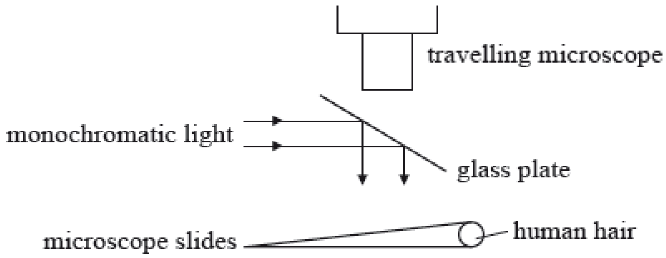
HL Paper 3

This question is about thin-film interference.

The diagram (not to scale) represents an experimental set-up designed to measure the diameter of a human hair.



A hair is used to separate two microscope slides. A monochromatic beam of light is reflected onto the two slides by the glass plate. The light is then reflected from the two slides and transmitted through the glass plate and is viewed by the travelling microscope.

a. State why the light reflected from the two microscope slides produces a system of interference fringes. [1]

b. The condition that a bright fringe is observed in the field of view of the travelling microscope is given by the relationship [1]

$$2t = \left(m + \frac{1}{2}\right)\lambda$$

where t is the thickness of the air film formed by the wedge at the point where the bright fringe is observed, m is an integer and λ is the wavelength of the incident light.

State the reason for the factor $\frac{1}{2}$ in the relationship.

c. In the diagram, the length of the slides is 5.00 cm. The wavelength of the monochromatic light is 5.92×10^{-7} m. Using the travelling microscope it is observed that 50 fringes occupy a length of 0.940 cm. Show that the diameter of the hair used to separate the slides is about $80\ \mu\text{m}$. [3]

This question is about thin-film interference.

A thin film of oil lies on a puddle of water. White light from above shines on the film at normal incidence.

a. Outline the process by which coloured fringes are formed. [3]

b. The following data are available: [2]

Refractive index of oil = 1.4
Refractive index of water = 1.3
Thickness of the oil film = 250 nm

Calculate the maximum wavelength of the incident light for which **destructive** interference occurs.

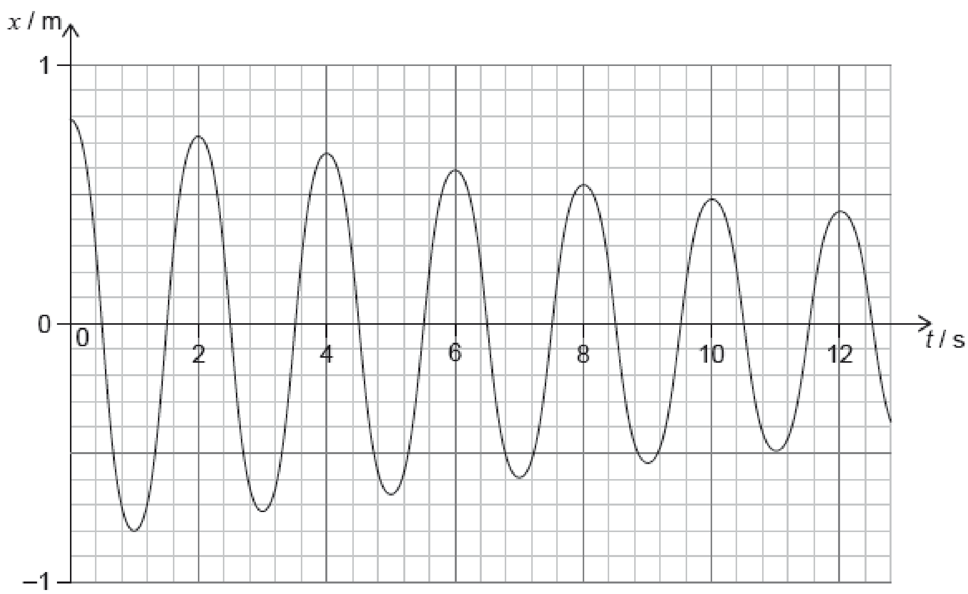
This question is about thin-film interference.

A thin film of oil of constant thickness floats on the surface of water. The refractive indices n of each material is shown on the diagram.

a. Explain why the film of oil appears to show coloured fringes. [2]

b. When white light is normally incident on the surface of the oil, the film appears green to an observer. The wavelength of green light in air is 520 nm. Calculate the thickness of the film of oil. [2]

The graph below represents the variation with time *t* of the horizontal displacement *x* of a mass attached to a vertical spring.



The total mass for the oscillating system is 30 kg. For this system

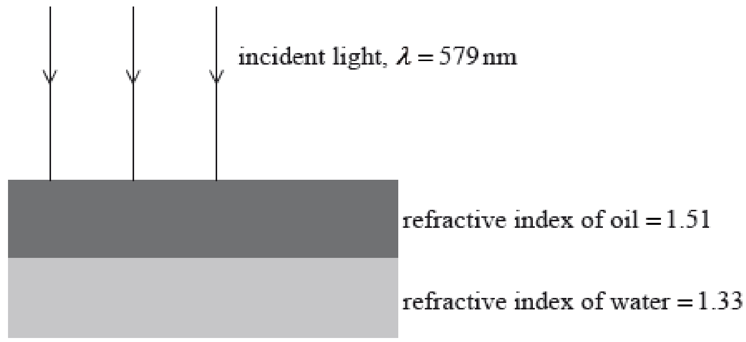
a. Describe the motion of the spring-mass system. [1]

b.i. determine the initial energy. [1]

b.ii. calculate the Q at the start of the motion. [2]

This question is about thin-film interference.

A thin layer of oil of refractive index 1.51 floats on water of refractive index 1.33. Light of wavelength 579 nm is incident normally to the surface.



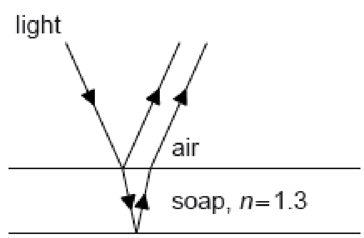
a. Determine the minimum thickness of the oil layer that gives rise to the least amount of light being reflected. [3]

b. Describe the change in the intensity of the reflected light as the thickness of the oil layer in (a) is gradually increased. [2]

This question is about thin-film interference.

Monochromatic light with wavelength 572 nm is incident from air on a thin soap film.

The soap solution has a refractive index of 1.3.



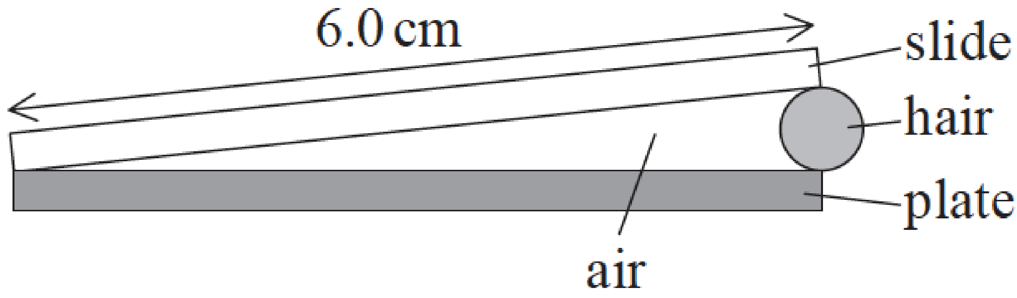
a. Calculate the wavelength of the light within the soap solution. [1]

b. Calculate the minimum thickness of the soap film that results in constructive interference for the reflected light. [1]

c. Without a calculation, explain why a soap film that is twice as thick as that calculated in (b) results in destructive interference. [2]

This question is about wedge fringes.

A glass microscope slide of length 6.0cm is placed on a glass plate and illuminated using a monochromatic source of light of wavelength 590nm. A hair is trapped at one end of the slide forming an air wedge between the glass plate and the slide.

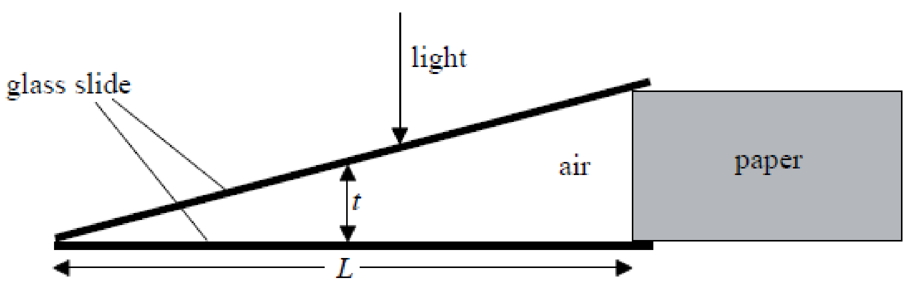


(not to scale)

An observer viewing the microscope slide at near-normal incidence measures the fringe spacing to be 0.29 mm. Calculate the thickness of the hair.

This question is about wedge film interference.

One flat, glass slide is placed at an angle on top of a second identical slide. The slides are in contact along one short edge and are separated at the other edge by a thin piece of paper, as shown below.



(diagram not to scale)

A thin wedge of air of variable thickness, t , is trapped between the two slides. The arrangement is viewed normally from above, using light of wavelength 590 nm. The glass plates are coated, so that reflection only takes place at the bottom surface of the top plate and the top surface of the bottom plate.

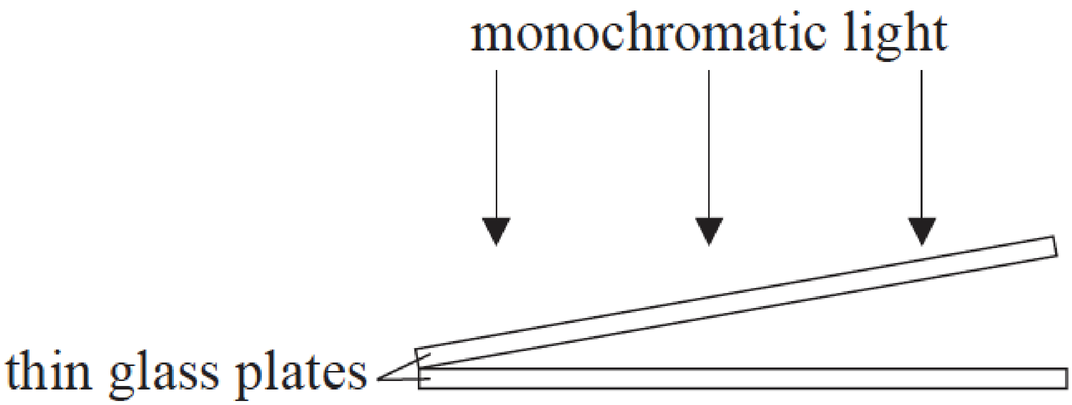
A series of straight bright and dark fringes, equally separated and parallel to the short edge of the slides, is seen.

a. Deduce that the thickness of the air wedge t that gives rise to a bright fringe, is given by $2t = (m + \frac{1}{2})\lambda$. [2]

b. The length of the air wedge, L, is 8.2 cm. The bright fringes are each separated by a distance of 1.2 mm. Calculate the thickness of the paper. [3]

This question is about wedge films.

The diagram shows two thin glass plates used to form a thin air wedge.



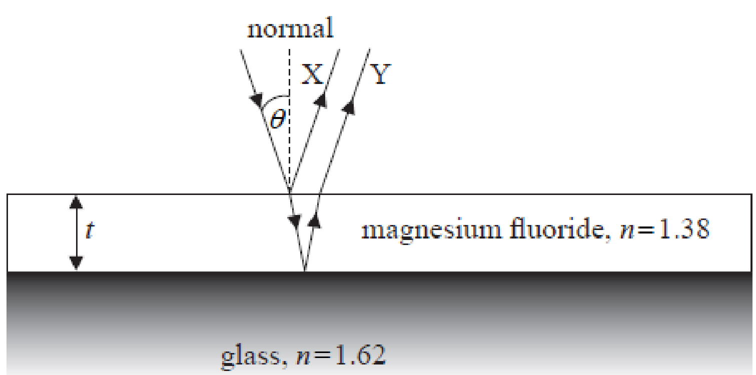
A beam of monochromatic light is incident on the air wedge. The reflected light is observed through a microscope and a pattern of equally spaced parallel fringes is observed.

a. Outline how the fringes are formed. [3]

b. State and explain how the fringe separation changes if the angle of the wedge is increased slightly. [2]

This question is about thin-film interference.

A piece of glass of refractive index 1.62 is covered with a thin film of magnesium fluoride of thickness *t* and refractive index 1.38. The diagram shows a ray of monochromatic light incident on the film at an angle θ to the normal.



X is a ray reflected from the surface of the film and Y is reflected from the surface of the glass.

a. Show that when θ=0 the condition for destructive interference between rays X and Y is [2]

$$2t=(m+½)\lambda$$

where *m* is an integer and λ is the wavelength of light in the magnesium fluoride film.

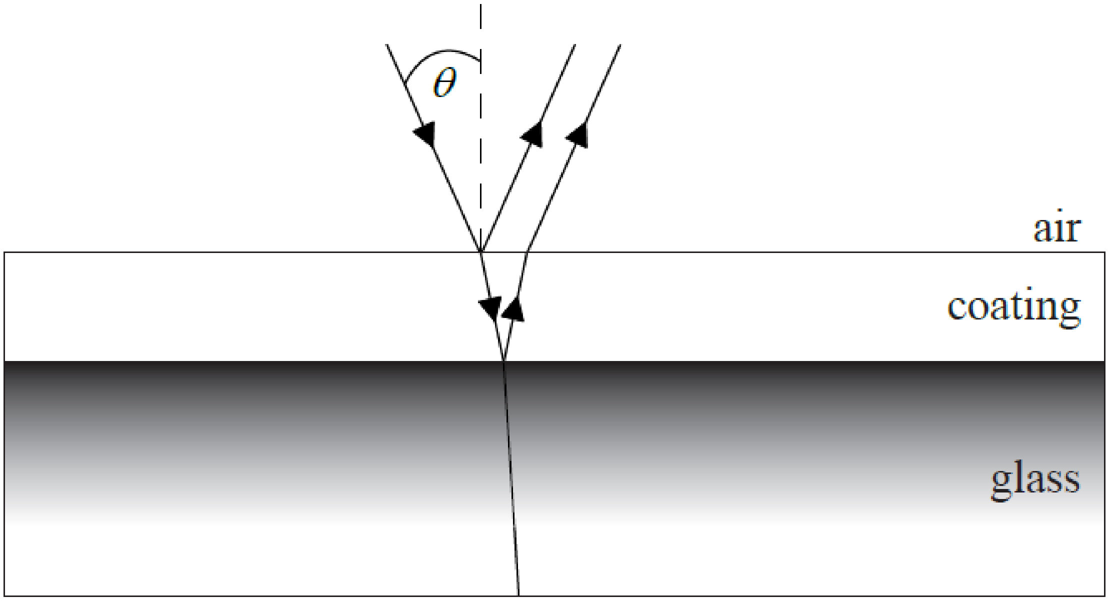
b. Light of wavelength 640 nm in air is incident normally on the glass surface. [3]

(i) Show that the wavelength of light in the magnesium fluoride film is 464 nm.

(ii) Calculate the minimum thickness of the film for which no light will be reflected back into the air.

This question is about thin-film interference.

The anti-reflective coating of a lens consists of a thin layer of a suitable material placed between the air and the glass of the lens.



The following data are available.

Refractive index of air = 1.0
Refractive index of coating = 1.2
Refractive index of glass = 1.5

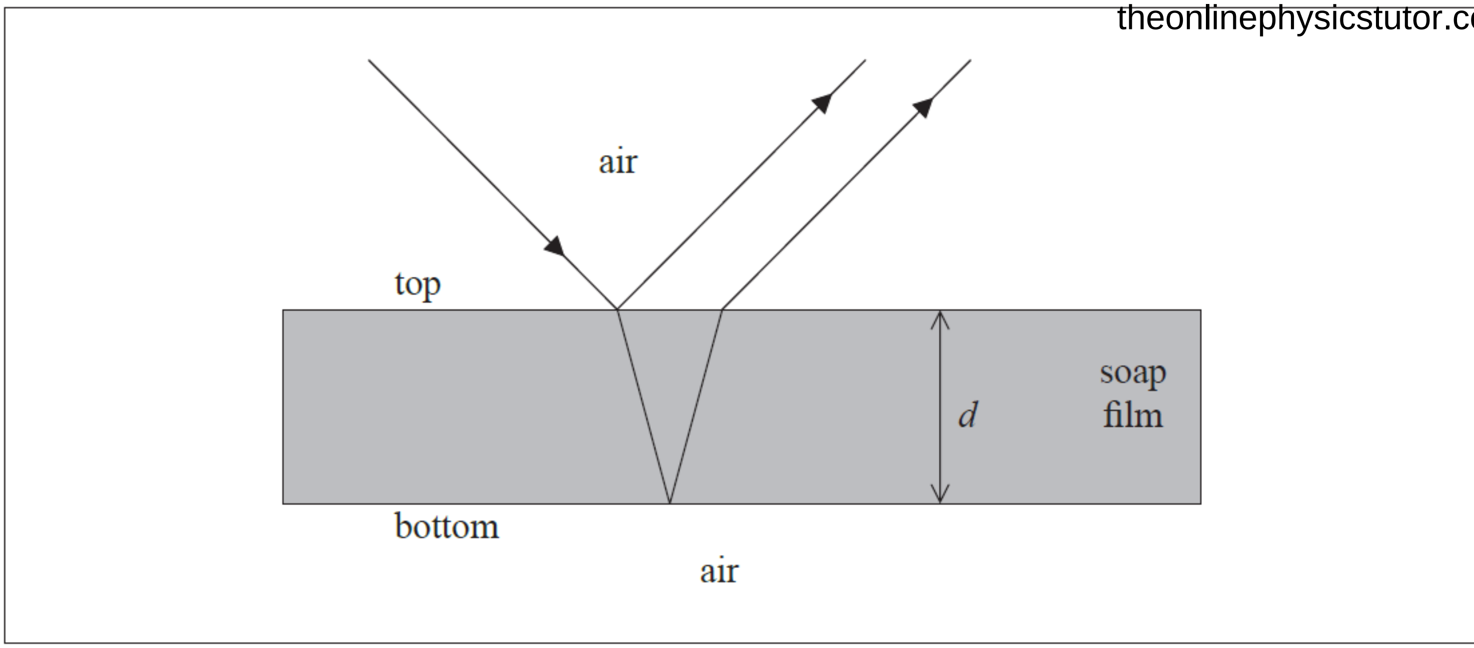
a. State what phase change occurs on reflection at the air-coating boundary and at the coating-glass boundary. [1]

b. The thickness *d* of the coating layer is 110 nm. [3]

Determine the wavelength for which there is no resultant reflection from the surface of the lens for light at normal incidence *(θ = 0°)*.

This question is about thin-film interference.

a. A ray of monochromatic light is incident on a thin film of soap water that is suspended in air. The diagram shows the reflection of this ray from the top and bottom surfaces of the film. [1]



On the diagram, label, with the letter P, the point at which a phase difference of π occurs.

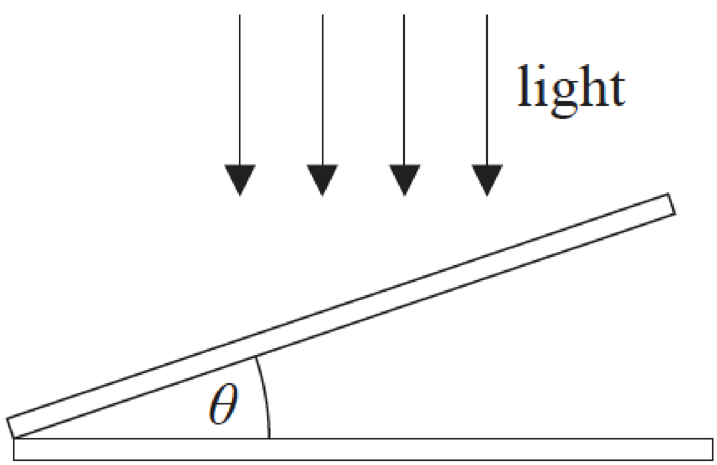
b. White light is incident normally on the soap film. The thickness d of the soap film is 225 nm and its refractive index is 1.34. [4]

(i) Show that the longest wavelength of light λ in air for which the reflected rays destructively interfere is 603 nm.

(ii) Explain why the soap film will appear coloured.

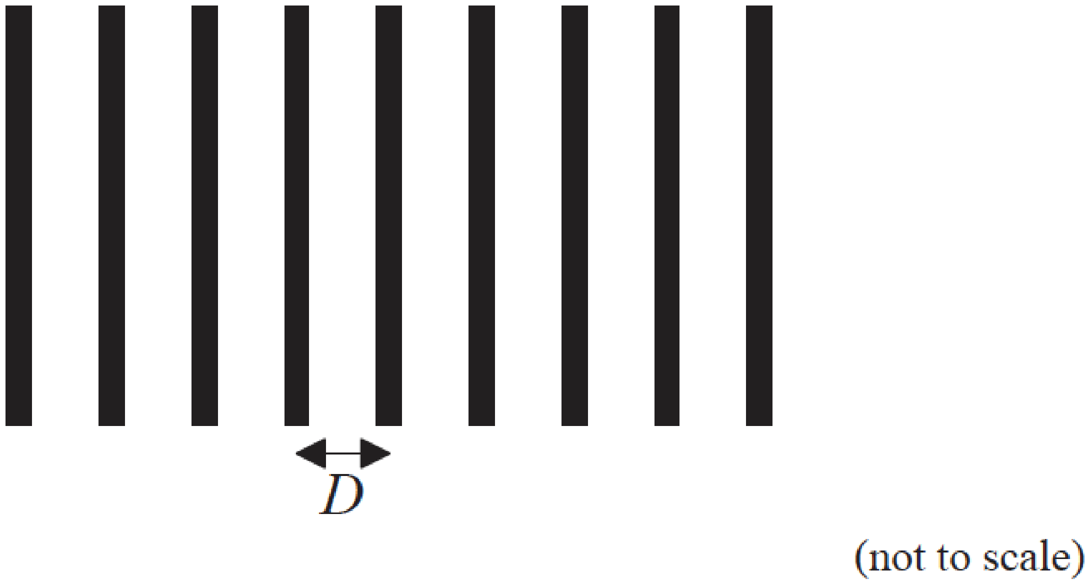
This question is about thin-film interference.

A thin air wedge consists of two flat glass plates that form an angle θ of 1.0×10^{-3}rad.



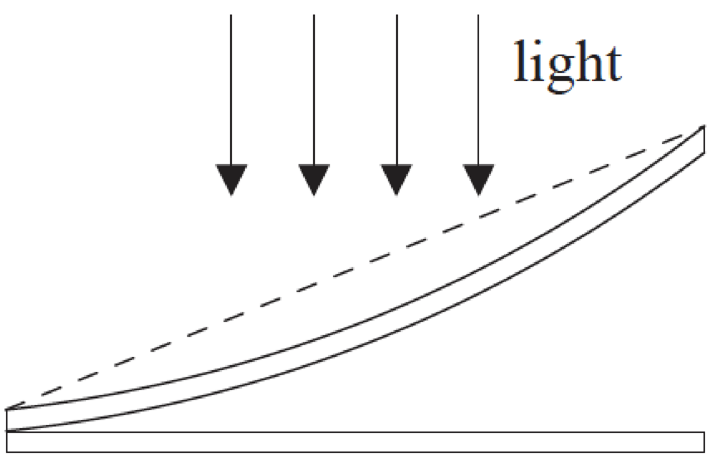
(not to scale)

When illuminated with monochromatic light from above, the fringe pattern below is observed in the reflected light. The distance D between two consecutive fringes is 0.30mm.



a. Calculate the wavelength of the light. [2]

b. The upper glass plate is now replaced with a curved glass plate. The dotted line represents the upper glass plate used in (a). [2]



Sketch the new fringe pattern in the space below. The fringe pattern of (a) is given for comparison.