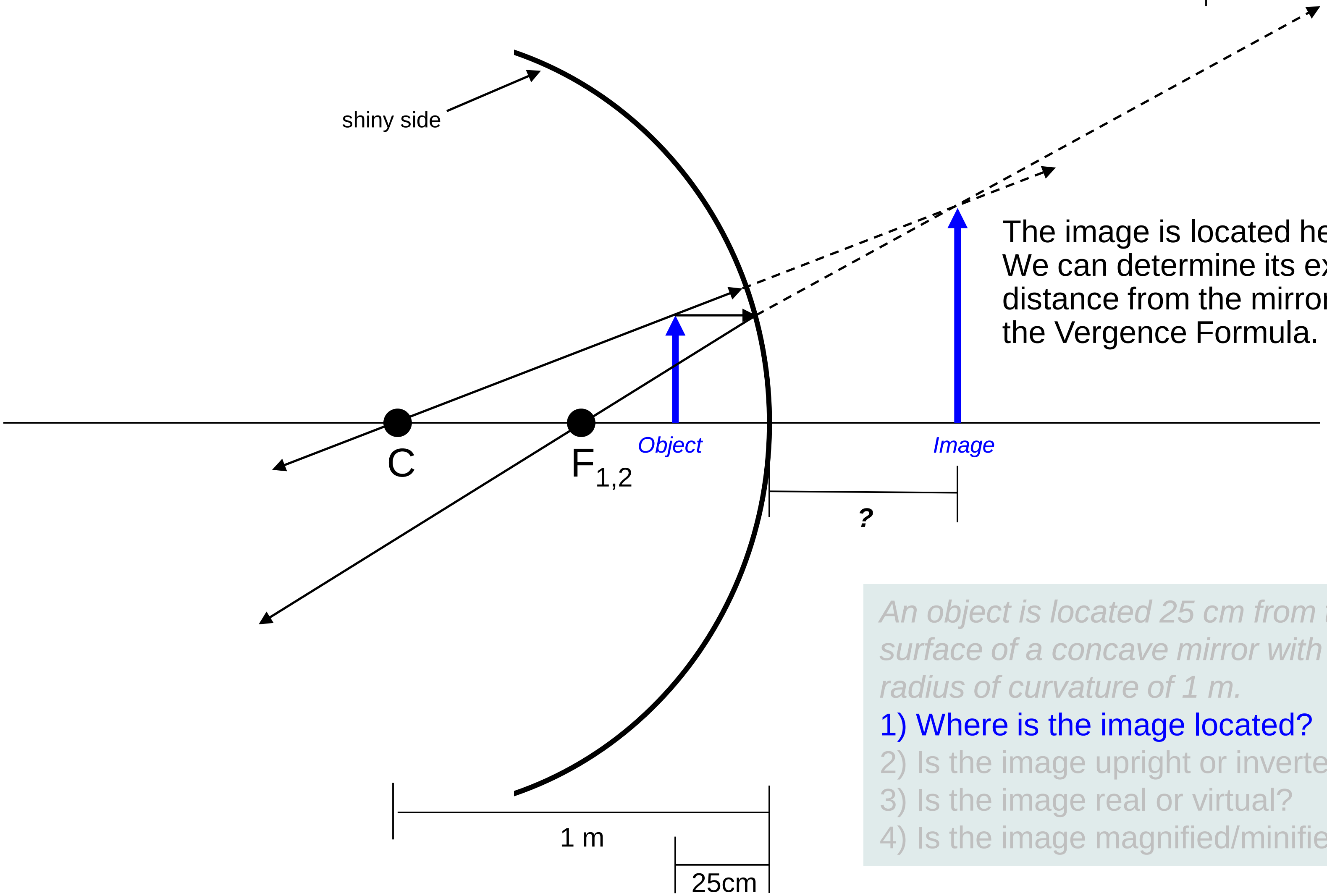


An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V



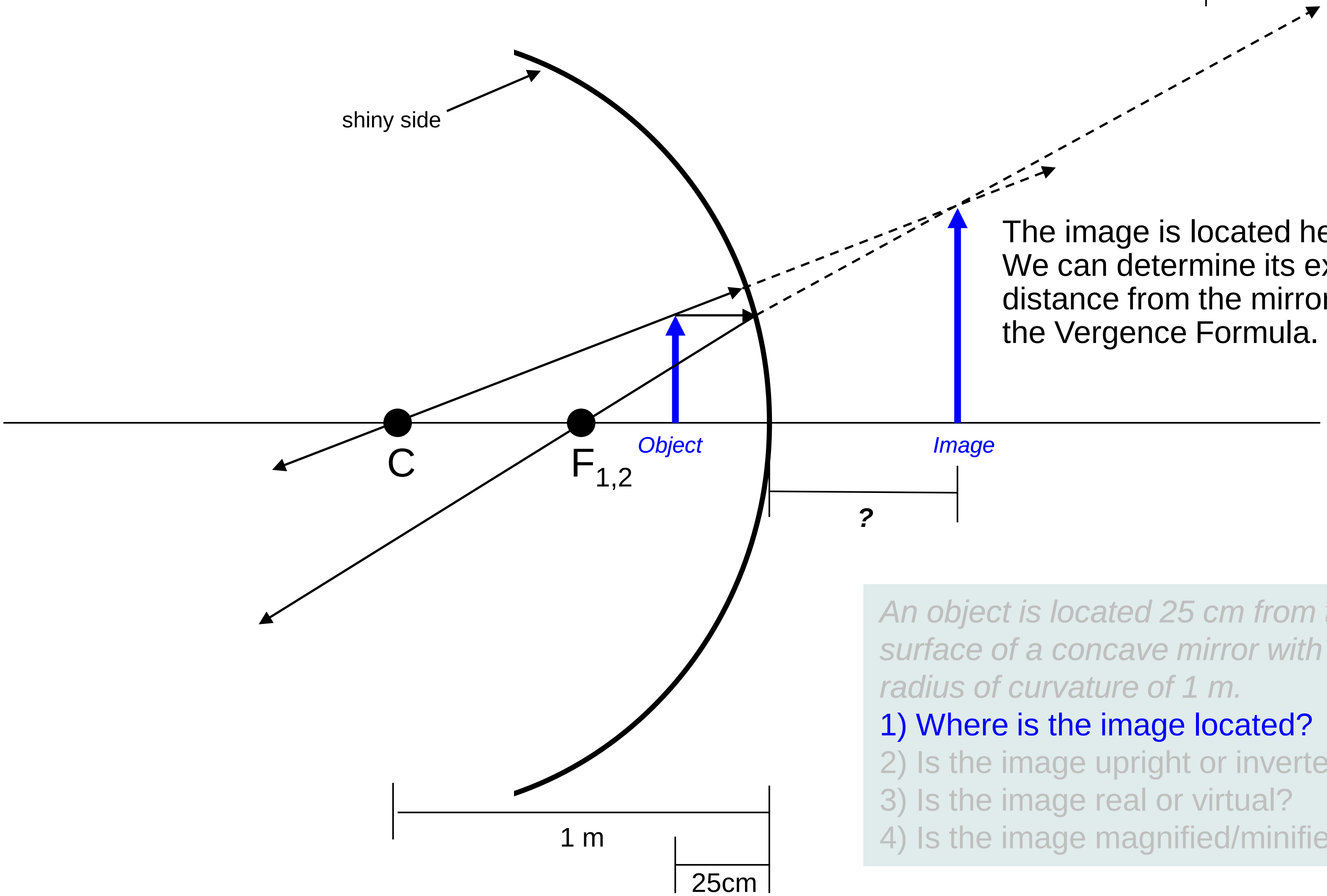
The image is located here. We can determine its exact distance from the mirror via the Vergence Formula.

An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	$+$	P	$=$	V
$-1/.25$	$+$	$1/.5$	$=$	V



The image is located here. We can determine its exact distance from the mirror via the Vergence Formula.

An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

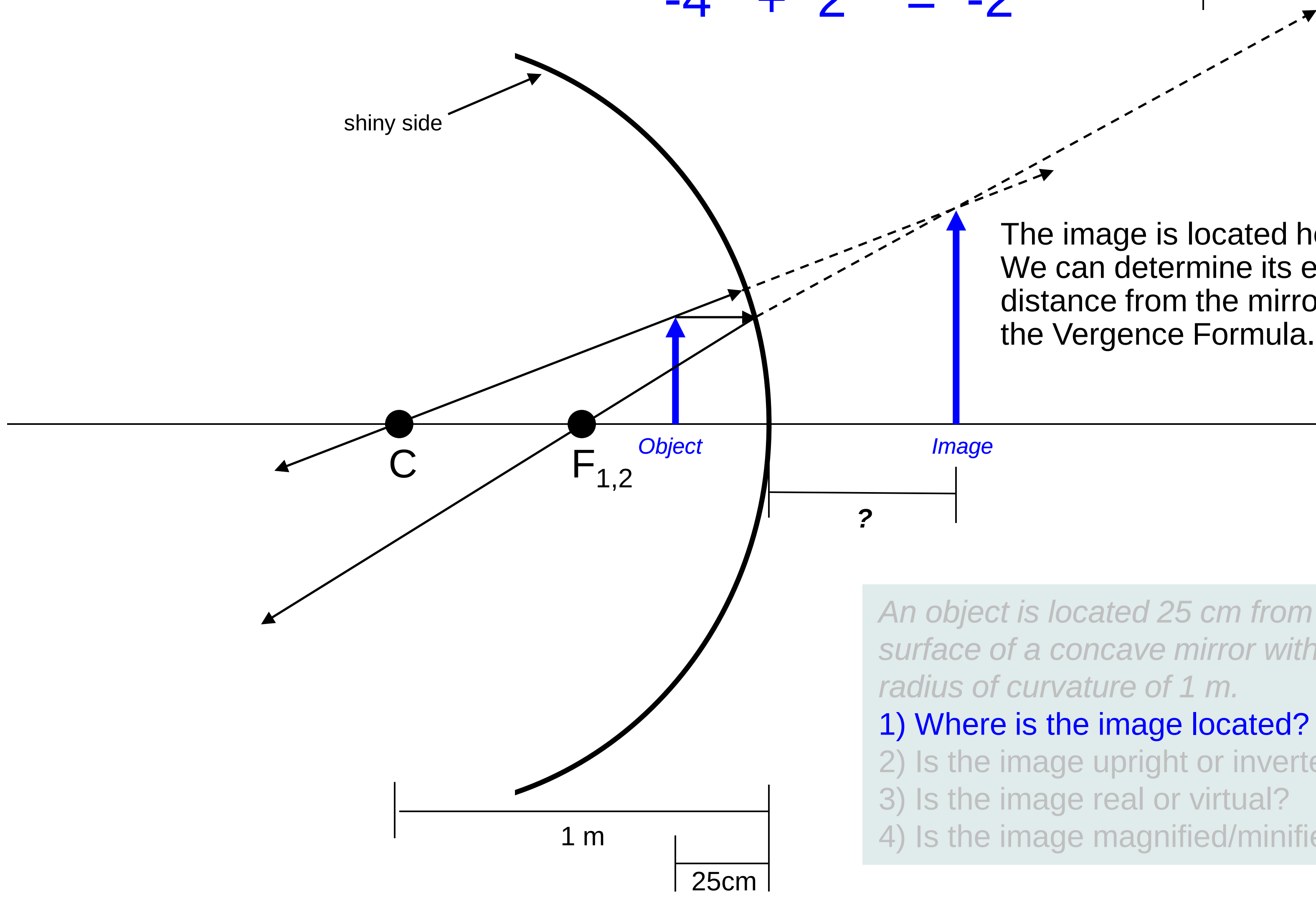
Mirrors

Vergence of incoming light	Vergence added by the mirror	Vergence of light leaving the mirror
U	$+ \; P$	$= \; V$

$$U + P = V$$

$$-1/.25 + 1/.5 = V$$

$$-4 + 2 = -2$$



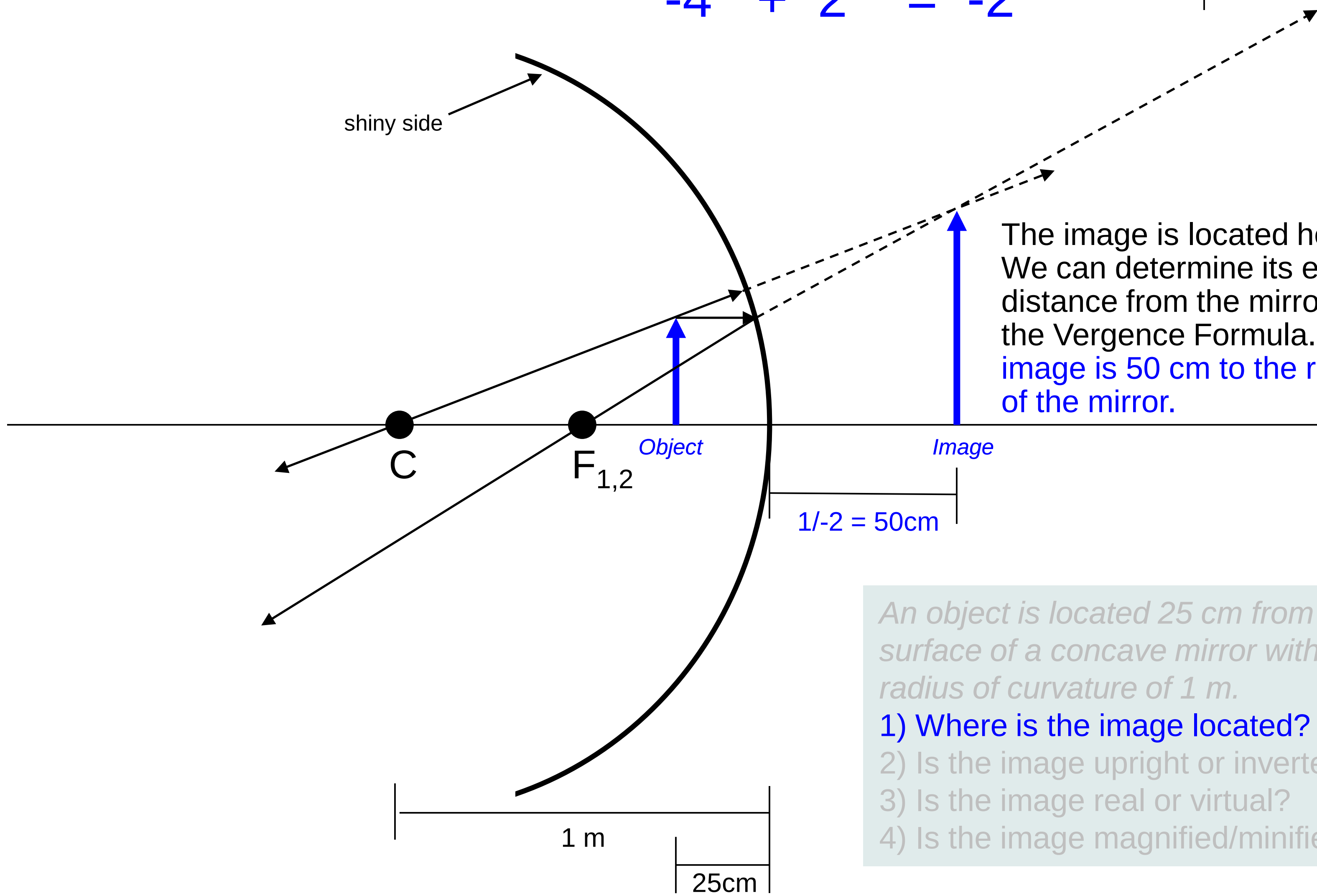
The image is located here. We can determine its exact distance from the mirror via the Vergence Formula.

An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.25	+	1/.5	=	V
-4	+	2	=	-2



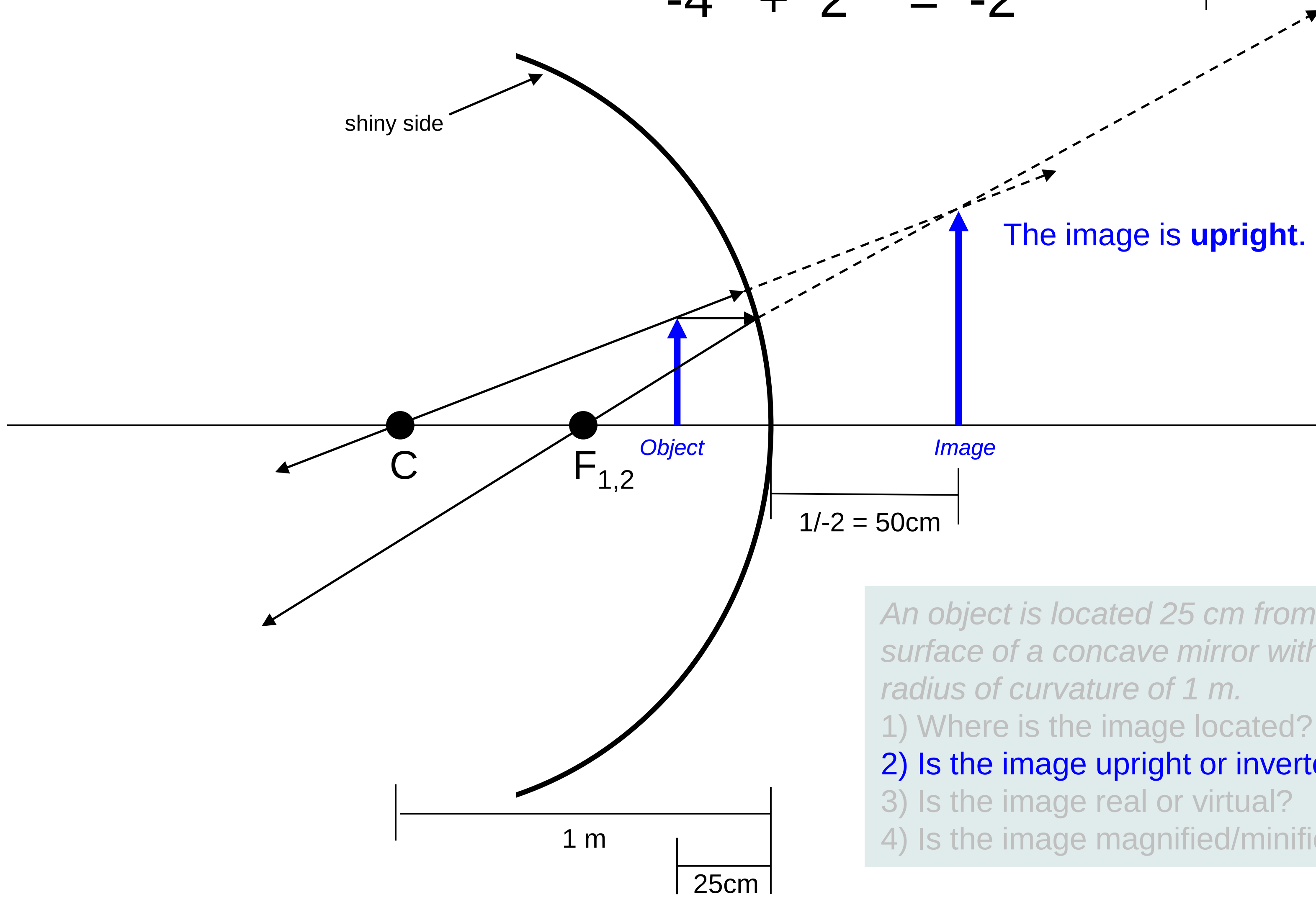
The image is located here. We can determine its exact distance from the mirror via the Vergence Formula. The image is 50 cm to the right of the mirror.

An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.25	+	1/.5	=	V
-4	+	2	=	-2

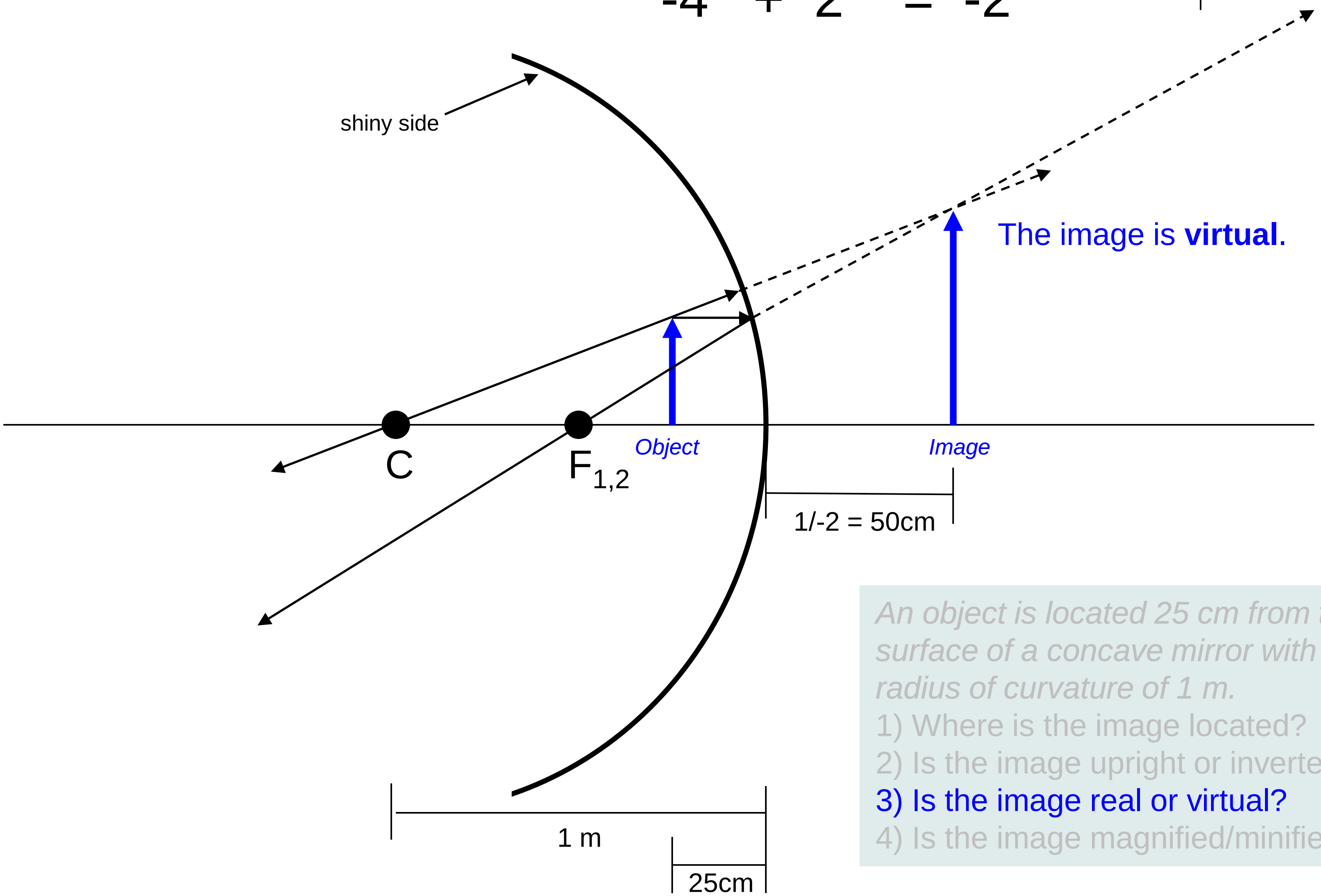


An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.25	+	1/.5	=	V
-4	+	2	=	-2

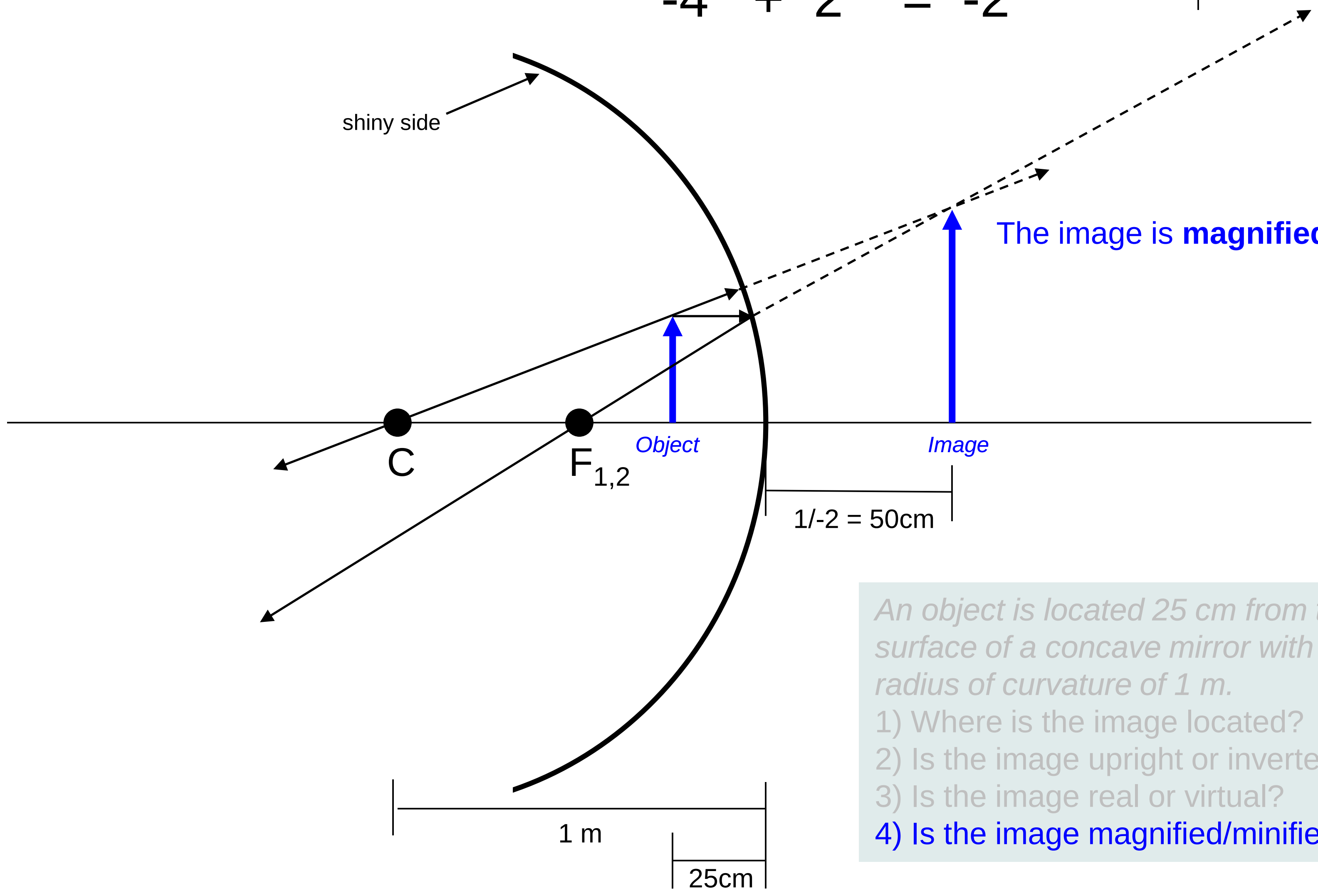


An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	+	P	=	V
-1/.25	+	1/.5	=	V
-4	+	2	=	-2

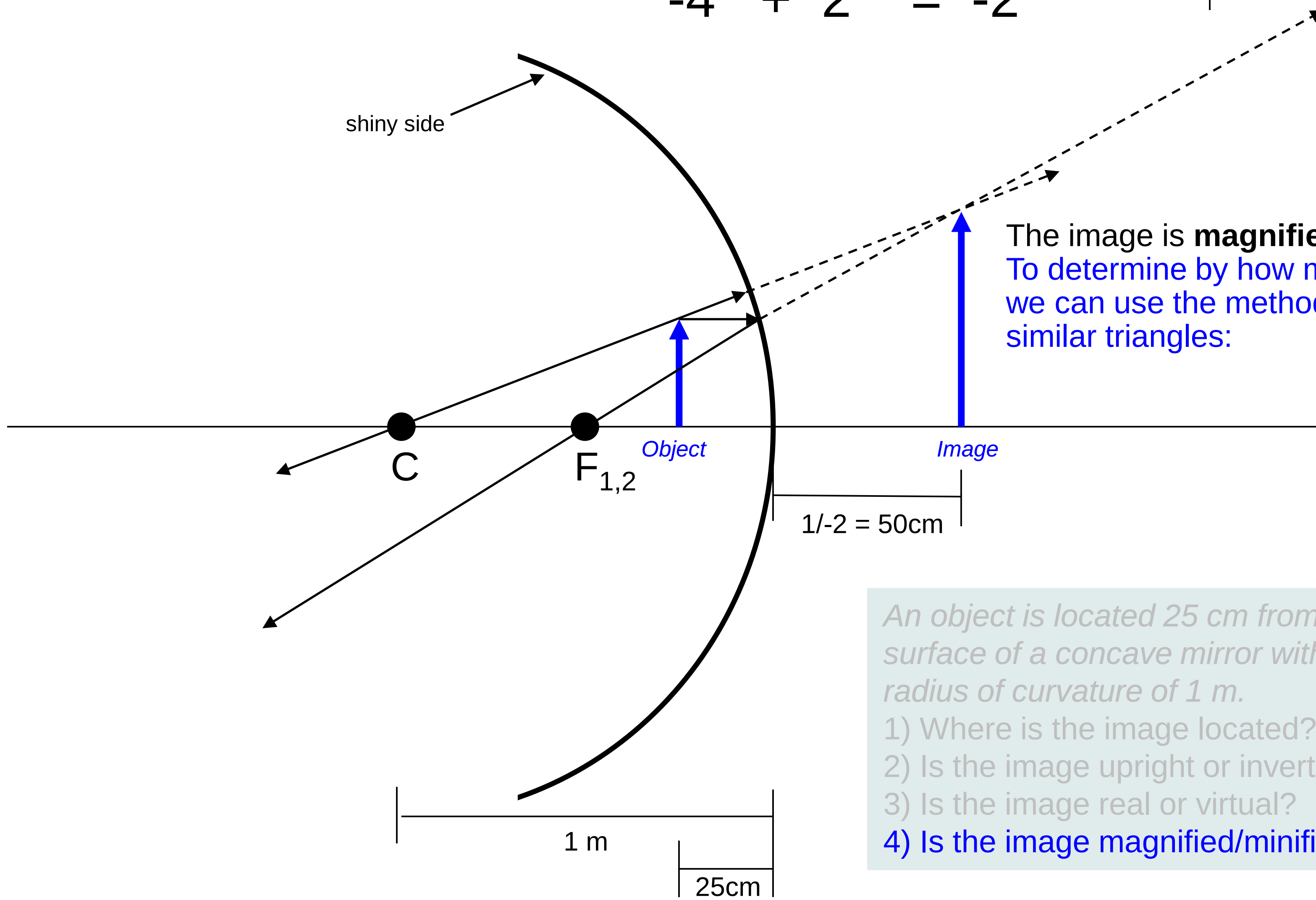


An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	$+$	P	$=$	V
$-1/.25$	$+$	$1/.5$	$=$	V
-4	$+$	2	$=$	-2



The image is **magnified.**
To determine by how much, we can use the method of similar triangles:

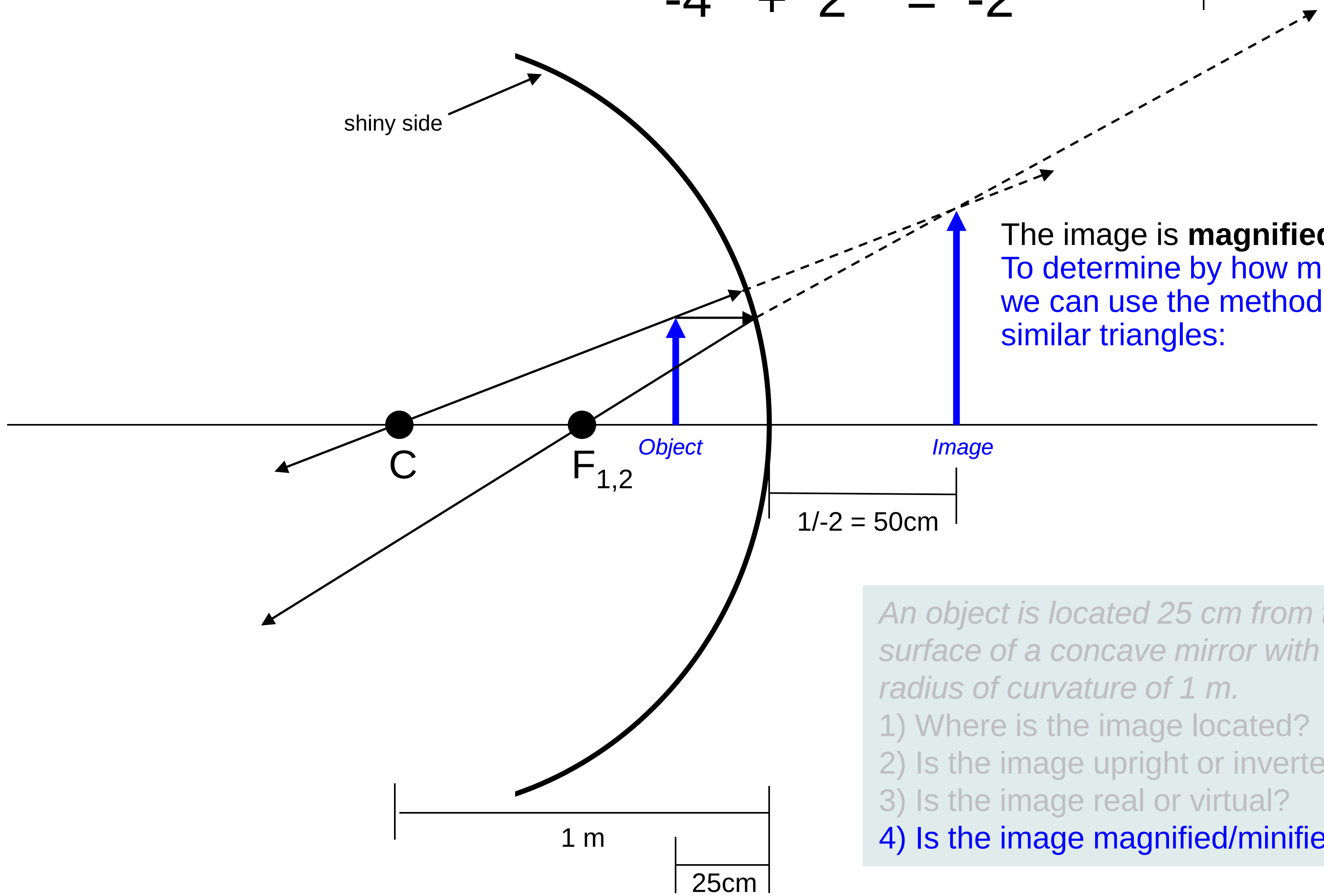
An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?

Mirrors

$$\frac{\text{Image size}}{\text{Object size}} = \frac{\text{Image distance}}{\text{Object distance}} = \frac{50\text{cm}}{25\text{cm}} = 2$$

Vergence of incoming light		Vergence added by the mirror		Vergence of light leaving the mirror
U	$+$	P	$=$	V
$-1/.25$	$+$	$1/.5$	$=$	V
-4	$+$	2	$=$	-2



The image is **magnified.**
To determine by how much, we can use the method of similar triangles:

An object is located 25 cm from the surface of a concave mirror with a radius of curvature of 1 m.

1) Where is the image located?
2) Is the image upright or inverted?
3) Is the image real or virtual?
4) Is the image magnified/minified?