PHY2208 Optics

22 lectures, 10 credits

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2 CA tests (30 minutes each)	40%
3 problem classes	10%
1 Exam (90 minutes)	50%
(plus 3 problem sheets)	

Recommended texts:

University Physics, Young and Freedman (Addison Wesley)
Principles of Optics, Pedrotti and Pedrotti (Prentice Hall)

Plan of syllabus

Lecture	**Subject**
1-6	Geometrical (ray) optics
7-13	Interference and spectrometers
14-16	Diffraction and resolution
17-19	Polarization
20-22	Lasers

What is light?

Light is a transverse electromagnetic (EM) wave which propagates through space at a speed $c = 2.997925\times10^8$ ms^{-1} (in a vacuum).

Light possesses a wavelength λ and a frequency υ which are related by $c = \upsilon\,\lambda$

'Light' is just one part of the electromagnetic spectrum i.e. radiation with λ=0.5 microns. Other forms of EM radiation:

	γ-ray	X-ray	UV	'Light'	IR	Radio
λ	pm	nm	~100nm	~500nm	1-100μm	1mm-1km

Ray optics

Ray optics is a *vastly simplified* model of light, but it is useful for describing the formation of the **image** of an **object**.

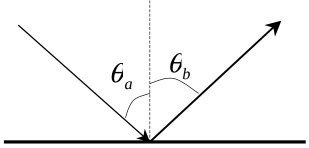
As a rule of thumb:

Ray optics gives a reasonable description of light propagation through any system **whose size is large compared to λ.**

Basic principles of ray optics

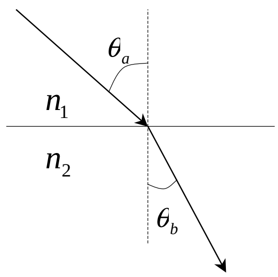
- In free space light travels along straight paths called 'rays'
- Rays are emitted in all directions from infinitesimal point sources
- Extended objects can be considered as comprising infinitely many point sources.
- Rays striking a surface may change direction by **reflection** or **refraction**

Reflection



Direction of travel is changed such that $\theta_a = \theta_b$

Refraction

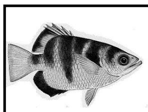


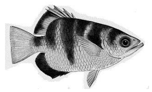
When a ray travels from one medium to another with a different refractive index *n* (see YF 34-3), it is deflected such that

$$n_1 \sin\theta_a = n_2 \sin\theta_b$$

This is **Snell's Law of Refraction**

The Archer Fish



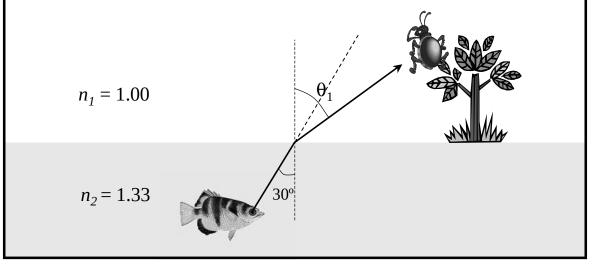


The Archer fish squirts a jet of water from beneath the surface to knock down insects from overhanging branches. In order to hit the insect the fish must understand Snell's law…

Q: If an Archer fish sees an insect at 30º from the normal (vertical) at what angle must it squirt its water to get lunch?

Applying Snell's law to find θ_1:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
$$1.0 \sin\theta_1 = 1.33 \sin 30°$$
$$\theta_1 = \sin^{-1}(0.665) = 42°$$

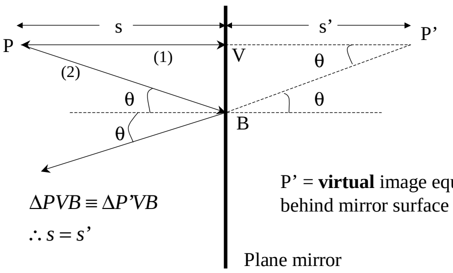


The **image** of a point source is the point in space where:

1) rays from the point source re-converge (a **real image**)

or

2) rays appear to emanate from (a **virtual image**)



$\Delta PVB \equiv \Delta P'VB$

$\therefore s = s'$

P' = **virtual** image equidistant behind mirror surface

Ray 1 leaves the source and strikes the mirror at normal incidence at V, hence is reflected back on itself.

Ray 2 strikes the mirror at some angle θ at B and hence is reflected at angle θ.

These two rays appear to emanate from a point source at P'.

Clearly ΔPVB and ΔP'VB are congruent hence PV=P'V for **any** θ, so **all** rays from P which strike the mirror appear to emanate from P' i.e. P' is a **virtual image** of P.

A plane mirror forms a **virtual image** of a point source, located on the normal from the object to the mirror and equidistant from the mirror surface.

Sign conventions

Object distances are **+ve** on the same side of the surface as **incoming rays.**

Image distances are **+ve** on the same side of the surface as **outgoing** rays.

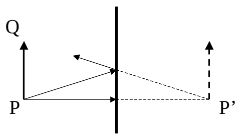
For spherical surfaces (radius of curvature *R*): *R* is **+ve** when the centre of curvature C is on the **same side** as the **outgoing** rays.

Object distances will generally be labelled *s* and image distances *s'*.

In our plane mirror example, *s* is +ve, *s'* is –ve and *R* is infinite. Hence *s* = -*s'* for a plane mirror.

Magnification

Consider an extended object (the arrow PQ) of height *y*:



Clearly all points comprising the object will produce virtual images similar to P', and hence a virtual image of height *y'* = *y*.

We define the lateral magnification *m* as $m = \frac{y'}{y}$

So *m* = +1 for a plane mirror.