Unit 14 · Reflection at Curved Mirrors

STUDY NOTES

WHAT NEB'S GRADE 11 EXAM ASKS

- **CDC's grid (2077):** Wave and Optics (Units 14–18 together): 9 of 75 marks
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **MCQ (1 mark)**
  - nature of an image from a ray diagram
  - widest field of view; mirror for shaving
  - f under water; f for each color
  - quick v, u or f from the formula
  - image speed in a moving plane mirror
- **Short (5 marks, in parts)**
  - define concave mirror + one daily use
  - projector mirror: why the image is larger; f from m and v
  - real vs virtual; a plane mirror's real image, with a figure
  - prove $f = R/2$; derive the mirror formula
  - lamp and screen; image size; a pole's image

Key terms

Reflection: light turned back into the medium it came from at a surface.

Image: point where rays from an object point meet, or seem to come from, after reflection or refraction.

Real image: rays really meet; caught on a screen; inverted (real object).

Virtual image: rays only seem to meet, produced back; not on a screen; upright (real object).

Virtual object: light already converging towards a point behind the mirror.

Spherical mirror: reflecting surface part of a sphere. **Concave**: reflects from the hollow side (outside silvered). **Convex**: from the bulging side (inside silvered).

Pole (P): middle point of the mirror's surface.

Center of curvature (C): center of the sphere; in front of concave, behind convex.

Radius of curvature (R): CP.

Principal axis: line through P and C.

Aperture: width of the mirror, diameter of its rim.

Principal focus (F): where rays parallel and close to the axis meet (concave, real) or seem to come from (convex, virtual).

Focal length (f): PF.

Paraxial rays: rays at very small angles to the axis.

Magnification (m): image size ÷ object size; no unit.

Spherical aberration: wide spherical mirror has no single sharp focus.

Field of view: stretch of the world a mirror shows.

Laws of reflection:

1. incident ray, reflected ray, normal at the point: one plane
2. angle of reflection = angle of incidence

- normal at any point of a spherical mirror = the radius through C

Formulas

$f = \frac{R}{2}$	small aperture **Use:** focus halfway between P and C
$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$	u object, v image distance from P **Use:** every mirror, with signs
$m = \frac{I}{O} = \frac{v}{u}$	I, O image, object size **Use:** size and nature of the image

Sign convention: real is positive

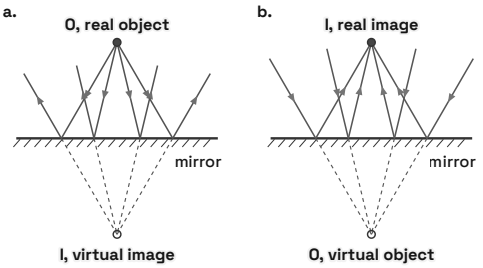
1. all distances from the **pole**
2. real objects and images +; virtual −
3. f, R: concave +, convex −

- m + → real (inverted, real object); m − → virtual (upright)
- size of m: 1 same size; < 1 diminished; > 1 enlarged

- "new Cartesian" convention (some books): u negative, concave f negative; same answers with its own signs; never mix; say which you use

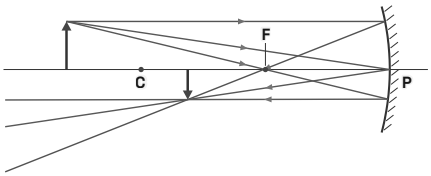
Real and virtual images

	Real	Virtual
forms	rays really meet	rays seem to meet, produced back
screen	can be caught	cannot
way up (real object)	inverted	upright
e.g.	cinema screen, retina, camera	plane mirror, convex mirror, magnifying glass

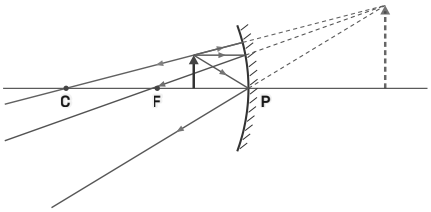


Plane mirror. a. real object O → virtual image I behind. b. converging light to O behind (virtual object) → **real** image I in front.

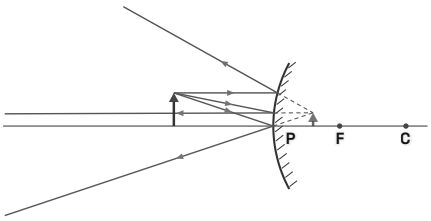
- plane mirror: image as far behind as object in front; $f = \infty \rightarrow v = -u$, $m = -1$ (size 1)
- mirror moves towards you at 10 m/s → image approaches you at **20 m/s**
- with a virtual object the rule turns: convex mirror can give a **real, upright** image
- concave, object beyond C → real, inverted, between C and F; at C → real, inverted, same size at C; between F and P → virtual, upright, enlarged (shaving mirror)
- convex, real object → always virtual, upright, diminished, between P and F behind



Concave, object beyond C: real, inverted, diminished image between C and F.



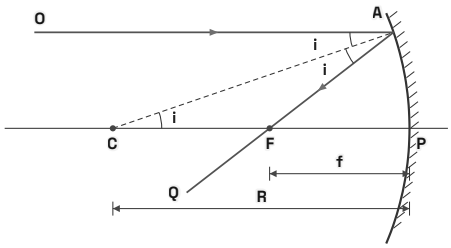
Concave, object between F and P: virtual, upright, enlarged (shaving mirror).



Convex: parallel ray leaves as if from F; ray to F leaves parallel; ray to P at an equal angle. Virtual, upright, diminished.

- object at infinity → image a point at F

Relation between f and R



Ray OA parallel to the axis → reflected through F; CA is the normal.

Concave:

1. CA normal → $\angle OAC = \angle CAF = i$
2. OA ∥ axis → $\angle ACF = i$ (alternate)
3. △FAC isosceles → FA = FC
4. small aperture: FA ≈ FP → FP = FC → $f = R/2$

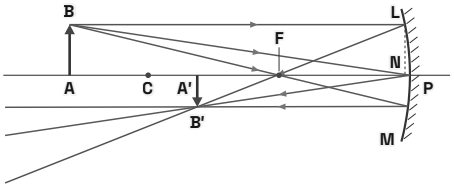
Convex: normal = CA produced to N; $\angle FAC = \angle NAQ = i$ (vertically opposite), $\angle ACF = i$ (corresponding) → FA = FC ≈ FP → $f = R/2$

- far rays cross nearer than F → spherical aberration → headlamps, dishes **parabolic**
- f depends only on shape → **same under water**, **same for every color** (reflection obeys one law in every medium)
- very large $R \rightarrow f \rightarrow \infty \rightarrow$ behaves as a **plane mirror**

Mirror formula

Assumptions

1. small aperture
2. paraxial rays
3. small (point) object on the axis



Object AB beyond C, real image A′B′. BL ∥ axis → through F; BP → reflected at equal angle; LN ⊥ axis.

1. $\triangle ABP \sim \triangle A'B'P$: $\frac{A'B'}{AB} = \frac{PA'}{PA}$
2. $\triangle LNF \sim \triangle B'A'F$, LN = AB, FN ≈ FP (small aperture): $\frac{A'B'}{AB} = \frac{PA' - PF}{PF}$
3. equate; $PA = u, PA' = v, PF = f$: $\frac{v}{u} = \frac{v - f}{f} \rightarrow$ $uv = uf + vf$
4. $\div uvf$: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

- virtual image or convex mirror: same formula, virtual distances negative
- step 1 also gives $m = v/u$
- e.g. concave, $f = 20$ cm, $u = 30$ cm → $v = 60$ cm, real
- e.g. convex, $f = -25$ cm, $u = 100$ cm → $v = -20$ cm, $m = -0.2$: virtual, upright, diminished
- real image, magnification m: $u = \frac{m + 1}{m} f$
- real image needs v on the object's side: a lamp and a screen in front of the mirror, $v - u = \pm$ their gap

Uses

Concave

- **reflecting telescopes**: huge lenses can't be made free of defects; mirror supported all over its back; no color splitting
- **shaving, make-up**: face between P and F → upright, enlarged, virtual
- **ophthalmoscope**: doctor looks through a hole in the middle; mirror lights the retina
- **reflectors**: torches, headlamps, projectors, searchlights; lamp at the focus of a parabolic mirror → parallel beam; solar cooker, satellite dish
- **dentists' mirrors**, **microscope mirror**

Convex: vehicles' rear-view mirrors, blind bends, car-park exits, shops

- always virtual, upright, diminished → **wide field of view**
- but things look smaller and farther → can't judge distance and speed of traffic behind

Telling them apart on a wall, without touching: convex → you always small, upright; concave → enlarged and upright up close, inverted from a few meters.

- ray falling normally (along a radius) → angle of incidence 0° → retraces its path

COMMON MISTAKES

✗ convex $f = +15$ cm
✓ convex f **negative**: -15 cm.

✗ virtual image with v positive
✓ virtual distances **negative**.

✗ $m = -0.5$ means inverted
✓ negative m: **virtual, upright** (real object).

✗ f changes under water
✓ mirror's $f = R/2$: **no change**.

✗ convex mirror never forms a real image
✓ it does, for a **virtual object** between P and F.

✗ image in a plane mirror approaches at the mirror's speed
✓ **twice** the mirror's speed.

✗ mixing the Cartesian formula with "real is positive" signs
✓ one convention throughout.