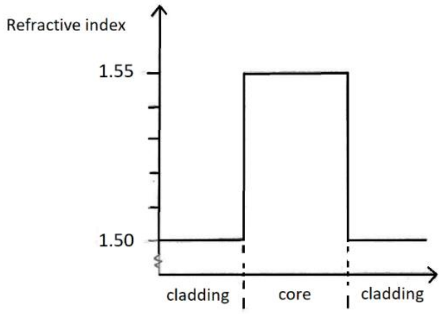
MEDICAL PHYSICS

4-2 Endoscopy

1. (a) The cladding on an optical fibre has a lower refractive index than the core so that light will be totally internally reflected at the boundary between the core and the cladding and thus be retained within the core.

(b) (i)



(ii) $\sin i_c = \frac{n_2}{n_1} = \frac{1.50}{1.55} = 0.9677$

$I_c = 75.4074 = 75.4°$ to 3 sf

Alternatively use $1.50 \times \sin 90° = 1.55 \times \sin i_c$ and solve for i_c

2. (a) The coherent bundle in an endoscope transmits light out of the body and provides the image. Each of the fibre ends are in the same relative positions at each end of the bundle so that a coherent image will be seen. Each fibre is about 0.01 mm across and the bundle consists of tens of thousands of such fibres.

The incoherent bundle in an endoscope transmits light into the body and is used to illuminate the area of interest. The fibres do not have to be in the same relative positions at both ends and the bundle is connected to a light source.

(b) A medical endoscope can be used for:

- observing internal body surfaces such as the gastro-intestinal tract (no risk from surgery and impossible otherwise)

- obtaining tissue samples/removing obstructions or diseased tissue (no cutting open the body with a large incision, treatment is faster, patient recovery time is shorter and the cost of the operation is reduced)

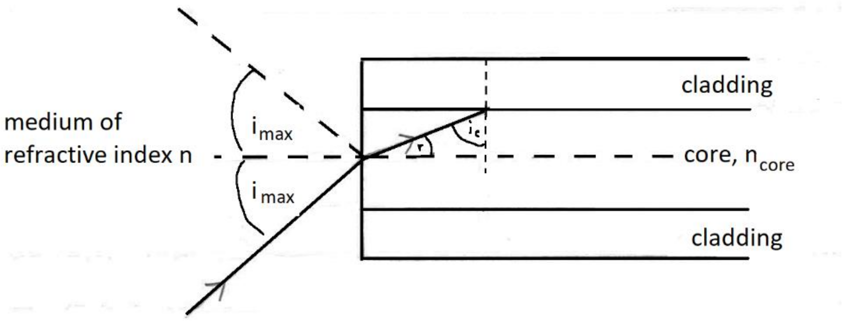
- laser treatment of diseased tissue/sealing blood vessels (no cutting open the body with a large incision and the laser can be tuned for the most effective absorption).

3. (a) (i) incoherent bundle to allow illumination of the cavity
(ii) coherent bundle to enable image of the cavity to be formed
(iii) eyepiece lens to view image from the coherent bundle
(iv) air/water channel to clean lens and fibre ends in the cavity
(v) objective lens over the image channel at the internal end

(b) The fibres in the coherent bundle need to be very thin so that the image will have sufficient resolution. (The end of each fibre gives a dot in the image). The thinner it is the more it can be bent without loss of light from the core but, if bent too much light will escape, the image will be degraded and information lost.

4. (a) (i) The viewing cone determines the field of view of the fibre. If it is too narrow, only a small part of the organ will be seen and if it is too large, the image will be poor and lacking contrast as the fibre collects light from too large an area.

(ii)



Light entering from within the cone is totally internally reflected at the core-cladding boundary.

Angle of incidence at the flat end = i_{max} for light to just undergo TIR in the fibre

Angle of refraction on entering the fibre = r = 90 – i_c at this angle of incidence

$n \times \sin i_{max} = n_{core} \times \sin(90 - i_c)$ for entry into the fibre

so $\sin i_{max} = \frac{n_{core}}{n} \times \sin(90 - i_c)$ and thus the value of i_{max} is dependent on the value of i_c

(b) (i) $n_{core} = 1.60$, $n_{cladding} = 1.55$

Therefore the critical angle i_c is given by $\sin i_c = \frac{1.55}{1.60} = 0.9688$

$I_c = 75.638 = 75.6°$ to 3 sf

Assuming the external medium is air so n = 1.00

$\sin i_{max} = \frac{1.60}{1.00} \times \sin(90 - 75.6)$

$\sin i_{max} = 1.60 \times \sin 14.4°$

$= 0.3979$ (0.3969 keeping calculator values)

$i_{max} = 23.447$ (23.382…)

$= 23.4°$ to 3 sf

(ii) n_{core} = 1.60, $n_{cladding}$ = 1.50

Therefore the critical angle i_c is given by $\sin i_c = \frac{1.50}{1.60}$ = 0.9375

I_c =69.635… = 69.6° to 3 sf

Assuming the external medium is air so n = 1.00

$\sin i_{max} = \frac{1.60}{1.00}$ x sin(90 -69.6)

$\sin i_{max}$ = 1.60 x sin20.4°

= 0.5577 (0.5568 keeping calculator values)

i_{max} = 33.897… (33.833…)

= 33.9° to 3 sf (33.8°)