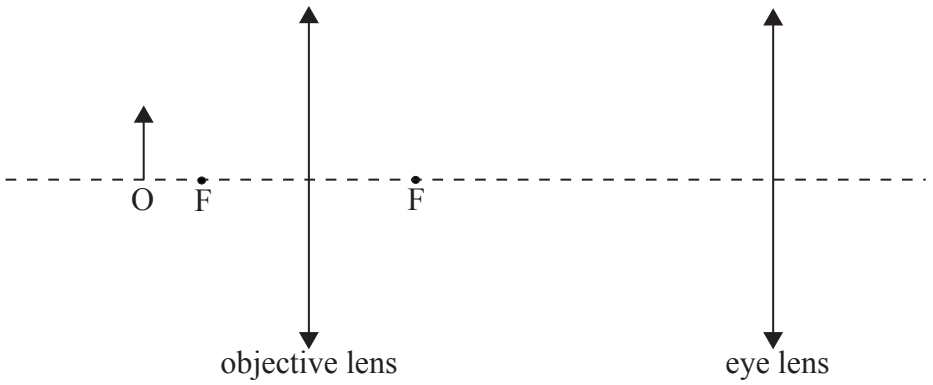
Option G — Electromagnetic waves

G1. This question is about a compound microscope, spherical aberration and chromatic aberration.

(a) An object O is placed in front of the objective lens of a compound microscope as shown below.



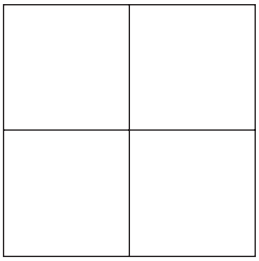
The focal points of the objective lens are at F. The microscope is in normal adjustment. Without drawing a ray diagram, label the approximate positions, on the principal axis, of

(i) the image produced by the objective lens (label this position X). *[1]*

(ii) the focal points of the eye lens (label these points E). *[1]*

(iii) the final image (label this image Y). *[1]*

(b) An object is viewed through a convex lens that has been corrected for spherical aberration. For a particular object distance, the image of the object is as shown below.



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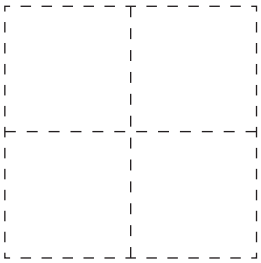
(Question G1 continued)

Another convex lens of the same focal length, but not corrected for spherical aberration, is now used to view the object. The object distance is unchanged.
In the space below, draw the image as it would be seen through this second lens.
The image as seen through the corrected lens is shown as a broken line. *[2]*



(c) Explain how chromatic aberration arises when an object is viewed through a single lens. *[2]*

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G2. This question is about the scattering of light.

(a) State an approximate wavelength for

(i) red light. *[1]*

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(ii) blue light. *[1]*

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(b) With reference to your answers in (a), explain why the setting Sun appears reddish in colour. *[3]*

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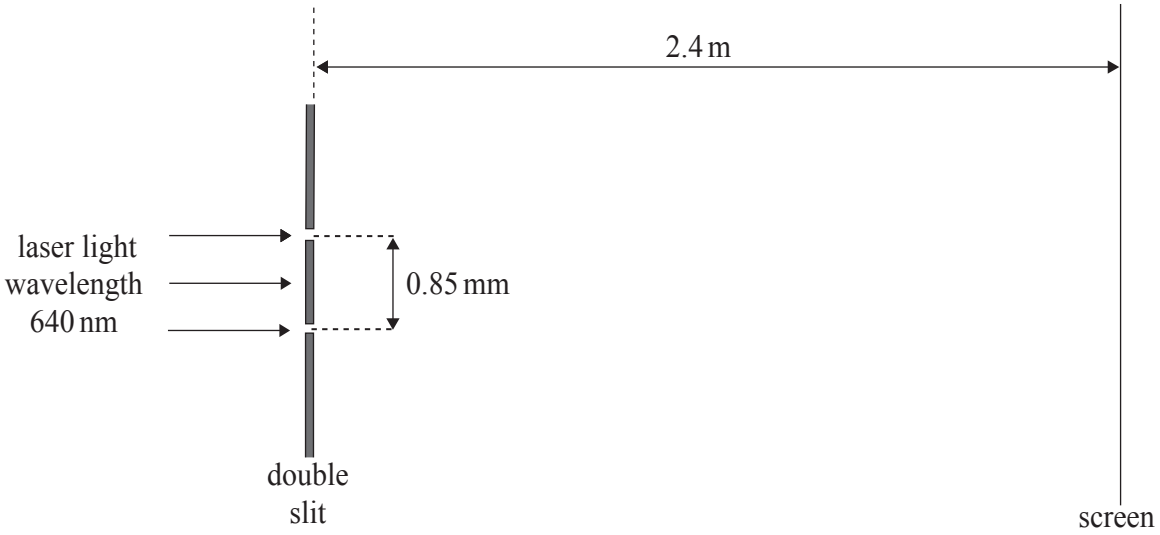
G3. This question is about two-source interference.

A double slit is arranged so that its plane is normal to a beam of laser light, as shown below.



The wavelength of the light is 640 nm. The slit separation in the double slit arrangement is 0.85 mm. Coherent light emerges from the slits and an interference pattern is observed on a screen. The screen is parallel to the plane of the double slits. The distance between the slits and the screen is 2.4 m.

(a) (i) State what is meant by coherent light. *[1]*

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(ii) Explain how an interference pattern is formed on the screen. *[3]*

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(b) Calculate the separation of the fringes in the interference pattern on the screen. *[2]*

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(This question continues on the following page)

(Question G3 continued)

(c) The interference pattern in (b) consists of a series of alternate light and dark fringes. The intensity of the light from one slit is now reduced. Suggest the effect on the appearance of the fringes. *[2]*

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G4. This question is about X-rays.

(a) In an X-ray tube having a tungsten target, electrons are accelerated from rest through a potential difference of 45 kV.
Calculate the range of wavelengths that will be observed in the X-ray spectrum produced by this bombardment. *[3]*

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(b) Explain the origins of the features of a characteristic X-ray spectrum. *[3]*

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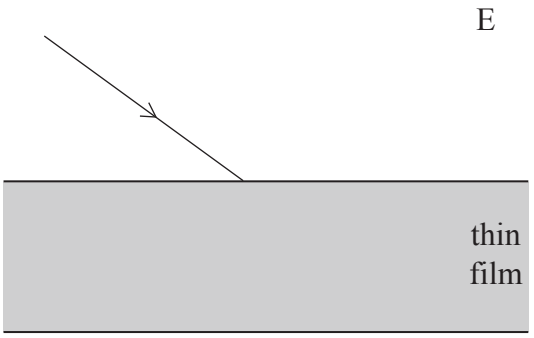
G5. This question is about thin film interference.

(a) The diagram below shows a ray of monochromatic light incident on a thin film in air.



On the diagram, draw the paths of rays that would give rise to interference as seen by an eye in the region near E. *[2]*

(b) White light is incident on a soap bubble. Explain why the soap film appears coloured. *[2]*

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Option G — Electromagnetic waves

G1. This question is about laser light.

(a) Outline how laser light is produced. *[3]*

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(b) State **two** ways in which light emitted by a laser differs from light emitted from an ordinary filament lamp. *[2]*

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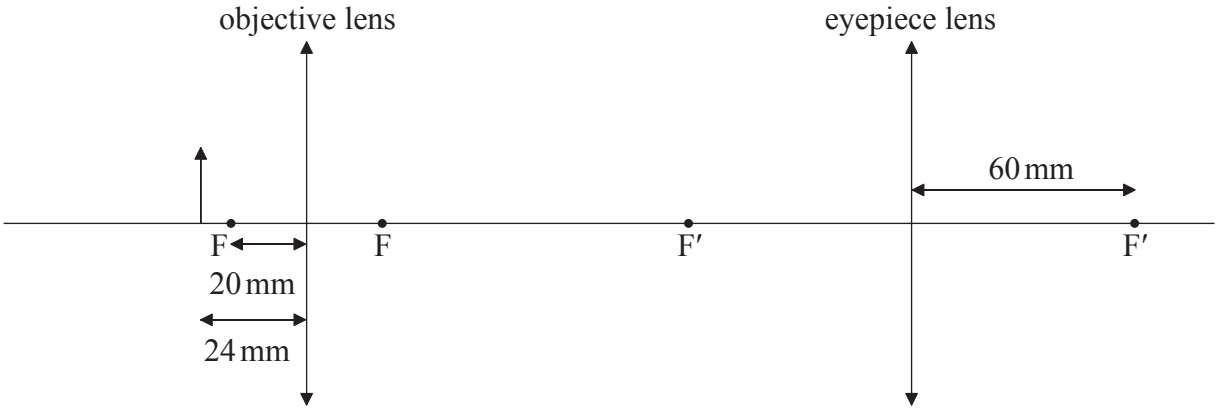
G2. This question is about a compound microscope.

The diagram (not to scale) is of a compound microscope.



The focal length of the objective lens is 20 mm and that of the eyepiece lens is 60 mm. A small object is placed at a distance of 24 mm from the objective lens. The microscope produces a final virtual image of the object at a distance of 240 mm from the eyepiece lens.

(a) (i) Determine, by calculation, the distance from the objective lens of the image formed by the objective lens. *[2]*

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(ii) Explain why the image in (a)(i) is real. *[1]*

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(iii) Determine the distance of the image formed by the objective lens from the eyepiece lens. *[2]*

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(b) Determine the overall magnification of the microscope. *[2]*

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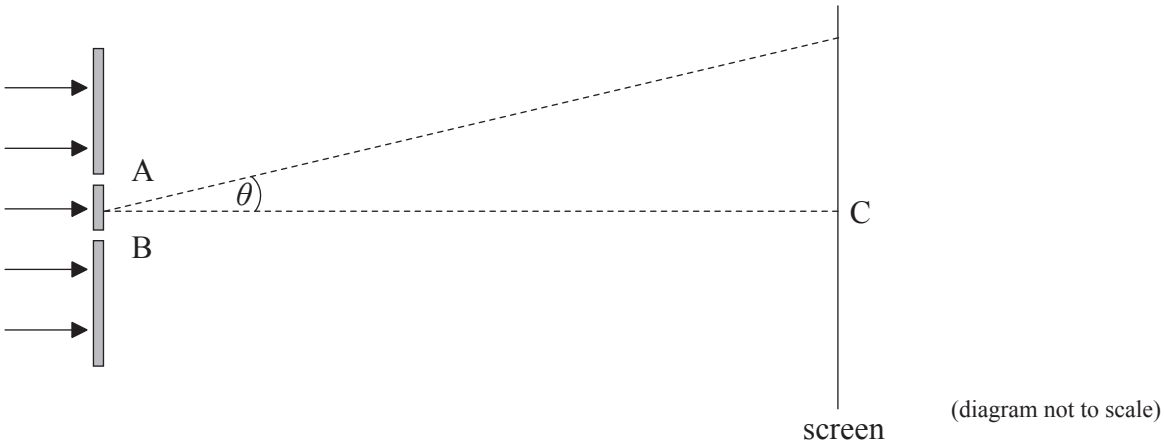
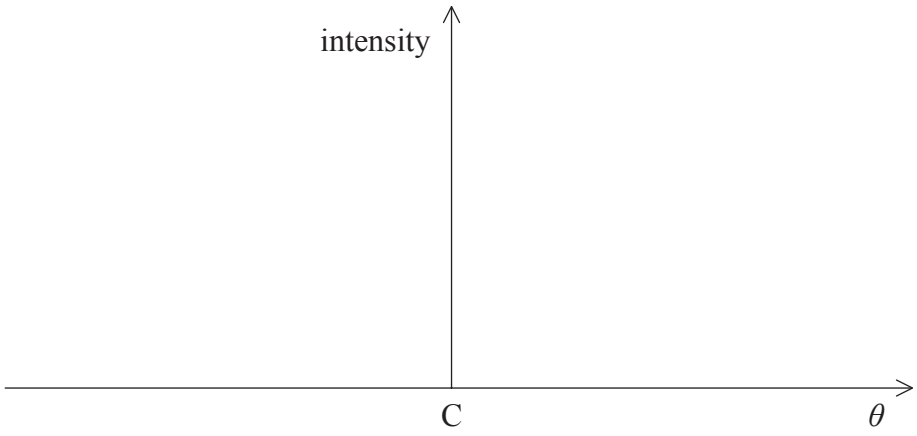
G3. This question is about interference.

(a) Light from a laser is incident on two very narrow slits A and B.



Point C on the screen is directly opposite the midpoint of the slits.

(i) On the axes below, sketch the variation with angle θ of the intensity of the light on the screen. *[2]*



(ii) The separation of the slits is 0.120 mm and the wavelength of the light is 6.80×10^{-7} m. The distance between the slits and the screen is 1.40 m. Calculate the separation of the bright fringes on the screen. *[2]*

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(This question continues on the following page)

(Question G3 continued)

(b) Slit A is covered with a transparent piece of glass. The effect of the glass is to increase the path length of the light from the slit to the screen by half a wavelength. It may be assumed that the amount of light absorbed by the glass is negligible. State and explain the effect(s), if any, of the glass on the

(i) intensity pattern you have drawn in (a)(i). *[2]*

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(ii) separation of the bright fringes calculated in (a)(ii). *[2]*

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G4. This question is about X-rays.

In an X-ray tube electrons are accelerated from rest through a potential difference and strike a metal target.

(a) On the axes below draw and annotate a typical X-ray spectrum. *[2]*

(b) Identify the mechanism by which the different regions of the X-ray spectrum are produced. *[3]*

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(c) In a particular X-ray tube the electrons are accelerated from rest through a potential difference of 24 kV. The minimum wavelength of the X-rays produced is 4.8×10^{-11} m. Determine a value for the Planck constant. *[3]*

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(d) X-rays of wavelength 2.25×10^{-10} m are directed towards the surface of a crystal. A strong first order reflected X-ray beam is observed when the X-rays make an angle of 28.1° with the crystal surface. Determine the separation of the atomic planes in the crystal. *[2]*

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Option G — Electromagnetic waves

G1. This question is about laser light.

(a) State **two** differences between the light emitted by a laser and that emitted by a filament lamp. *[2]*

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2. . . . . .

(b) The production of laser light relies on population inversion. Outline the meaning of the term population inversion. *[2]*

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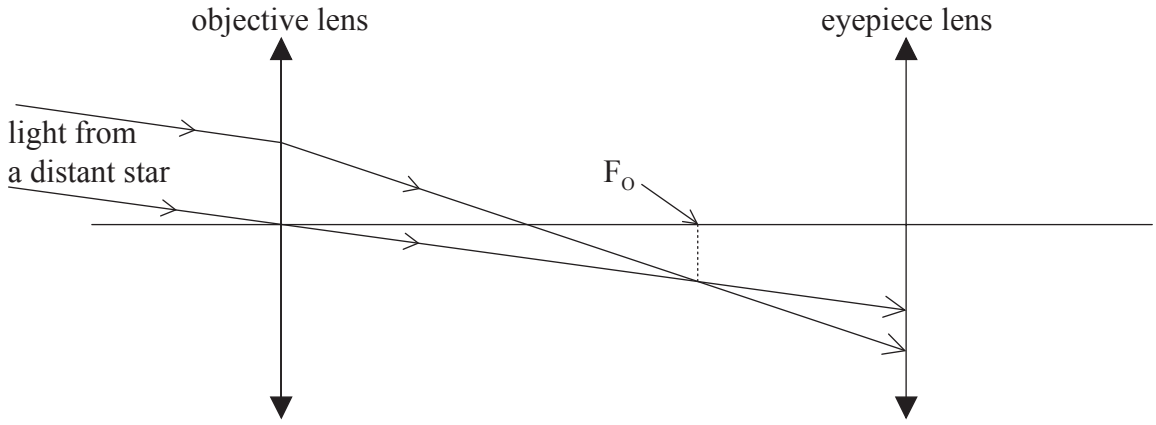
G2. This question is about an astronomical telescope.

(a) The diagram below shows two rays of light from a distant star incident on the objective of an astronomical telescope. The paths of the rays are also shown after they pass through the objective lens and are incident on the eyepiece lens of the telescope.



The principal focus of the objective lens is F_O.

On the diagram above, mark the position of the

(i) principal focus of the eyepiece lens (label this F_E). *[1]*

(ii) image of the star formed by the objective lens (label this I). *[1]*

(b) State where the final image is formed when the telescope is in normal adjustment. *[1]*

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(c) Complete the diagram in (a) to show the direction in which the final image of the star is formed for the telescope in normal adjustment. *[2]*

(This question continues on the following page)

(Question G2 continued)

The eye ring of an astronomical telescope is a device that is placed outside the eyepiece lens of the telescope at the position where the image of the objective lens is formed by the eyepiece lens. The diameter of the eye ring is the same as the diameter of the image of the objective lens. This ensures that all the light passing through the telescope passes through the eye ring.

(d) A particular astronomical telescope has an objective lens of focal length 98.0 cm and an eyepiece lens of focal length 2.00 cm (*i.e.* f_O = 98.0 cm, f_E = 2.00 cm). Determine the position of the eye ring. *[4]*

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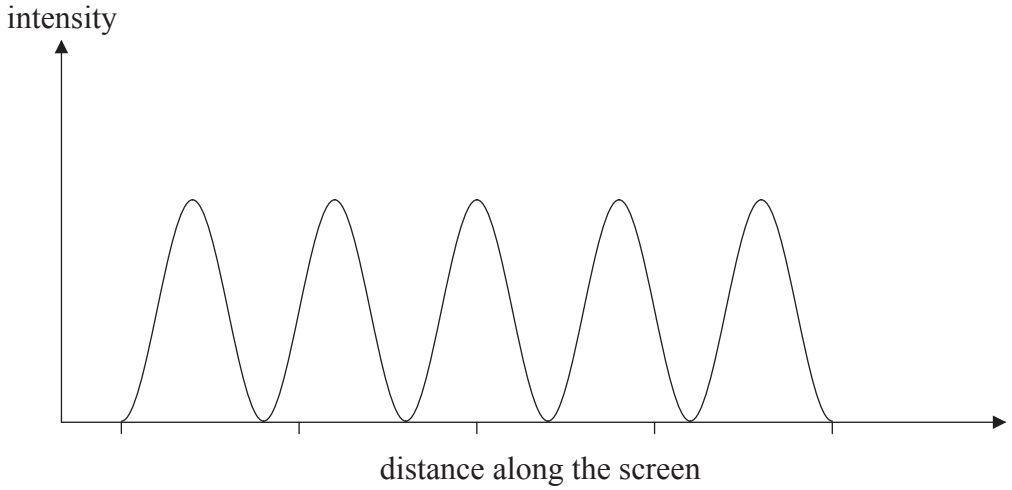
G3. This question is about interference and diffraction.

Light from a laser is incident on two slits of equal width. After passing through the slits, the light is incident on a screen. The diagram below shows the intensity distribution of the light on the screen.



(a) The wavelength of the light from the laser is 633 nm and the angular separation of the bright fringes on the screen is 4.00×10^{-4} rad. Calculate the separation of the slits. *[3]*

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(b) Light from the laser is incident on many slits of the same width as the widths of the slits above. Draw, on the above diagram, a possible new intensity distribution of the light on the screen. *[2]*

(c) The laser is replaced by a source of white light. Describe, if any, the changes to the fringes on the screen. *[2]*

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(Option G continues on page 18)

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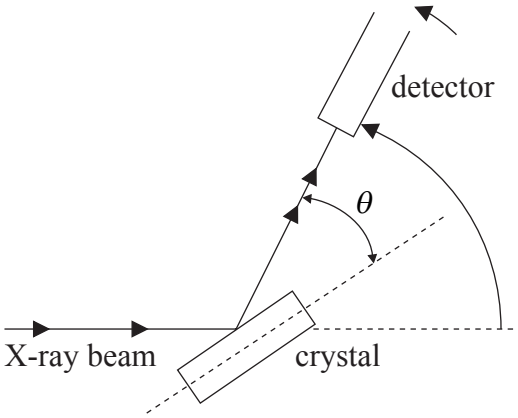
G4. This question is about X-ray diffraction.

The diagram below represents an arrangement for measuring the intensity of X-rays scattered from the surface of a cubic crystal. The angle between the surface of the crystal and the reflected ray is θ.



(This question continues on the following page)

(Question G4 continued)

The diagram below represents two lattice planes of the crystal. The lattice ions are represented by the black dots.

(a) Add lines to the diagram above to represent the incident and scattered X-rays, explain why, as the detector of the scattered X-rays is rotated, it registers a maximum of intensity at various values of the angle θ. *[4]*

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(b) The wavelength of the incident X-rays is 1.2×10^{-10} m. The first maximum value of intensity is recorded at $\theta = 12^{\circ}$. Show that the lattice spacing d in the diagram above is 2.9×10^{-10} m. *[1]*

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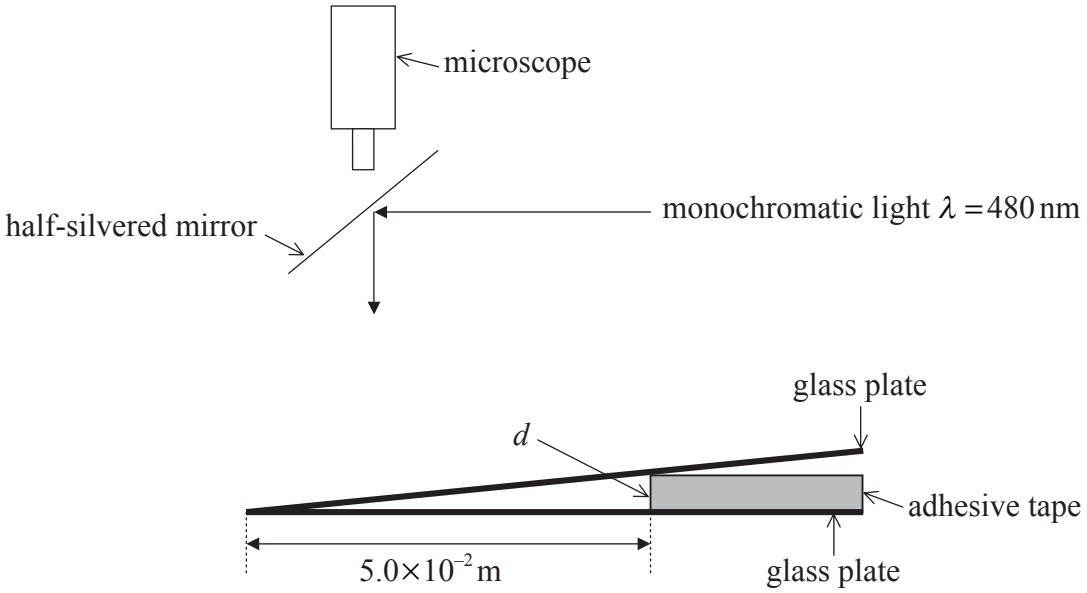
G5. This question is about a wedge film.

In an experiment to measure the thickness d of a piece of adhesive tape, the tape is used to separate two flat plates of glass as shown below. This forms a wedge shaped air film.



A beam of monochromatic light is incident on the wedge film. The light that is reflected at right angles to the wedge, is viewed using the microscope. A system of parallel fringes of equal spacing is observed in the field of view of the microscope.

(a) Outline how the fringe system is formed. *[2]*

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(b) The spacing between the fringes is $1.2\times10^{-4}\,\text{m}$. The distance from where the two plates of glass touch and the edge of the adhesive tape is $5.0\times10^{-2}\,\text{m}$. The wavelength of the light is 480 nm. Estimate the thickness d of the adhesive tape. *[3]*

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