PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 5: WAVES AND PARTICLE NATURE OF LIGHT

REFLECTION, REFRACTION AND LENSES

SCORE	PERCENTAGE
/630	%

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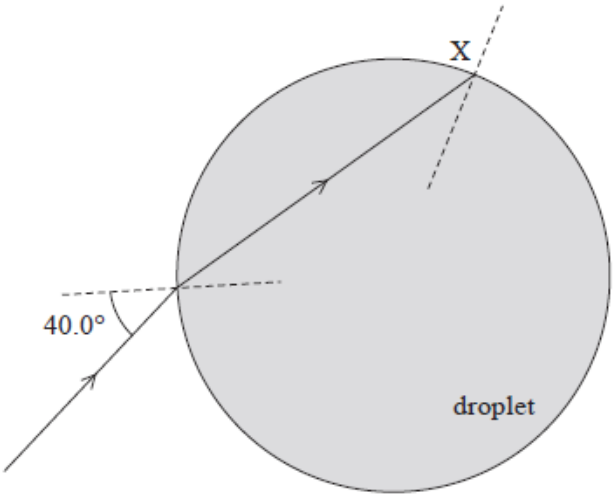
Q1.

Lighthouses are located along coastlines to aid navigation. A lighthouse emits an intense beam of light. In clear weather the beam is visible for long distances, but in foggy weather the visibility of the beam is limited.

The beam is refracted by water droplets in the air.

A light ray in the beam is incident on a spherical water droplet with an angle of incidence of 40.0°. The ray passes through the droplet and meets the water-air boundary at X as shown.

Diagram **NOT** to scale



Deduce whether the ray leaves the water droplet at point X.

speed of light in water = 2.25×10^8 m s^{-1}

(4)

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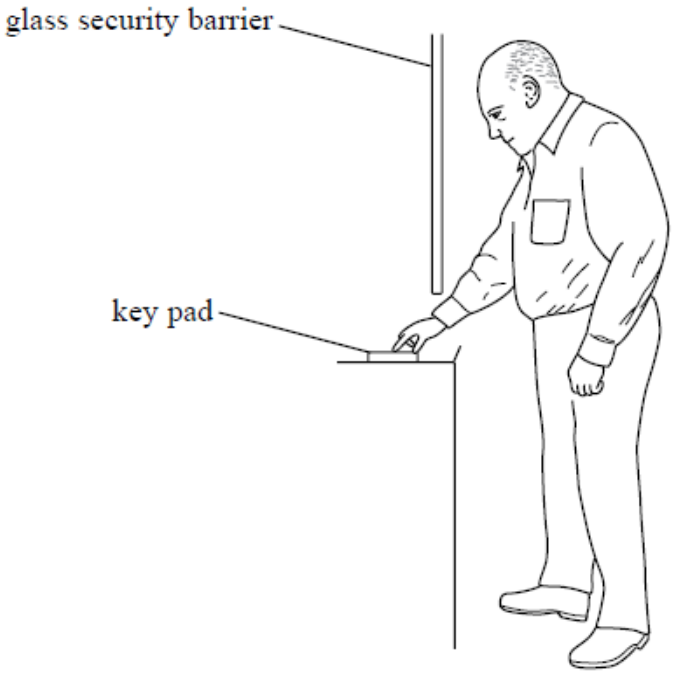
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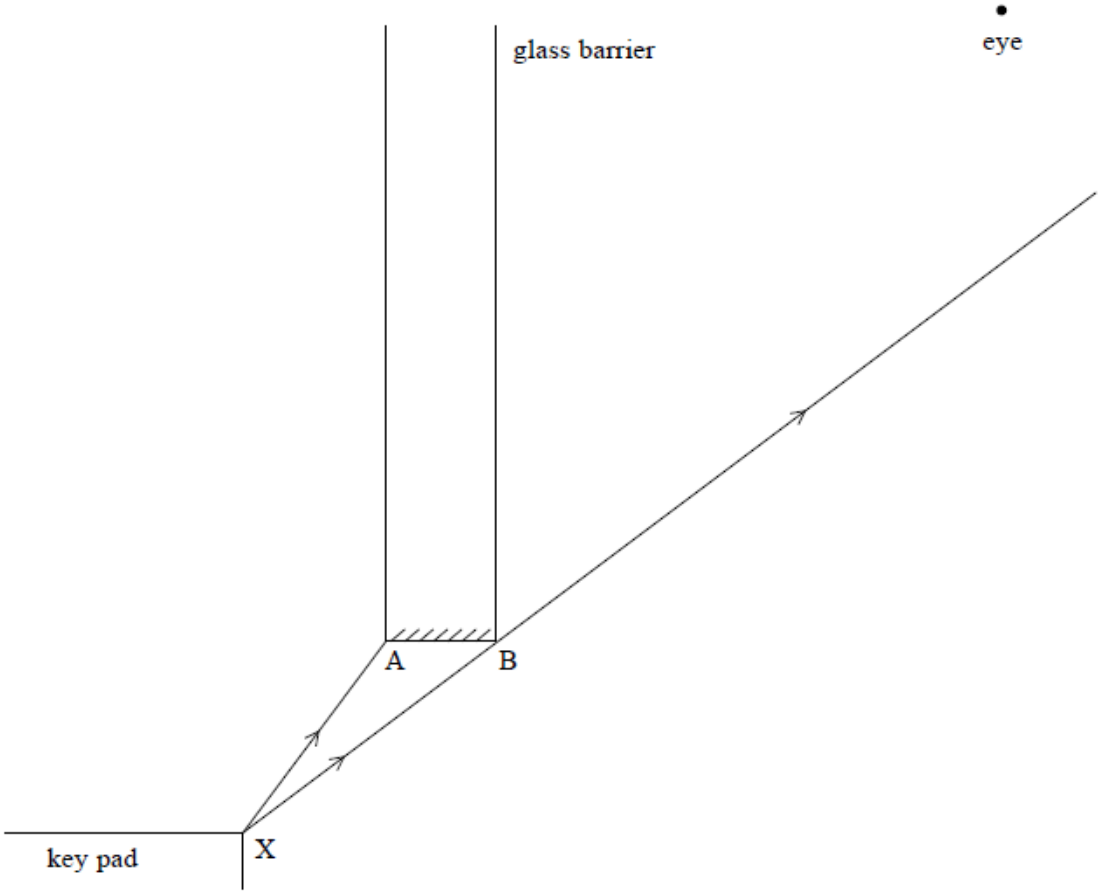
Q2.

A motorist pays for petrol at a filling station using a bank card for which a personal identification number must be entered on a key pad.

There is a thick sheet of glass between the cashier and the motorist, with a gap at the bottom to give access to the key pad.



When standing as shown in the diagram, refraction of light through the glass means that the motorist is unable to see the key pad without moving his head to see under the glass.



The diagram shows rays from the key pad. The light travelling initially along the path XA, which then passes through the glass, does not reach the motorist's eye. Assume no light passes through the surface AB.

(i) Measure the angle of incidence for the ray travelling along XA and calculate the angle of refraction in the glass.

refractive index of glass = 1.5

(3)

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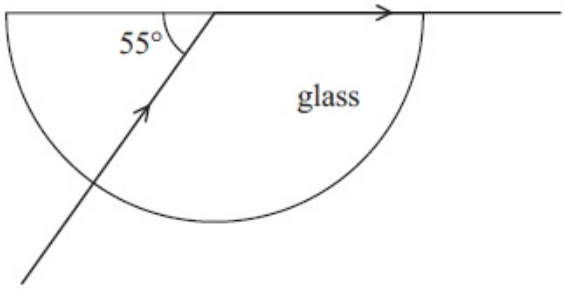
(ii) Add to the diagram to show that light travelling initially along the path XA does not reach the eye of the motorist.

(1)

(Total for question = 4 marks)

Q3.

A ray of monochromatic light passes into a glass block as shown.



The refractive index of the glass for this light is

☒ **A** 0.57

☒ **B** 0.81

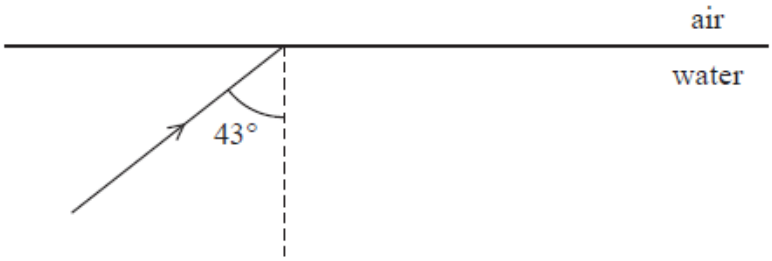
☒ **C** 1.22

☒ **D** 1.74

(Total for question = 1 marks)

Q4.

A ray of light travelling through water strikes the surface at angle of 43° as shown in the diagram.



Determine whether the ray will undergo total internal reflection.

speed of light in water = 2.25 × 108 m s^{-1}

speed of light in air = 3.00 × 108 m s^{-1}

(3)

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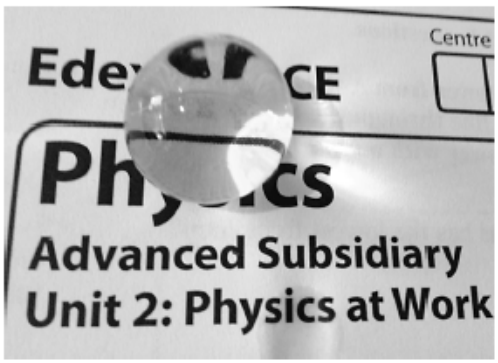
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Q5.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photograph below shows some writing seen through one of these gel balls. The writing is distorted because the gel ball refracts light.



(a) Explain what is meant by refraction.

(2)

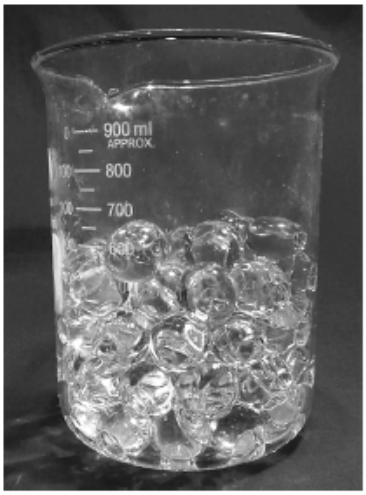
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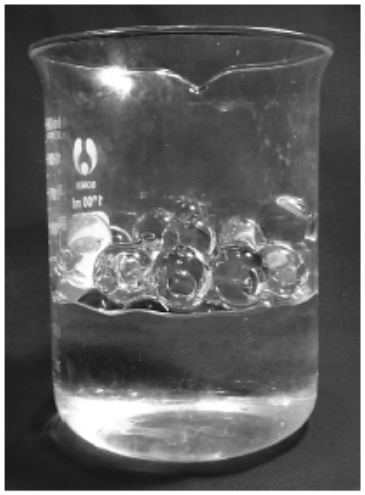
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(b) The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.





Explain how this shows that the gel has the same refractive index as water.

(2)

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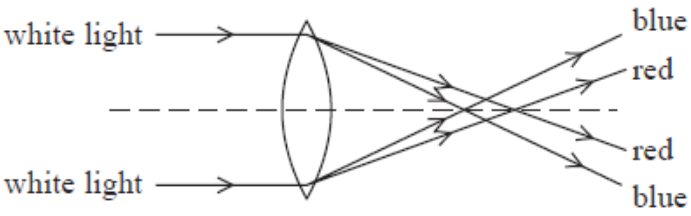
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Q6.

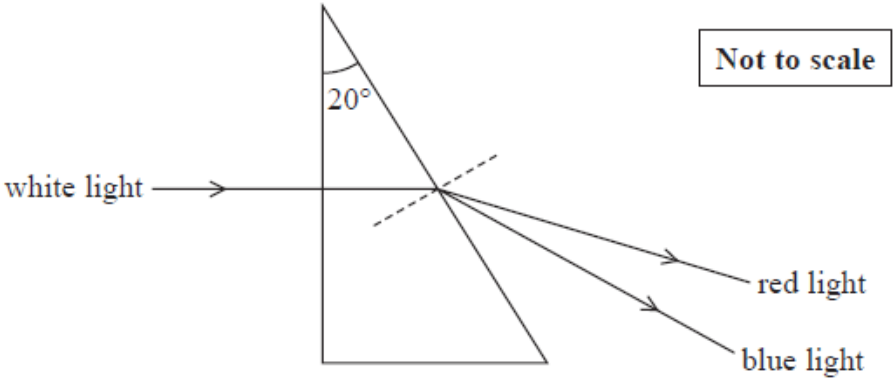
A magnifying glass consists of a converging lens and is used to magnify the details of an object.

A biologist is studying a flower using a magnifying glass. The anther of the flower has a width of 0.2 mm. The magnifying glass is placed 5.0 cm from the flower and an image of the anther is produced that is 3.5 mm wide.

The biologist notices coloured fringes around the edges of the image. This is caused by different coloured light being refracted by different angles as it passes through the lens.



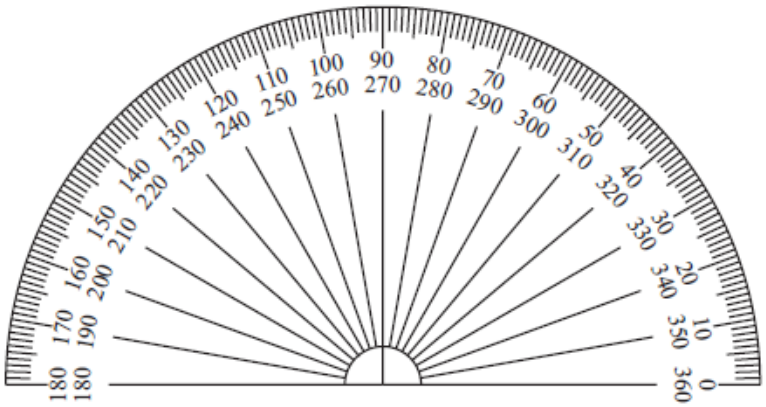
The refractive index of red and blue light as the light passes from glass into air can be investigated using a 20° glass prism.



A ray of white light is incident along the normal and passes straight into the prism.

Blue and red light rays are refracted by different angles as they leave the prism.

The angles of refraction are measured using a protractor, like the one shown.



(i) Deduce whether the measurements made using the protractor are sufficient to measure the difference in the angles of refraction between blue and red light.

refractive index of red light in glass = 1.509

refractive index of blue light in glass = 1.517

(3)

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(ii) The angle of incidence at the glass-air interface can be changed by altering the path of the light as it enters the prism. The angle of incidence of the red light at the glass-air interface is changed to 35°.

Deduce whether the red light will still be refracted at the glass-air boundary.

(3)

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(Total for question = 6 marks)

Q7.

Light passes between medium X and medium Y.

Speed of light in X = 2.00×10^8 m s^{-1}

Speed of light in Y = 2.25×10^8 m s^{-1}

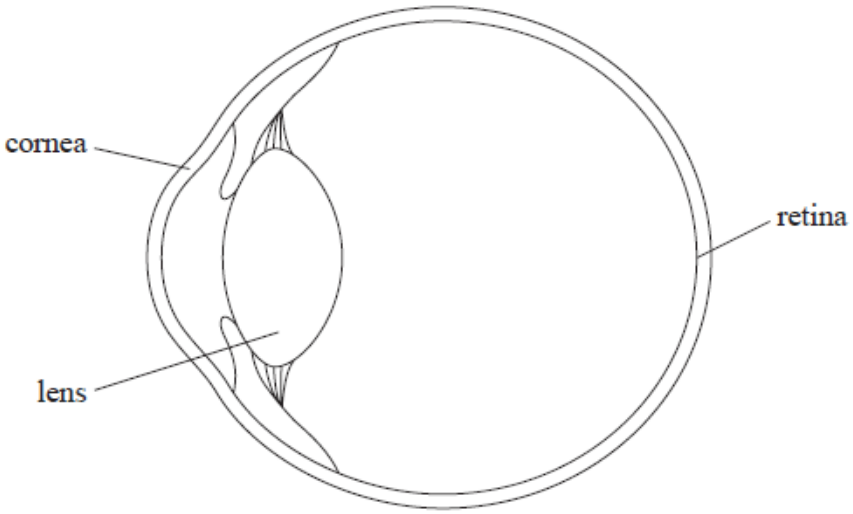
Which line of the table correctly shows what happens to the frequency and wavelength of the light as it passes from medium X to medium Y?

	Frequency	Wavelength
☒ **A**	decreases	increases
☒ **B**	increases	decreases
☒ **C**	unchanged	increases
☒ **D**	unchanged	decreases

(Total for question = 1 mark)

Q8.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



People swimming under water often wear goggles. The goggles enable them to see objects under water clearly whereas without goggles objects appear blurred.

Explain why wearing goggles has this effect.

speed of light in water = 2.25×10^{8} m s^{-1}

(3)

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(Total for question = 3 marks)

Q9.

The lens in the eye of an octopus focuses light onto the retina at the back of the eye.

The octopus focuses on objects at different distances from the eye by changing the shape of the eye to move the lens closer or further from the retina.

(i) The power of an octopus lens is 118 D.

Show that the focal length of the lens is about 8.5 mm.

(2)

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(ii) Calculate the shortest distance from the eye at which an object may be focused clearly on the retina.

maximum distance from lens to retina = 2.0 cm

(2)

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Shortest distance from the eye = ...

(iii) The lens in the eye of an octopus is in contact with seawater. The refractive index of freshwater is less than the refractive index of seawater.

Deduce what would happen to the shortest distance from the eye at which an object may be focused clearly if the octopus was in freshwater.

(3)

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(iv) Calculate the speed of light in seawater.

refractive index of seawater = 1.37

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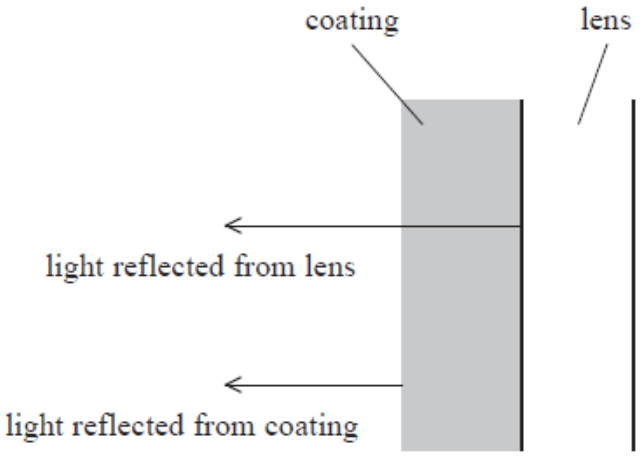
Speed of light in seawater = ...

(Total for question = 9 marks)

Q10.

Glass lenses used for optical instruments often have an anti-reflective coating. The coating is a thin layer of a transparent substance with refractive index n^c.

Light is reflected from the coating surface and from the lens surface as shown. The reflected light interferes destructively.



When a single-layer coating is used, the coating thickness is chosen to eliminate reflections for green light, which is in the middle of the visible spectrum.

(i) Calculate the minimum thickness d of the coating required for the reflection of green light to be eliminated.

frequency of green light = 6.00×10^{14} Hz
$n_c = 1.38$

(4)

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d = ...

(ii) State why white light reflected from coated lenses is seen as purple.

(1)

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(Total for question = 5 marks)

Q11.

Read the extract and answer the question that follows.

In the 17th century there were two proposed theories to explain the refraction of light. Using a wave model, Huygens stated that light slows down when it passes from air to water. Using a particle model, Newton stated that light speeds up when it passes from air to water. Newton's theory was more readily accepted until the speed of light in water was measured in the 19th century.

In the early 20th century, Einstein used observations from the photoelectric effect to provide evidence for the particle model of light.

Nowadays, both the wave model of light and the particle model of light are accepted, as each can be used to explain different aspects of the behaviour of light.

A ray of light travelling in air is incident on some water with an angle of incidence of 35°. The angle of refraction is 26°.

Deduce whether this is consistent with Huygens' statement about the speed of light as it passes from air to water. Your answer should include a calculation.

(3)

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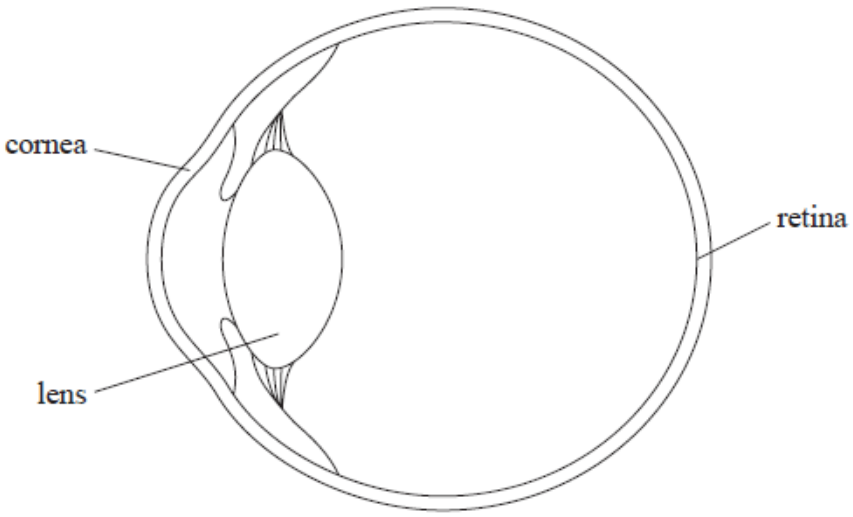
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(Total for question = 3 marks)

Q12.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



Light from a point object forms a focused image on the retina.

The cornea and lens may be treated as a single lens of focal length 1.6 cm that is 2.4 cm from the retina.

(i) Calculate the distance from the point object to this single lens when a focused image is formed on the retina.

(2)

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Distance = ...

(ii) A ray of light strikes the front of the cornea at an angle to the normal in air of 15°.

Calculate the angle of the ray to the normal in the cornea.

speed of light in air = 3.00×10^8 m s^{-1}

speed of light in cornea = 2.18×10^8 m s^{-1}

(3)

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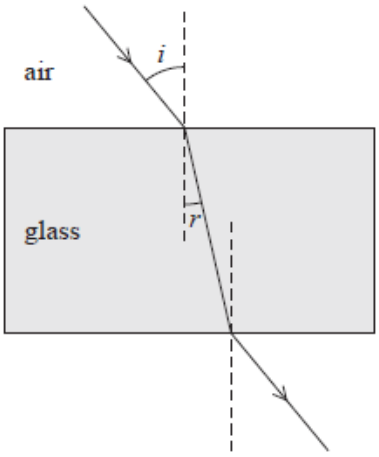
Angle to normal in cornea = ...

(Total for question = 5 marks)

Q13.

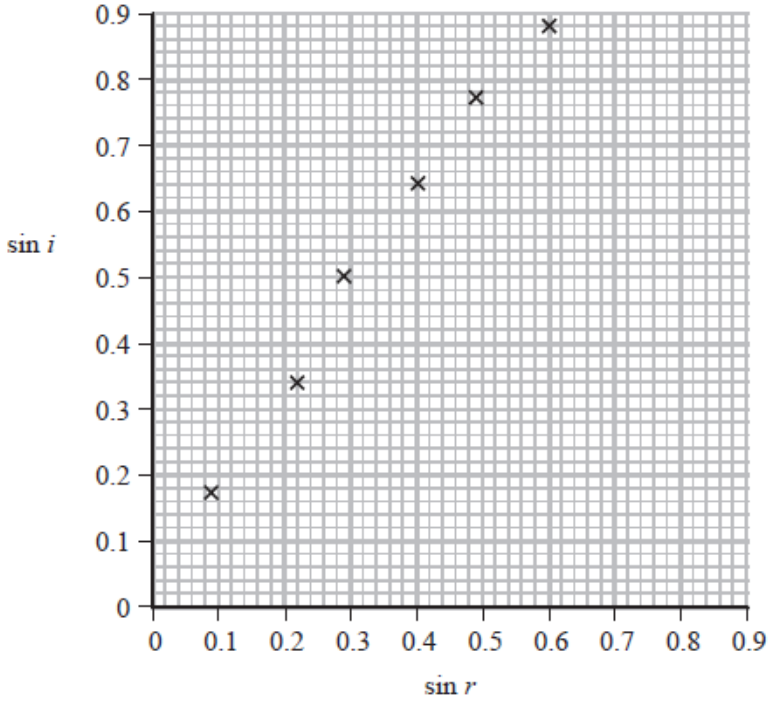
A student is carrying out an experiment to identify which type of glass a rectangular block is made from.

The student shines a ray of light onto one surface of the rectangular block.



The student marks the path of the ray on paper. He takes corresponding measurements of the angle of incidence *i* and the angle of refraction *r* at the air-glass interface.

The student plots his results on a graph of sin *i* against sin *r*.



The refractive index for three types of glass is shown.

Type of glass	Refractive index
Silica	1.458
Crown	1.755
Flint	1.925

(i) Draw a line of best fit.

(1)

(ii) Deduce which type of glass the rectangular block is made from.

(3)

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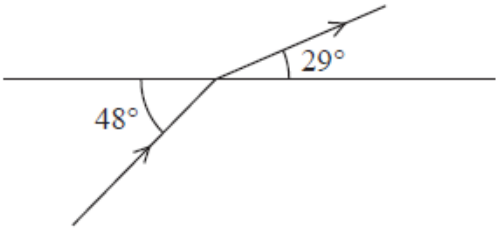
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Type of glass .....

(Total for question = 4 marks)

Q14.

The diagram shows a ray of light travelling from a transparent medium into air.



The refractive index of the transparent medium is given by

☒ **A** sin 48° / sin 29°

☒ **B** sin 42° / sin 29°

☒ **C** sin 61° / sin 48°

☒ **D** sin 61° / sin 42°

(Total for question = 1 mark)

Q15.

A student has the equipment shown in Figure 1:

- protractor
- 15 cm ruler
- laser light source
- pencil
- sheet of paper
- rectangular block of plastic.

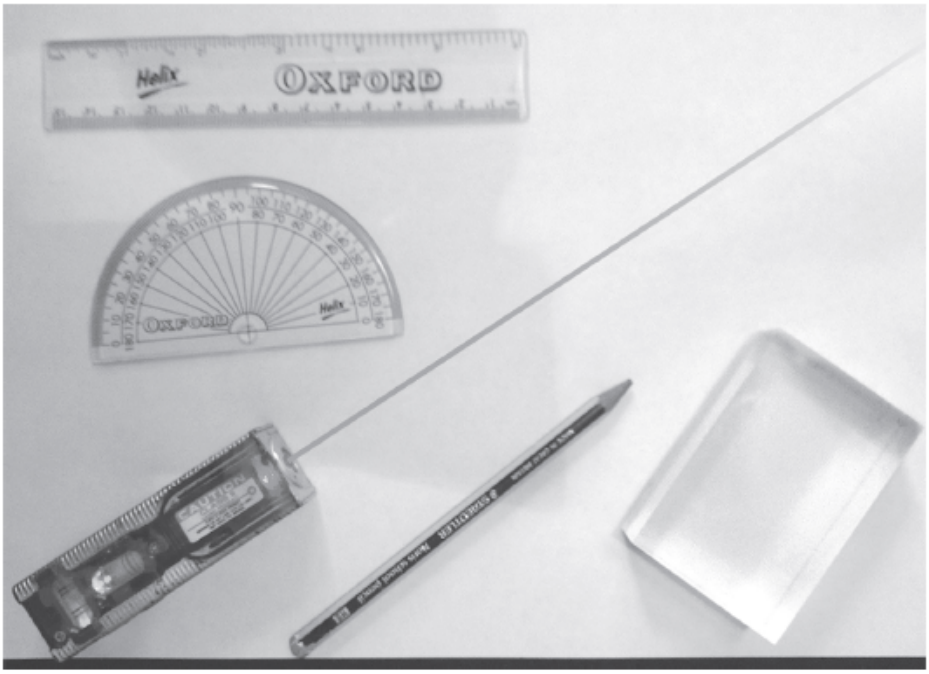


Figure 1

(a) The student uses the equipment shown in Figure 1 to take the measurements needed to determine the refractive index for light travelling from air into the plastic.

Explain **one** limitation of this equipment when used to obtain the measurements.

(2)

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(b) The value of refractive index obtained by the student was 1.52.

(i) Calculate the speed of light in the plastic.

(2)

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Speed of light in the plastic = ...

(ii) Calculate the critical angle for the plastic.

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Critical angle = ...

*(c) The student was given the shape shown in Figure 2 made from the same plastic.

Figure 3 shows what happens when light from a laser was directed at one end of the shape.



Figure 2



Figure 3

Explain the path of the laser light through the plastic as shown in Figure 3.

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(Total for question = 10 marks)

Q16. (a) You are asked to find the refractive index for light passing from air to glass by tracing the path of a ray of light through a glass block.

State the measurements you would take, the graph you would plot and how you would use the graph to determine a value for the refractive index.

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(b) (i) State what is meant by critical angle.

(2)

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(ii) Calculate the critical angle for light passing from water to air.

refractive index of water = 1.33

(2)

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Critical angle = ...

(Total for Question = 7 marks)

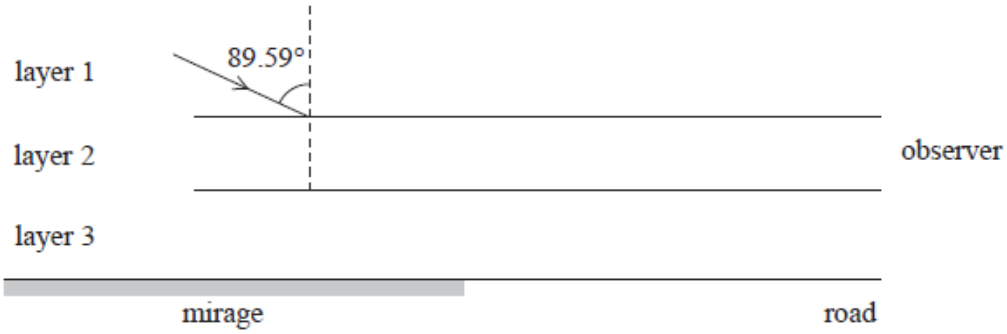
Q17.

On sunny days a mirage can sometimes be observed when a virtual image of the sky is seen on the surface of a road.



The Sun's rays heat up the surface of the road. The heated road then heats the surrounding air so that the layer of air just above the road is at a higher temperature than the air above it. Warm air has a lower refractive index than cool air.

The diagram represents a simple model which is sometimes used to explain how a mirage is formed. The three layers, each with a different refractive index, represent air at three different temperatures. Layer 3 represents the air at the highest temperature closest to the road. A light ray is shown incident at the interface between layer 1 and layer 2.



	refractive index
layer 1	1.00032
layer 2	1.00030
layer 3	1.00028

critical angle for light travelling from layer 1 to layer 2 = 89.64°
critical angle for light travelling from layer 2 to layer 3 = 89.64°

Use the information to discuss whether the observer sees a mirage on the road in the position shown.

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(Total for question = 6 marks)

Q18.

The photograph shows a man wearing a virtual reality (VR) headset.



The VR headset gives the illusion of three-dimensional vision.

Inside the VR headset a pair of lenses is used to enable the user to focus on a magnified virtual image of a screen. The lenses can be changed to suit the vision of the user.



Plastic Fresnel lenses are used in the VR headset because they are thinner and lighter than traditional glass lenses.

Instead of the continuous curved surface of a converging lens the Fresnel lens has circular ridges, each with an edge at a different angle to the adjacent ridge, as shown in the simplified cross-section in Figure 1. Figure 2 shows a ray of light entering a section of the lens.



Figure 1

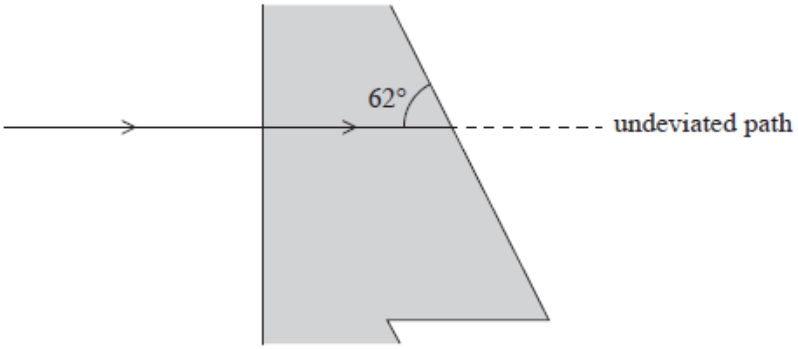


Figure 2

(i) Calculate the angle through which the ray has been deviated as it emerges from the plastic.

(4)

refractive index of plastic = 1.47

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Angle = ...

(ii) Explain how the lens focuses a beam of light travelling parallel to the principal axis.

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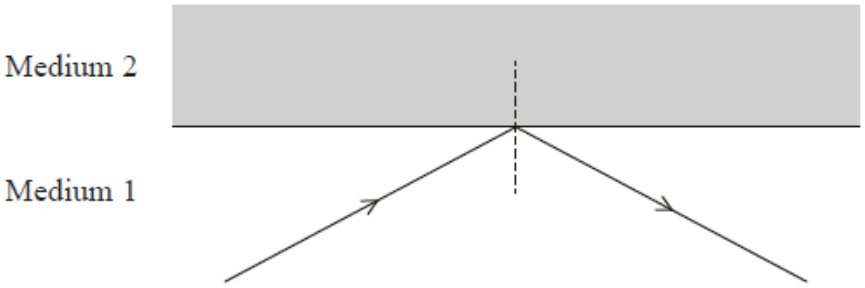
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(Total for question = 7 marks)

Q19.

A ray of light travels through medium 1 of refractive index n_1 and is incident at an interface with medium 2 of refractive index n_2. The ray is totally internally reflected at the interface.



speed of the light in medium 1 = v_1

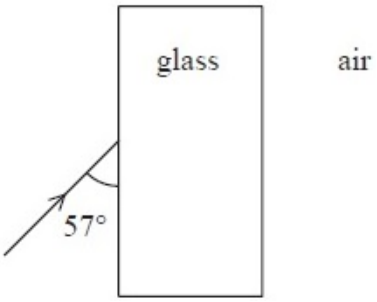
speed of the light in medium 2 = v_2

Which row of the table is correct for this situation?

☒ A	$v_1 > v_2$	$n_1 > n_2$
☒ B	$v_1 < v_2$	$n_1 > n_2$
☒ C	$v_1 > v_2$	$n_1 < n_2$
☒ D	$v_1 < v_2$	$n_1 < n_2$

(Total for question = 1 mark)

Q20. The diagram shows a ray of light incident upon the surface of a glass block.



Which line could correctly show the angle of incidence and the angle of refraction?

	Angle of incidence	Angle of refraction
☒ A	33°	21°
☒ B	33°	55°
☒ C	57°	34°
☒ D	57°	38°

(Total for Question = 1 mark)

Q21. When light rays enter the Earth's atmosphere from space they undergo refraction. This can lead to a star appearing to be in a different position from its actual position.

(a) Explain what is meant by refraction and why it occurs for light entering the Earth's atmosphere.

(3)

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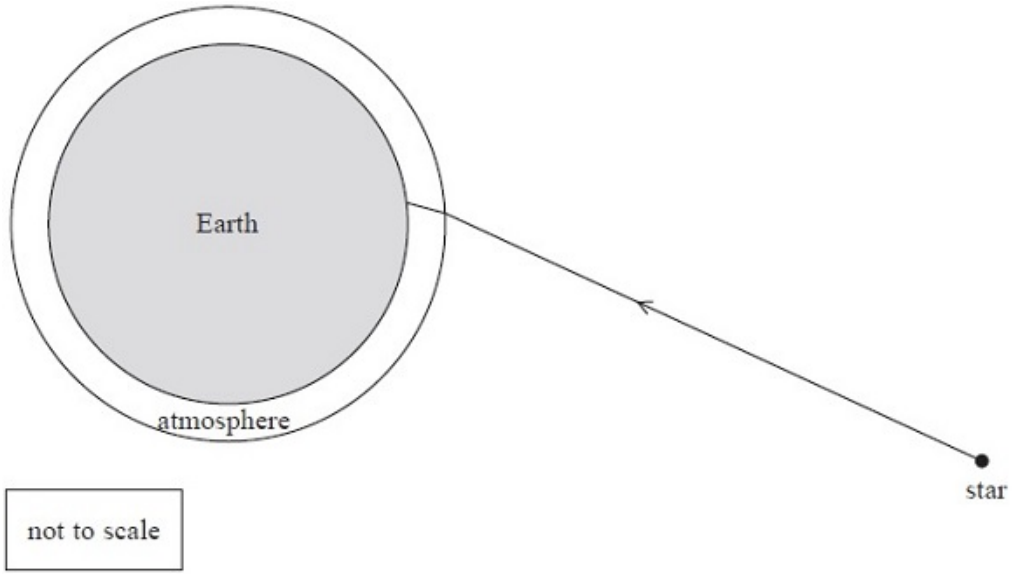
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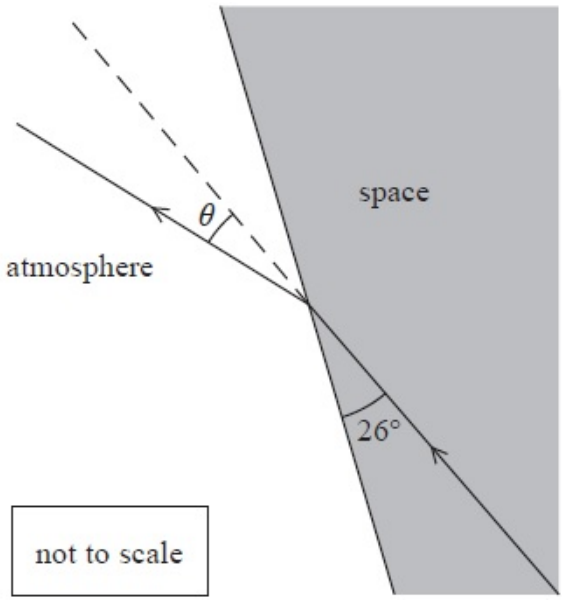
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(b) The diagram shows a ray of light from a star reaching the Earth's surface.



The diagram shows in more detail the ray of light as it enters the atmosphere.



Calculate the change in direction θ of the ray.

refractive index of atmosphere = 1.001

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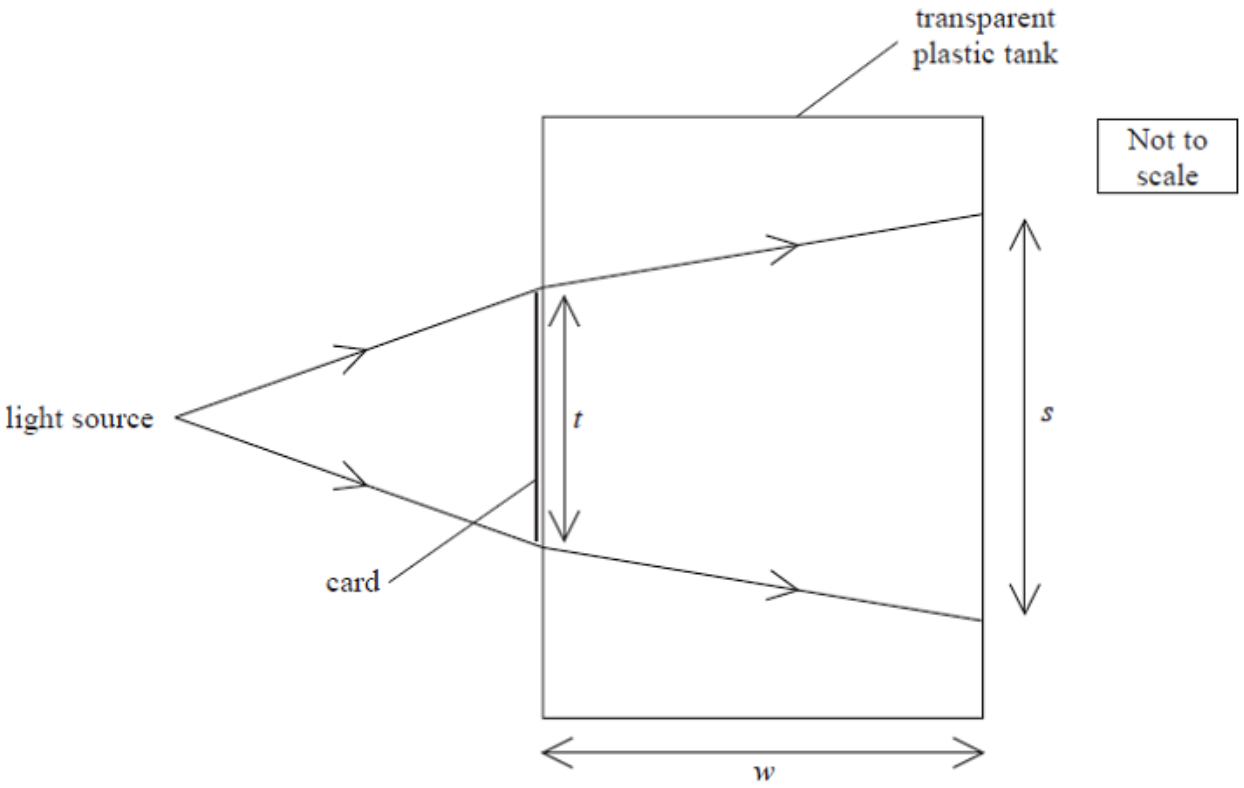
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θ = ...

(Total for Question = 7 marks)

Q22.

The diagram shows a transparent tank, with thin plastic sides, that can be used to determine the refractive index of a transparent liquid.



A rectangle of opaque card is stuck on the side of the tank containing the liquid. A light source is placed in front of the tank and the width *s* of the shadow of the card, which is formed on the back of the tank, is measured. The width *t* of the card and the width *w* of the tank are also measured.

The angle of incidence of the light as it enters the tank is 7.2°

Show that the refractive index of the liquid is about 1.4

w = 35.0 cm
t = 4.0 cm
s = 10.2 cm

(3)

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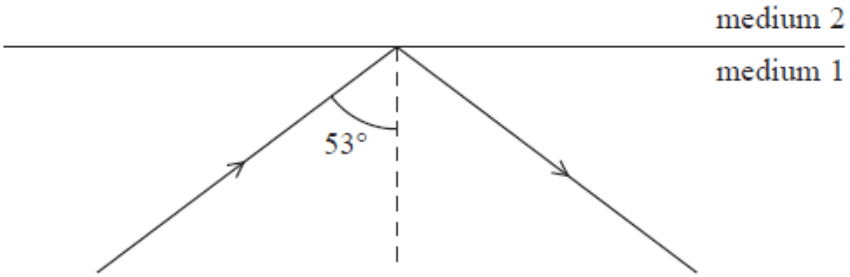
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(Total for question = 3 marks)

Q23.

Light in medium 1 strikes a boundary with medium 2 which is also transparent. The diagram shows what happens.



Which of the following can be deduced?

☒ **A** The critical angle for light travelling from medium 1 into medium 2 is 53°.

☒ **B** The refractive index of medium 1 is greater than the refractive index of medium 2.

☒ **C** The speed of light in medium 1 is greater than the speed of light in medium 2.

☒ **D** The frequency of light in medium 1 is less than the frequency of light in medium 2.

(Total for question = 1 mark)

Q24. Which of the following is a base SI unit?

☒ **A** ampere

☒ **B** coulomb

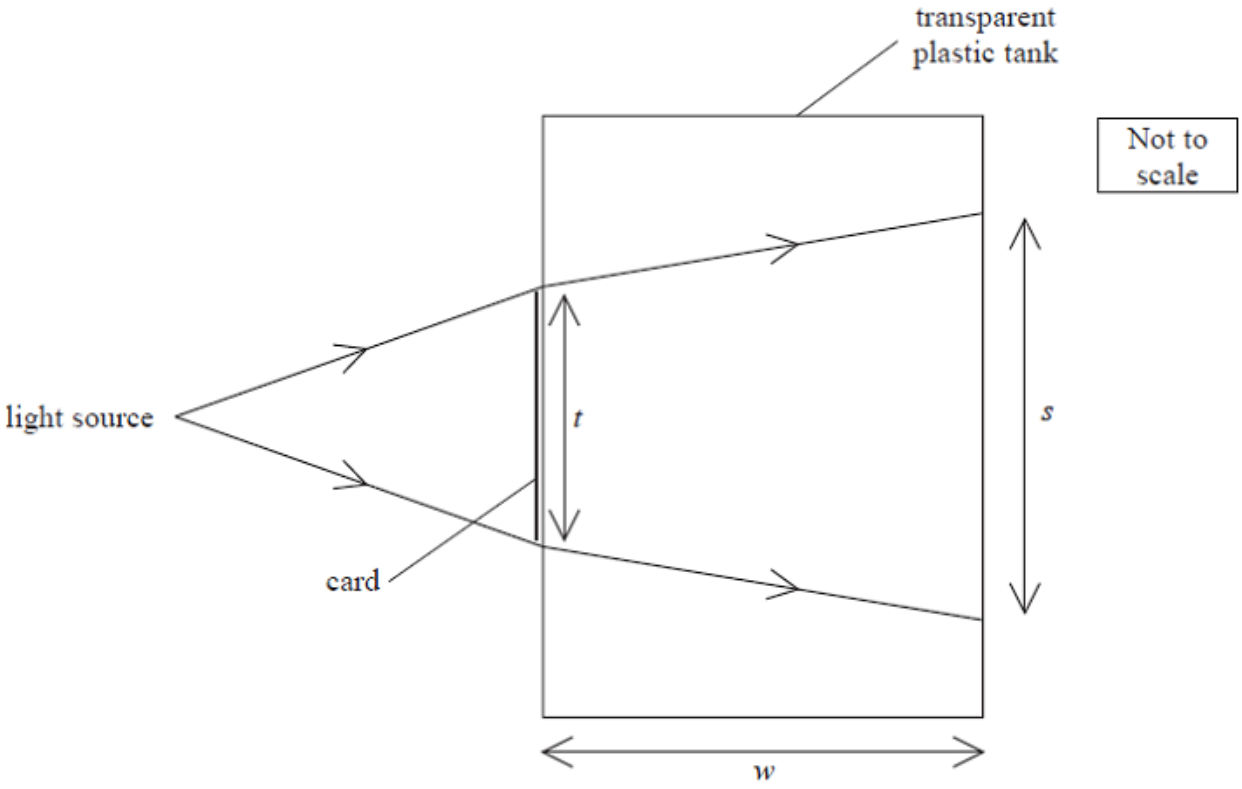
☒ **C** ohm

☒ **D** volt

(Total for Question = 1 mark)

Q25.

The diagram shows a transparent tank, with thin plastic sides, that can be used to determine the refractive index of a transparent liquid.



A rectangle of opaque card is stuck on the side of the tank containing the liquid. A light source is placed in front of the tank and the width *s* of the shadow of the card, which is formed on the back of the tank, is measured. The width *t* of the card and the width *w* of the tank are also measured.

Determine the speed of light in the liquid.

(2)

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Speed of light = ...

(Total for question = 2 marks)

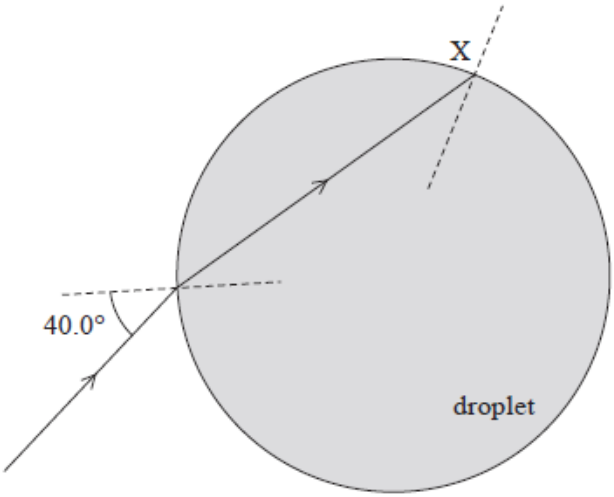
Q1.

Lighthouses are located along coastlines to aid navigation. A lighthouse emits an intense beam of light. In clear weather the beam is visible for long distances, but in foggy weather the visibility of the beam is limited.

The beam is refracted by water droplets in the air.

A light ray in the beam is incident on a spherical water droplet with an angle of incidence of 40.0°. The ray passes through the droplet and meets the water-air boundary at X as shown.

Diagram **NOT** to scale



Deduce whether the ray leaves the water droplet at point X.

speed of light in water = 2.25×10^8 m s^{-1}

(4)

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(Total for question = 4 marks)

Q2.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Light travelling in glass of refractive index n_g is incident at a boundary with water of refractive index n_w. The critical angle for the boundary is C.

Which of the following expressions is correct for this boundary?

☐ **A** $\sin C = \frac{1}{n_g}$

☐ **B** $\sin C = \frac{n_w}{n_g}$

☐ **C** $\sin C = \frac{n_g}{n_w}$

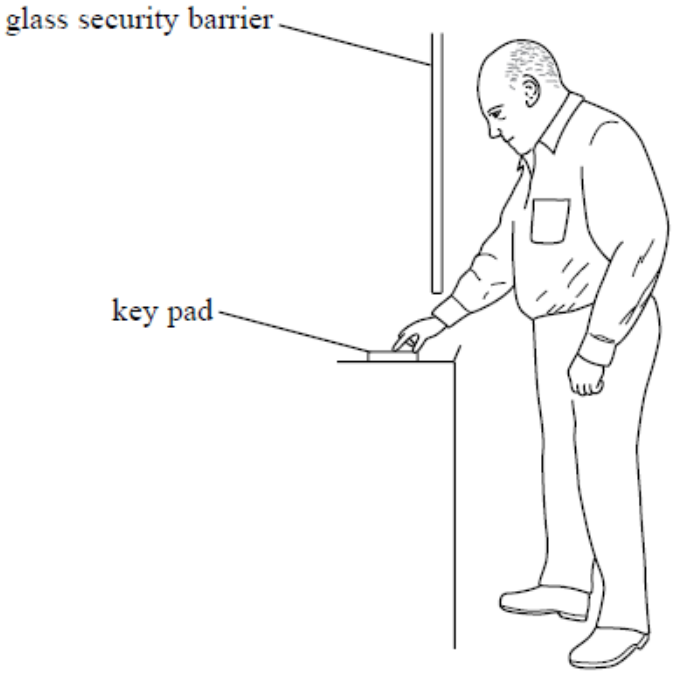
☐ **D** $\sin C = \frac{1}{n_w}$

(Total for question = 1 mark)

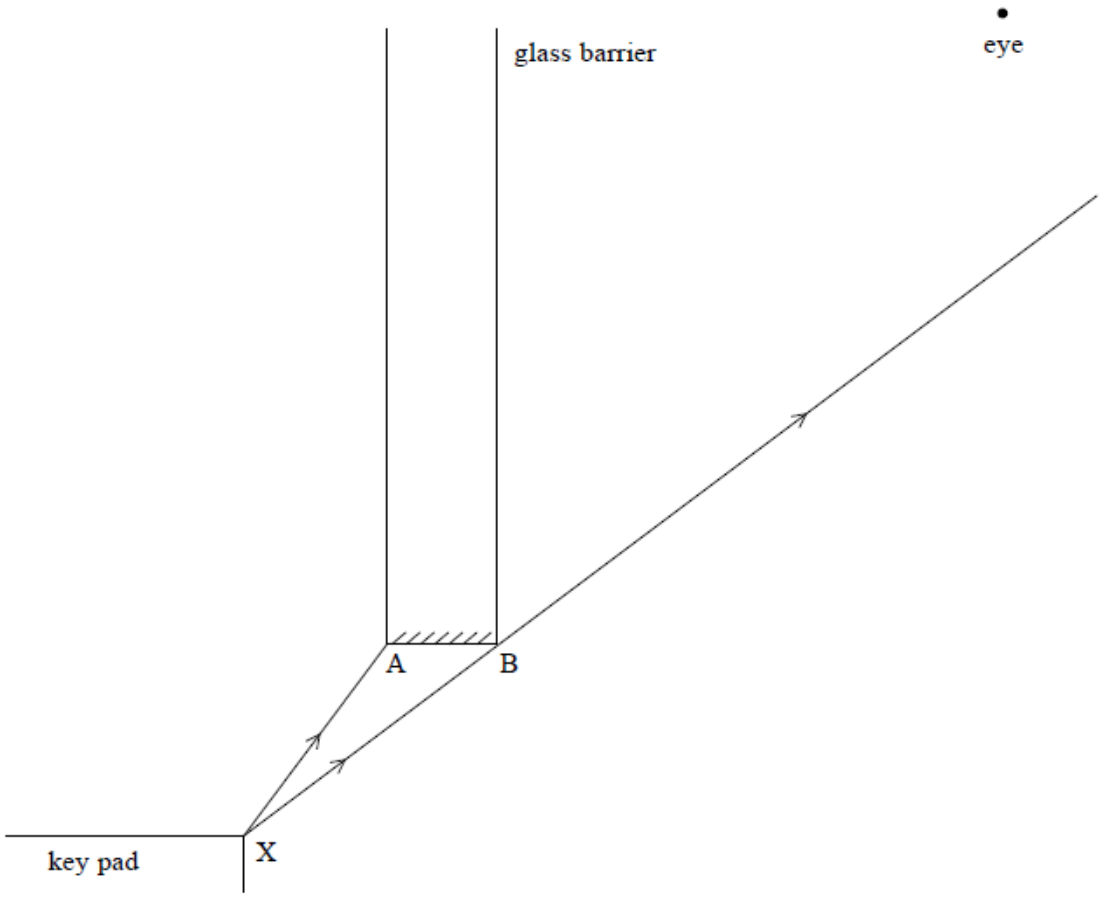
Q3.

A motorist pays for petrol at a filling station using a bank card for which a personal identification number must be entered on a key pad.

There is a thick sheet of glass between the cashier and the motorist, with a gap at the bottom to give access to the key pad.



When standing as shown in the diagram, refraction of light through the glass means that the motorist is unable to see the key pad without moving his head to see under the glass.



The diagram shows rays from the key pad. The light travelling initially along the path XA, which then passes through the glass, does not reach the motorist's eye. Assume no light passes through the surface AB.

(i) Measure the angle of incidence for the ray travelling along XA and calculate the angle of refraction in the glass.

refractive index of glass = 1.5

(3)

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(ii) Add to the diagram to show that light travelling initially along the path XA does not reach the eye of the motorist.

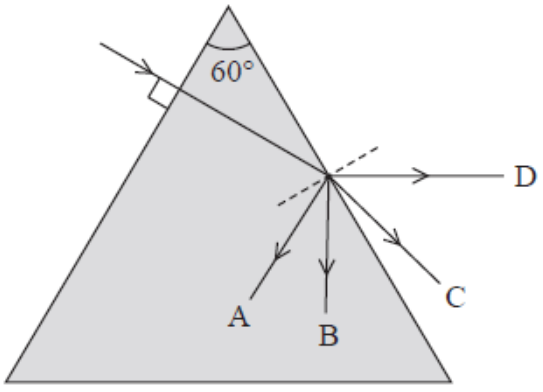
(1)

(Total for question = 4 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A ray of light, in air, is incident on the edge of a triangular glass prism as shown. The critical angle for a light ray meeting a glass to air boundary is 35°.



Which of the following gives the value of the refractive index of the glass?

☒ **A** $\sin 35$

☒ **B** $\frac{1}{\sin 35}$

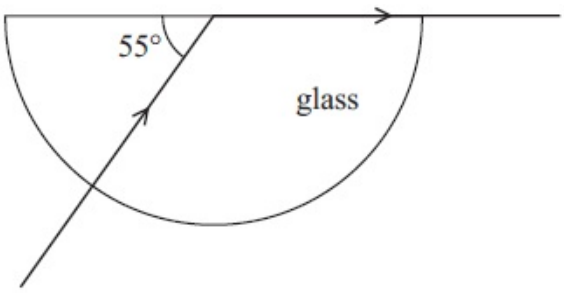
☒ **C** $\sin^{-1}\left(\frac{1}{35}\right)$

☒ **D** $\frac{1}{\sin^{-1}\left(\frac{1}{35}\right)}$

(Total for question = 1 mark)

Q5.

A ray of monochromatic light passes into a glass block as shown.



The refractive index of the glass for this light is

☒ **A** 0.57

☒ **B** 0.81

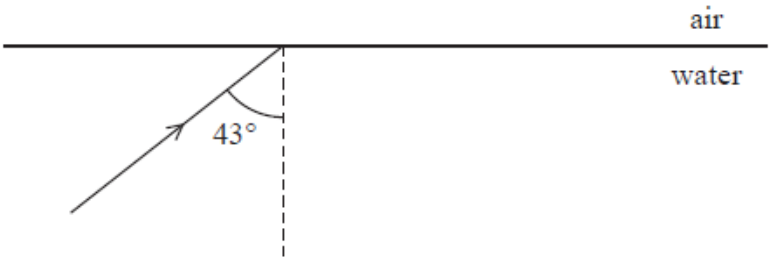
☒ **C** 1.22

☒ **D** 1.74

(Total for question = 1 marks)

Q6.

A ray of light travelling through water strikes the surface at angle of 43° as shown in the diagram.



Determine whether the ray will undergo total internal reflection.

speed of light in water = 2.25 × 108 m s^{-1}

speed of light in air = 3.00 × 108 m s^{-1}

(3)

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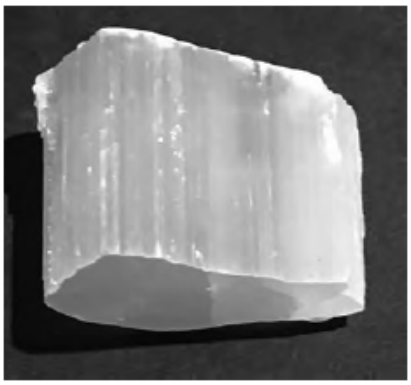
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(Total for question = # marks)

Q7.

The photograph shows a sample of the mineral selenite. Selenite is made up of many long, narrow crystals.



Selenite has a refractive index of 1.52

(i) State what is meant by critical angle.

(1)

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(ii) Calculate the critical angle for light in selenite.

(2)

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Critical angle for light in selenite = ...

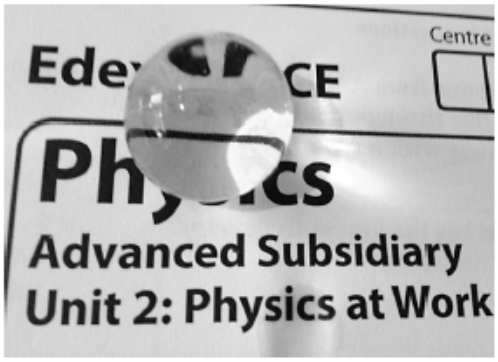
(Total for question = 3 marks)

Q8.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photograph below shows some writing seen through one of these gel balls. The writing is distorted because the gel ball refracts light.



(a) Explain what is meant by refraction.

(2)

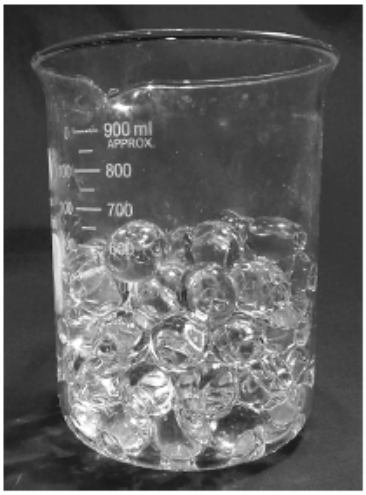
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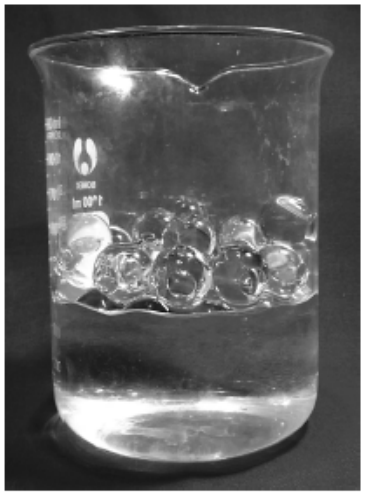
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(b) The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.





Explain how this shows that the gel has the same refractive index as water.

(2)

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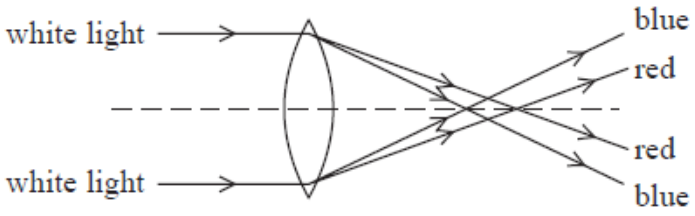
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Q9.

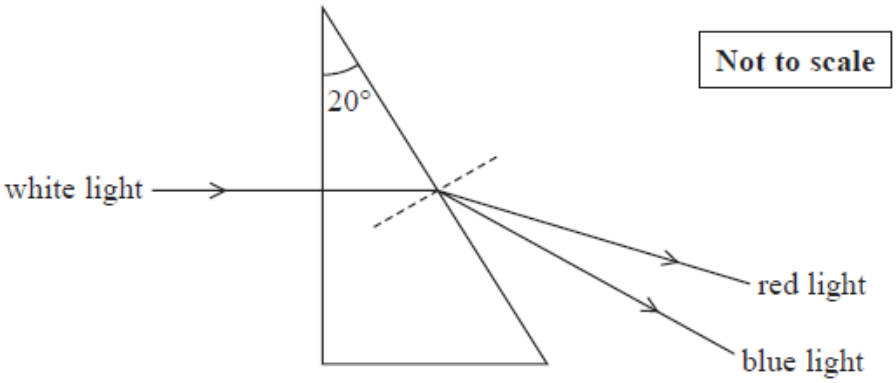
A magnifying glass consists of a converging lens and is used to magnify the details of an object.

A biologist is studying a flower using a magnifying glass. The anther of the flower has a width of 0.2 mm. The magnifying glass is placed 5.0 cm from the flower and an image of the anther is produced that is 3.5 mm wide.

The biologist notices coloured fringes around the edges of the image. This is caused by different coloured light being refracted by different angles as it passes through the lens.



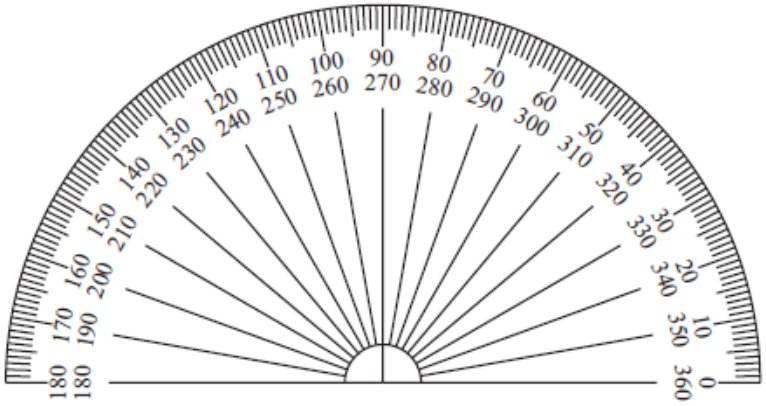
The refractive index of red and blue light as the light passes from glass into air can be investigated using a 20° glass prism.



A ray of white light is incident along the normal and passes straight into the prism.

Blue and red light rays are refracted by different angles as they leave the prism.

The angles of refraction are measured using a protractor, like the one shown.



(i) Deduce whether the measurements made using the protractor are sufficient to measure the

difference in the angles of refraction between blue and red light.

refractive index of red light in glass = 1.509

refractive index of blue light in glass = 1.517

(3)

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(ii) The angle of incidence at the glass-air interface can be changed by altering the path of the light as it enters the prism. The angle of incidence of the red light at the glass-air interface is changed to 35°.

Deduce whether the red light will still be refracted at the glass-air boundary.

(3)

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(Total for question = 6 marks)

Q10.

A student has the equipment shown in Figure 1:

- protractor

- 15 cm ruler
- laser light source
- pencil
- sheet of paper
- rectangular block of plastic.

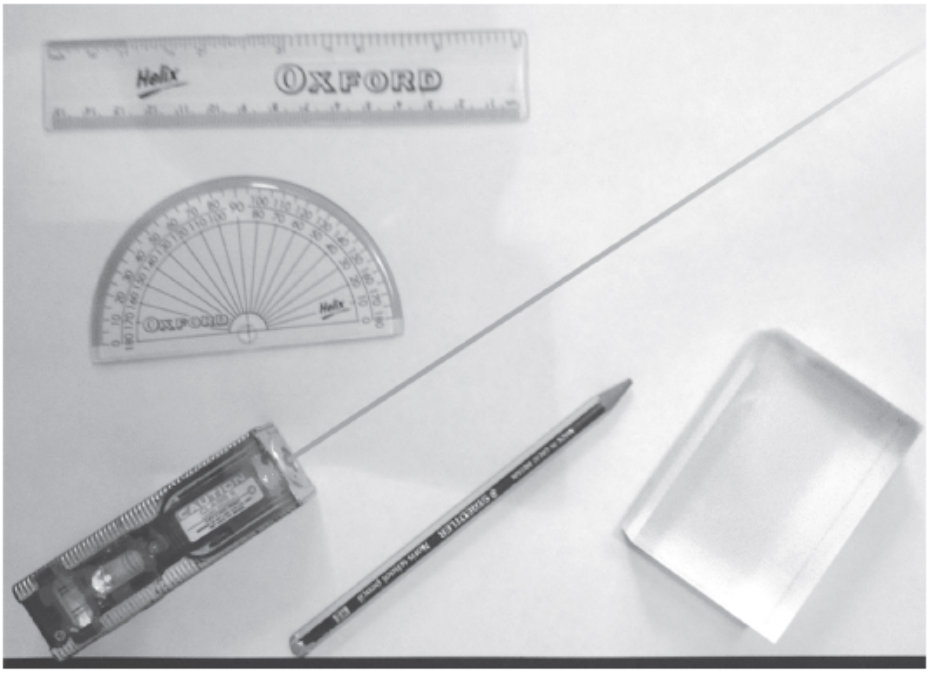


Figure 1

(a) The student uses the equipment shown in Figure 1 to take the measurements needed to determine the refractive index for light travelling from air into the plastic.

Explain **one** limitation of this equipment when used to obtain the measurements.

(2)

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(b) The value of refractive index obtained by the student was 1.52.

(i) Calculate the speed of light in the plastic.

(2)

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Speed of light in the plastic = ...

(ii) Calculate the critical angle for the plastic.

(2)

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Critical angle = ...

*(c) The student was given the shape shown in Figure 2 made from the same plastic.

Figure 3 shows what happens when light from a laser was directed at one end of the shape.



Figure 2



Figure 3

Explain the path of the laser light through the plastic as shown in Figure 3.

(4)

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(Total for question = 10 marks)

Q11. (a) You are asked to find the refractive index for light passing from air to glass by tracing the path of a ray of light through a glass block.

State the measurements you would take, the graph you would plot and how you would use the graph to determine a value for the refractive index.

(3)

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(b) (i) State what is meant by critical angle.

(2)

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(ii) Calculate the critical angle for light passing from water to air.

refractive index of water = 1.33

(2)

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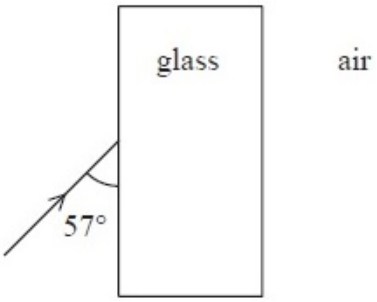
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Critical angle = ...

(Total for Question = 7 marks)

Q12. The diagram shows a ray of light incident upon the surface of a glass block.



Which line could correctly show the angle of incidence and the angle of refraction?

	Angle of incidence	Angle of refraction
☒ A	33°	21°
☒ B	33°	55°
☒ C	57°	34°
☒ D	57°	38°

(Total for Question = 1 mark)

Q13. When light rays enter the Earth's atmosphere from space they undergo refraction. This can lead to a star appearing to be in a different position from its actual position.

(a) Explain what is meant by refraction and why it occurs for light entering the Earth's atmosphere.

(3)

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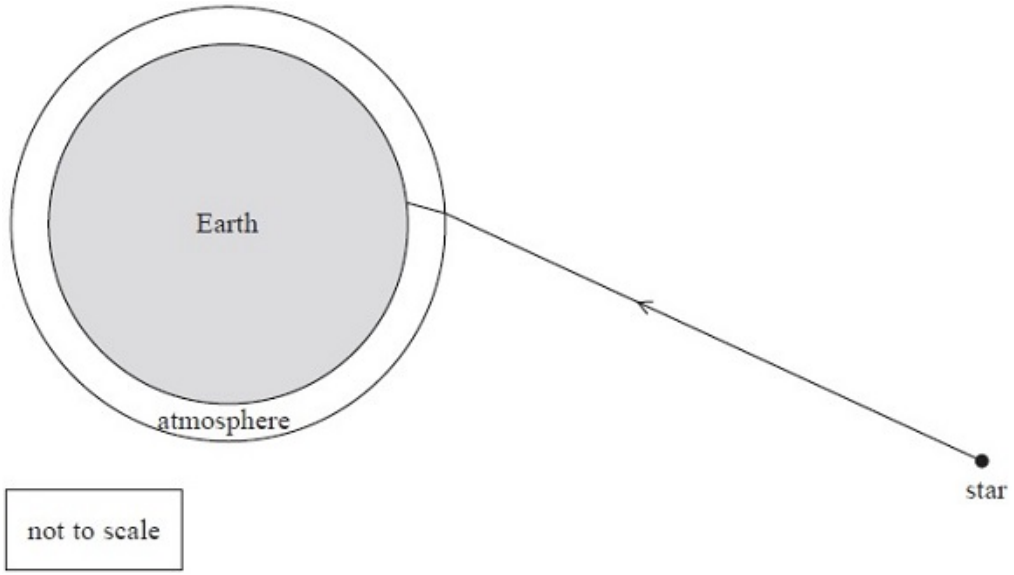
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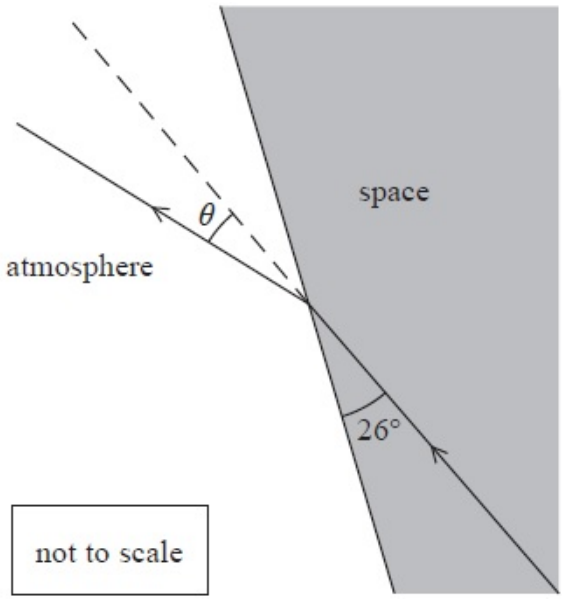
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(b) The diagram shows a ray of light from a star reaching the Earth's surface.



The diagram shows in more detail the ray of light as it enters the atmosphere.



Calculate the change in direction θ of the ray.

refractive index of atmosphere = 1.001

(4)

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θ = ...

(Total for Question = 7 marks)

Q14. Which of the following is a base SI unit?

- ☒ **A** ampere
- ☒ **B** coulomb
- ☒ **C** ohm
- ☒ **D** volt

(Total for Question = 1 mark)

Q15.

A simple optical fibre consists of a core surrounded by cladding. The refractive index of the core is 1.56 and the refractive index of the cladding is 1.20.

(a) Show that the critical angle for light between these two media is about 50°.

(3)

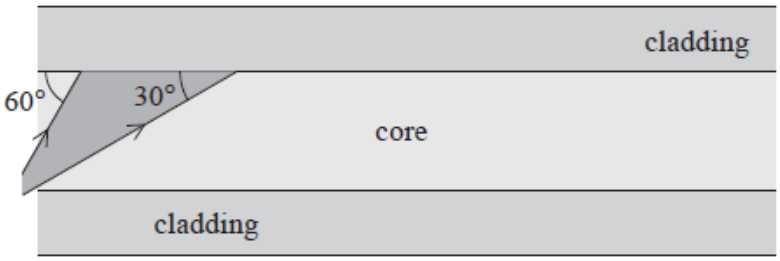
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(b) The diagram shows a diverging beam of light incident on the boundary between the core and the cladding. One side of the beam strikes the boundary at 60° and the other side at 30° as shown.



Three students each suggest a different outcome for the beam of light at the boundary.

Student A says "all the beam will totally internally reflect".

Student B says "all the beam will refract".

Student C says "some of the beam will totally internally reflect and some will refract".

State which student is correct, adding to the diagram to illustrate your answer.

(3)

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(Total for question = 6 marks)

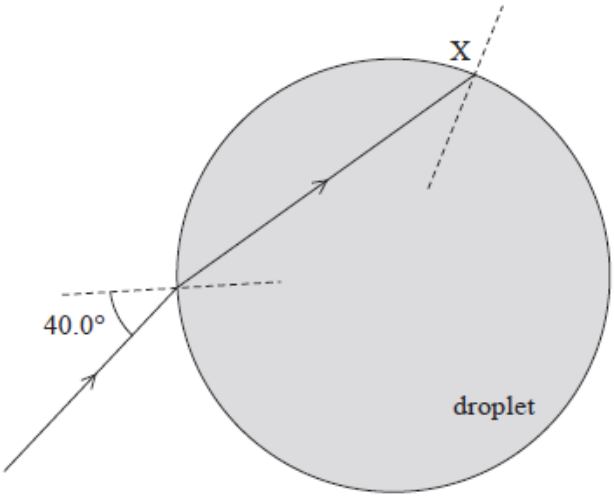
Q1.

Lighthouses are located along coastlines to aid navigation. A lighthouse emits an intense beam of light. In clear weather the beam is visible for long distances, but in foggy weather the visibility of the beam is limited.

The beam is refracted by water droplets in the air.

A light ray in the beam is incident on a spherical water droplet with an angle of incidence of 40.0°. The ray passes through the droplet and meets the water-air boundary at X as shown.

Diagram **NOT** to scale



Deduce whether the ray leaves the water droplet at point X.

speed of light in water = 2.25×10^8 m s^{-1}

(4)

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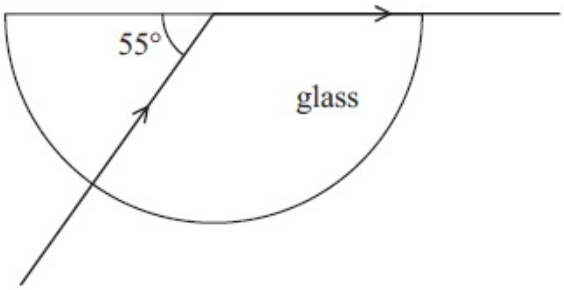
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(Total for question = 4 marks)

Q2.

A ray of monochromatic light passes into a glass block as shown.



The refractive index of the glass for this light is

☒ **A** 0.57

☒ **B** 0.81

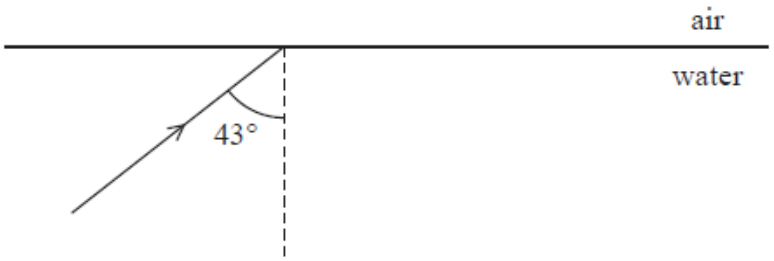
☒ **C** 1.22

☒ **D** 1.74

(Total for question = 1 marks)

Q3.

A ray of light travelling through water strikes the surface at angle of 43° as shown in the diagram.



Determine whether the ray will undergo total internal reflection.

speed of light in water = 2.25 × 108 m s^{-1}

speed of light in air = 3.00 × 108 m s^{-1}

(3)

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(Total for question = # marks)

Q4.

Magnifying 'bug boxes' are used to observe small insects. One type consists of a clear plastic pot with a snap-on lid.



© 2004 Educational Field Equipment UK Ltd.

The lid acts as a converging lens of focal length 8.5 cm.

An insect inside the box appears to be 3.5 times bigger when viewed through the lid.

(i) Draw a ray diagram to show the formation of the image by the lens when used in this way.

(3)

(ii) Calculate the distance of the insect from the lid.

(3)

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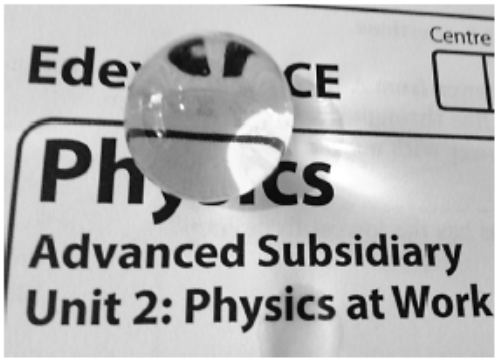
(Total for question = 6 marks)

Q5.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photograph below shows some writing seen through one of these gel balls. The writing is distorted because the gel ball refracts light.



(a) Explain what is meant by refraction.

(2)

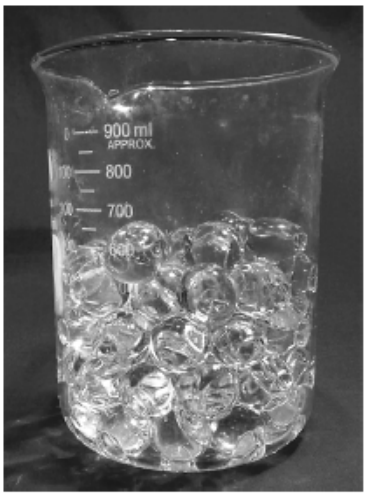
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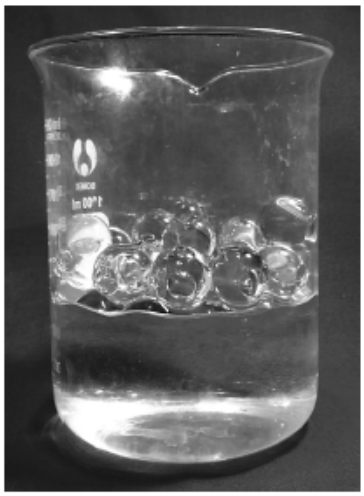
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(b) The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.





Explain how this shows that the gel has the same refractive index as water.

(2)

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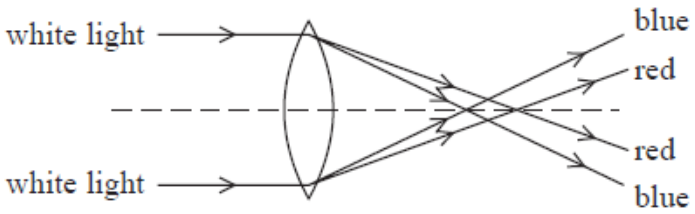
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Q6.

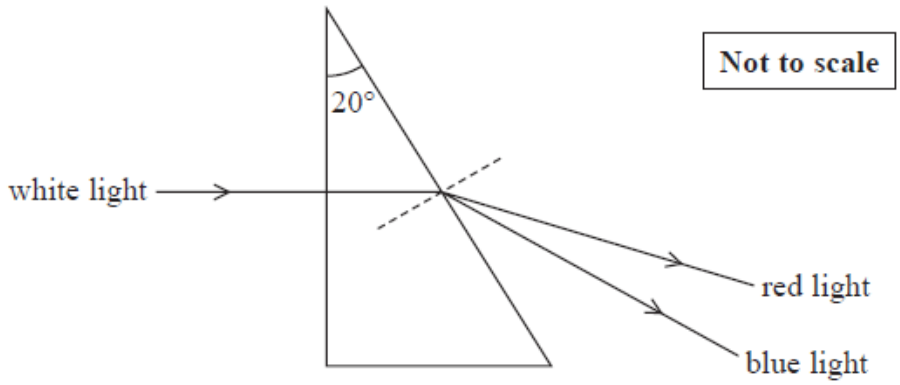
A magnifying glass consists of a converging lens and is used to magnify the details of an object.

A biologist is studying a flower using a magnifying glass. The anther of the flower has a width of 0.2 mm. The magnifying glass is placed 5.0 cm from the flower and an image of the anther is produced that is 3.5 mm wide.

The biologist notices coloured fringes around the edges of the image. This is caused by different coloured light being refracted by different angles as it passes through the lens.



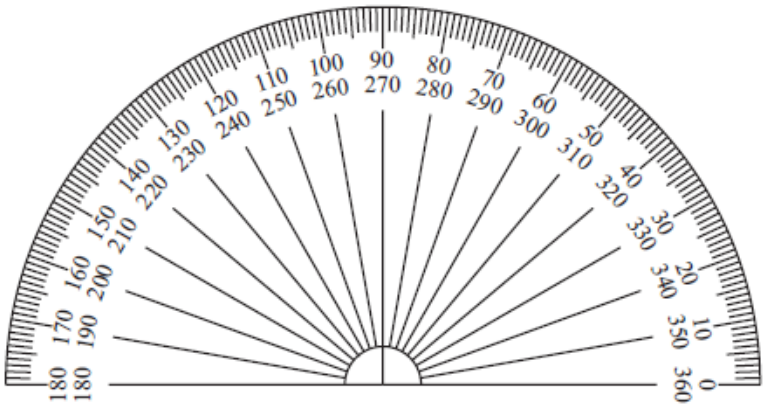
The refractive index of red and blue light as the light passes from glass into air can be investigated using a 20° glass prism.



A ray of white light is incident along the normal and passes straight into the prism.

Blue and red light rays are refracted by different angles as they leave the prism.

The angles of refraction are measured using a protractor, like the one shown.



(i) Deduce whether the measurements made using the protractor are sufficient to measure the difference in the angles of refraction between blue and red light.

refractive index of red light in glass = 1.509

refractive index of blue light in glass = 1.517

(3)

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(ii) The angle of incidence at the glass-air interface can be changed by altering the path of the light as it enters the prism. The angle of incidence of the red light at the glass-air interface is changed to 35°.

Deduce whether the red light will still be refracted at the glass-air boundary.

(3)

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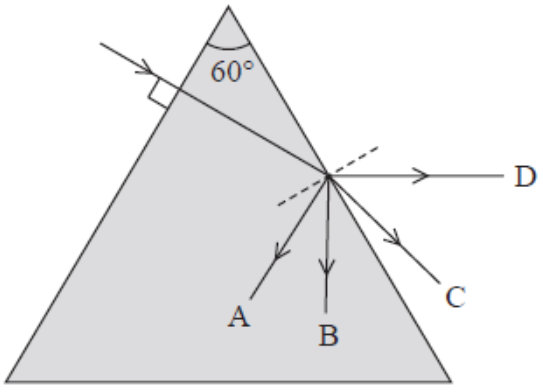
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(Total for question = 6 marks)

Q7.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A ray of light, in air, is incident on the edge of a triangular glass prism as shown.
The critical angle for a light ray meeting a glass to air boundary is 35°.



Which path, A, B, C or D, will the ray follow?

☒ **A**

☒ **B**

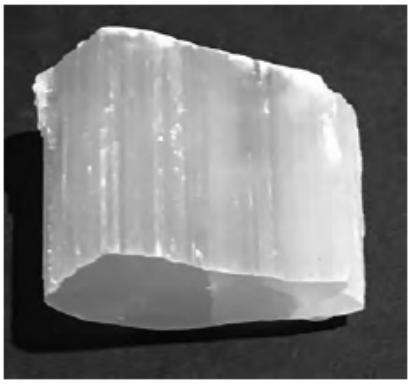
☒ **C**

☒ **D**

(Total for question = 1 mark)

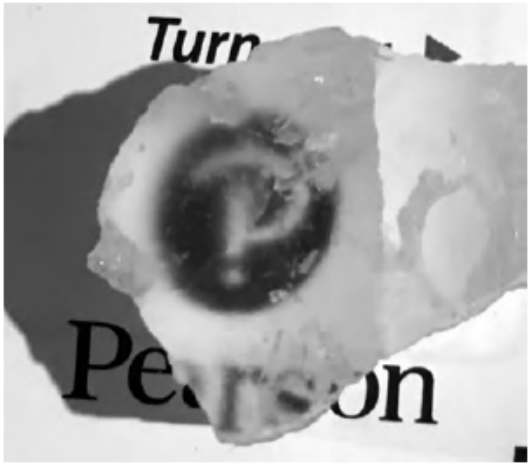
Q8.

The photograph shows a sample of the mineral selenite. Selenite is made up of many long, narrow crystals.



Selenite has a refractive index of 1.52

Selenite can act as a collection of optical fibres, so that an image of writing beneath the mineral sample appears as if it is at the upper surface as shown.



Explain how light travels through a selenite crystal.

(2)

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(Total for question = 2 marks)

Q9.

A student has the equipment shown in Figure 1:

- protractor
- 15 cm ruler
- laser light source
- pencil
- sheet of paper
- rectangular block of plastic.

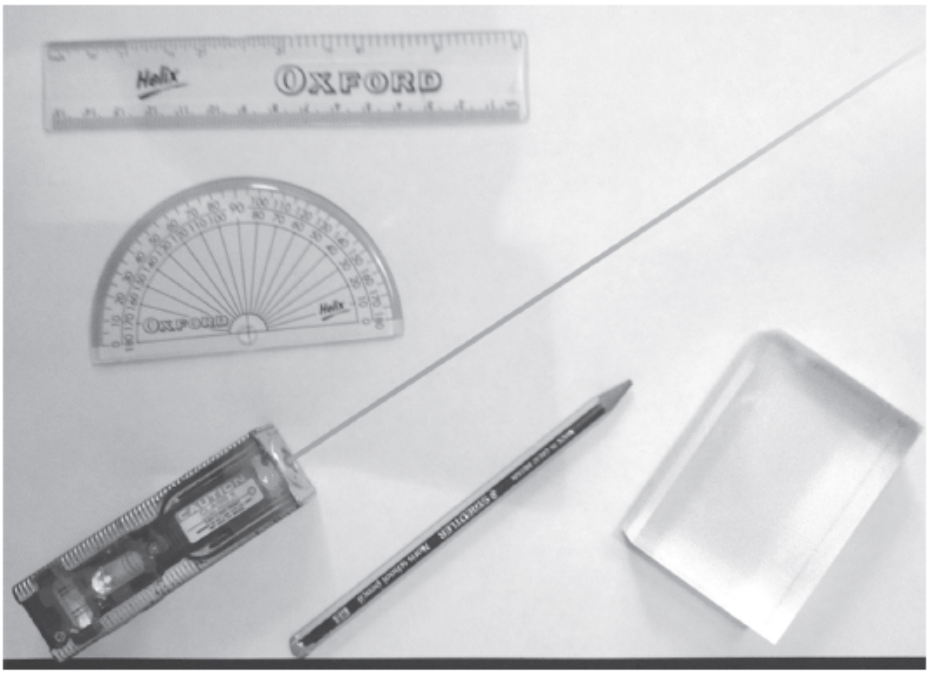


Figure 1

(a) The student uses the equipment shown in Figure 1 to take the measurements needed to determine the refractive index for light travelling from air into the plastic.

Explain **one** limitation of this equipment when used to obtain the measurements.

(2)

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(b) The value of refractive index obtained by the student was 1.52.

(i) Calculate the speed of light in the plastic.

(2)

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Speed of light in the plastic = ...

(ii) Calculate the critical angle for the plastic.

(2)

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Critical angle = ...

*(c) The student was given the shape shown in Figure 2 made from the same plastic.

Figure 3 shows what happens when light from a laser was directed at one end of the shape.



Figure 2



Figure 3

Explain the path of the laser light through the plastic as shown in Figure 3.

(4)

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(Total for question = 10 marks)

Q10. (a) You are asked to find the refractive index for light passing from air to glass by tracing the path of a ray of light through a glass block.

State the measurements you would take, the graph you would plot and how you would use the graph to determine a value for the refractive index.

(3)

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(b) (i) State what is meant by critical angle.

(2)

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(ii) Calculate the critical angle for light passing from water to air.

refractive index of water = 1.33

(2)

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Critical angle = ...

(Total for Question = 7 marks)

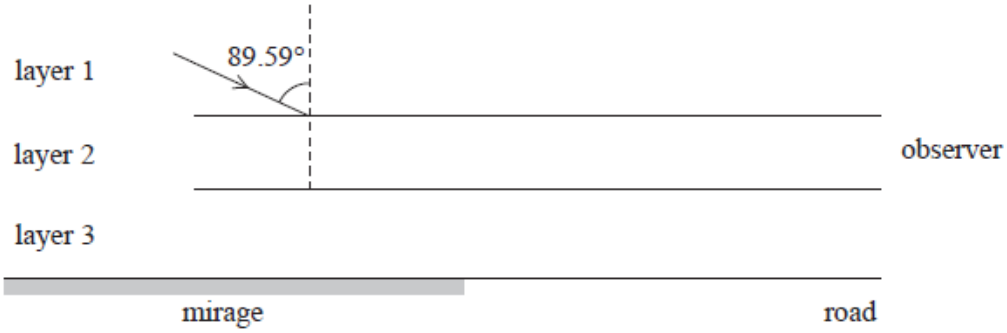
Q11.

On sunny days a mirage can sometimes be observed when a virtual image of the sky is seen on the surface of a road.



The Sun's rays heat up the surface of the road. The heated road then heats the surrounding air so that the layer of air just above the road is at a higher temperature than the air above it. Warm air has a lower refractive index than cool air.

The diagram represents a simple model which is sometimes used to explain how a mirage is formed. The three layers, each with a different refractive index, represent air at three different temperatures. Layer 3 represents the air at the highest temperature closest to the road. A light ray is shown incident at the interface between layer 1 and layer 2.



	refractive index
layer 1	1.00032
layer 2	1.00030
layer 3	1.00028

critical angle for light travelling from layer 1 to layer 2 = 89.64°
critical angle for light travelling from layer 2 to layer 3 = 89.64°

Use the information to discuss whether the observer sees a mirage on the road in the position shown.

(6)

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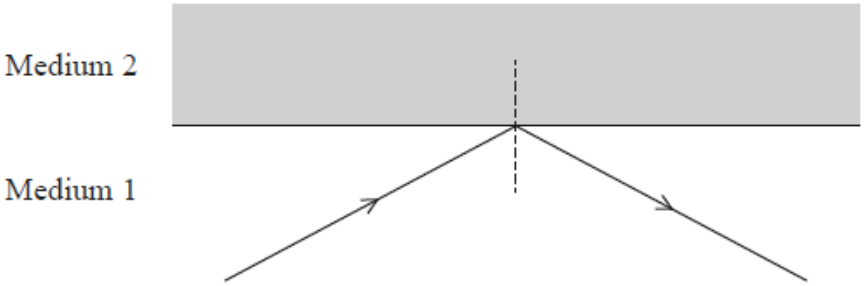
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(Total for question = 6 marks)

Q12.

A ray of light travels through medium 1 of refractive index n_1 and is incident at an interface with medium 2 of refractive index n_2. The ray is totally internally reflected at the interface.



speed of the light in medium 1 = v_1

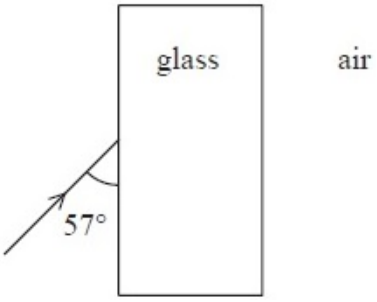
speed of the light in medium 2 = v_2

Which row of the table is correct for this situation?

☒ **A**	$v_1 > v_2$	$n_1 > n_2$
☒ **B**	$v_1 < v_2$	$n_1 > n_2$
☒ **C**	$v_1 > v_2$	$n_1 < n_2$
☒ **D**	$v_1 < v_2$	$n_1 < n_2$

(Total for question = 1 mark)

Q13. The diagram shows a ray of light incident upon the surface of a glass block.



Which line could correctly show the angle of incidence and the angle of refraction?

	Angle of incidence	Angle of refraction
☒ A	33°	21°
☒ B	33°	55°
☒ C	57°	34°
☒ D	57°	38°

(Total for Question = 1 mark)

Q14. When light rays enter the Earth's atmosphere from space they undergo refraction. This can lead to a star appearing to be in a different position from its actual position.

(a) Explain what is meant by refraction and why it occurs for light entering the Earth's atmosphere.

(3)

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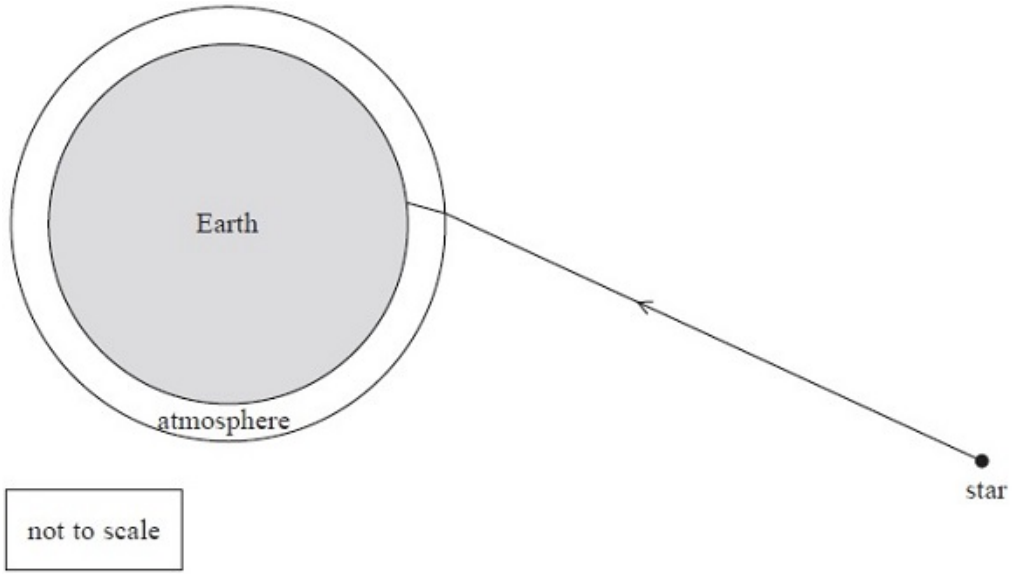
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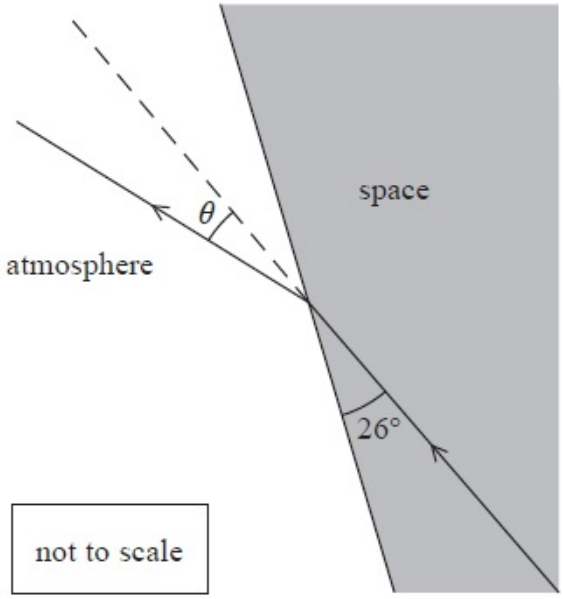
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(b) The diagram shows a ray of light from a star reaching the Earth's surface.



The diagram shows in more detail the ray of light as it enters the atmosphere.



Calculate the change in direction θ of the ray.

refractive index of atmosphere = 1.001

(4)

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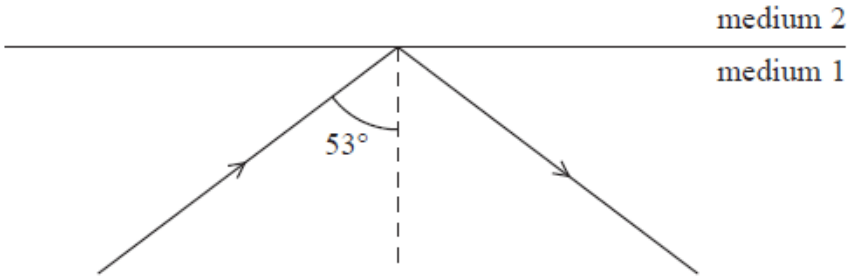
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θ = ...

(Total for Question = 7 marks)

Q15.

Light in medium 1 strikes a boundary with medium 2 which is also transparent. The diagram shows what happens.



Which of the following can be deduced?

☒ **A** The critical angle for light travelling from medium 1 into medium 2 is 53°.

☒ **B** The refractive index of medium 1 is greater than the refractive index of medium 2.

☒ **C** The speed of light in medium 1 is greater than the speed of light in medium 2.

☒ **D** The frequency of light in medium 1 is less than the frequency of light in medium 2.

(Total for question = 1 mark)

Q16. Which of the following is a base SI unit?

☒ **A** ampere

☒ **B** coulomb

☒ **C** ohm

☒ **D** volt

(Total for Question = 1 mark)

Q17.

A simple optical fibre consists of a core surrounded by cladding. The refractive index of the core is 1.56 and the refractive index of the cladding is 1.20.

(a) Show that the critical angle for light between these two media is about 50°.

(3)

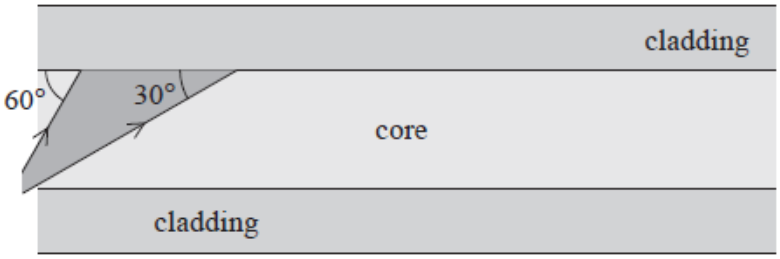
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(b) The diagram shows a diverging beam of light incident on the boundary between the core and the cladding. One side of the beam strikes the boundary at 60° and the other side at 30° as shown.



Three students each suggest a different outcome for the beam of light at the boundary.

Student A says "all the beam will totally internally reflect".

Student B says "all the beam will refract".

Student C says "some of the beam will totally internally reflect and some will refract".

State which student is correct, adding to the diagram to illustrate your answer.

(3)

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(Total for question = 6 marks)

Q18.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

For total internal reflection to take place, the angle of incidence must be

☒ **A** greater than or equal to the critical angle.

☒ **B** greater than the critical angle.

☒ **C** less than or equal to the critical angle.

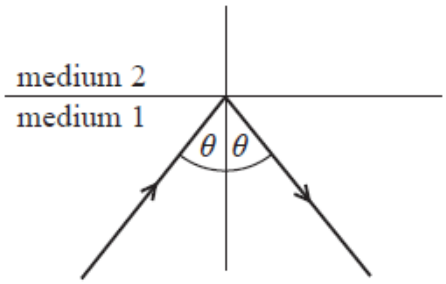
☒ **D** less than the critical angle.

(Total for question = 1 mark)

Q19.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Total internal reflection occurs when light is incident on the boundary between medium 1 and medium 2, as shown.



The refractive index of medium 1 is n_1 and the refractive index of medium 2 is n_2.

The critical angle for the boundary is C.

Which row of the table is correct?

☒	**A**	$\theta < C$	$n_1 > n_2$
☒	**B**	$\theta < C$	$n_2 > n_1$
☒	**C**	$\theta > C$	$n_1 < n_2$
☒	**D**	$\theta > C$	$n_2 < n_1$

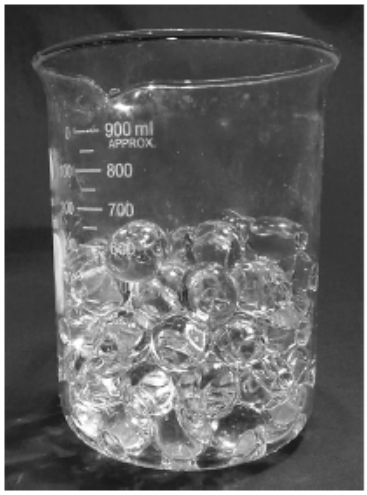
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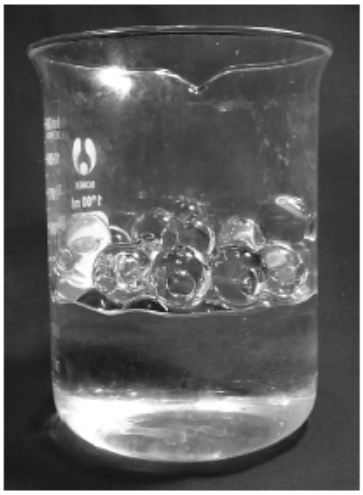
Q20.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.





(a) A student decides to use a gel ball to model the formation of a rainbow by raindrops. He wants to see if total internal reflection occurs.

Explain what is meant by total internal reflection.

(2)

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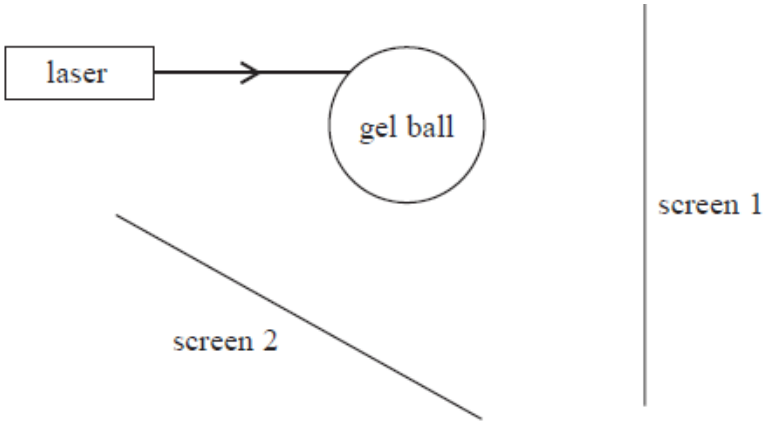
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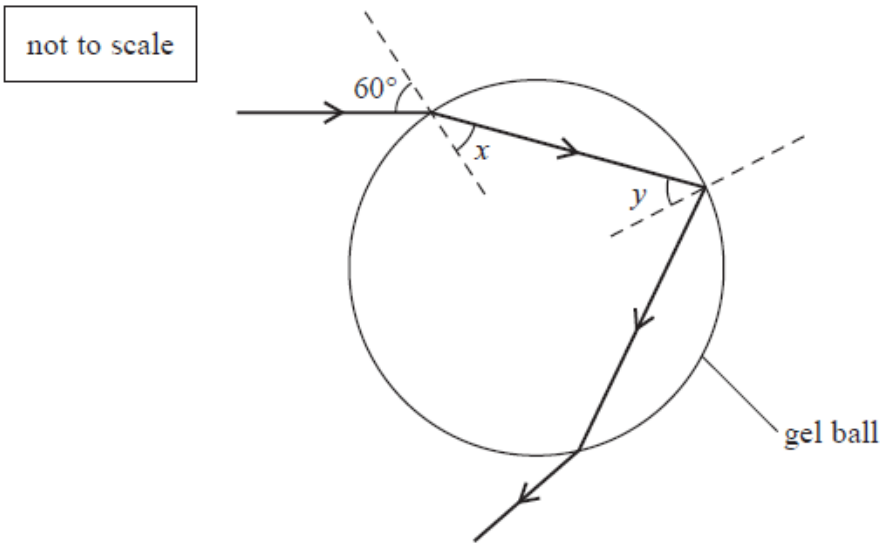
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(b) The student shines a narrow laser beam at a gel ball using the arrangement shown.



When the angle of incidence of the laser beam with the gel ball is 60°, light from the laser illuminates screen 2 following the path shown.



(i) Show that the angle x is about 40°.

refractive index of gel = 1.33

(2)

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(ii) Show that the critical angle for light striking the boundary of gel with air is about 50°.

(2)

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(iii) Angle *x* has the same value as angle *y*.
Explain whether light from the laser will be observed on screen 1.

(2)

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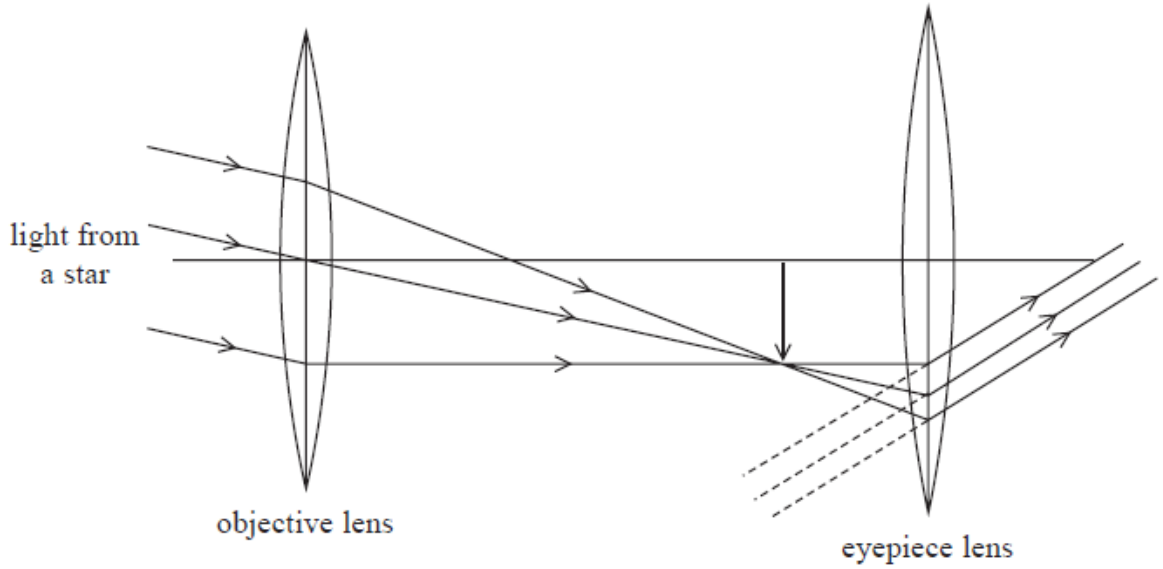
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Q3.

Q1.

A simple astronomical refracting telescope consists of two converging lenses. Light from a star is brought to a focus by the objective lens and then viewed through an eyepiece lens as shown.



(i) In the arrangement shown, the final image is formed at infinity.

Explain why the separation of the objective and eyepiece lenses is equal to the sum of their focal lengths.

(2)

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(ii) State why the final image is inverted.

(1)

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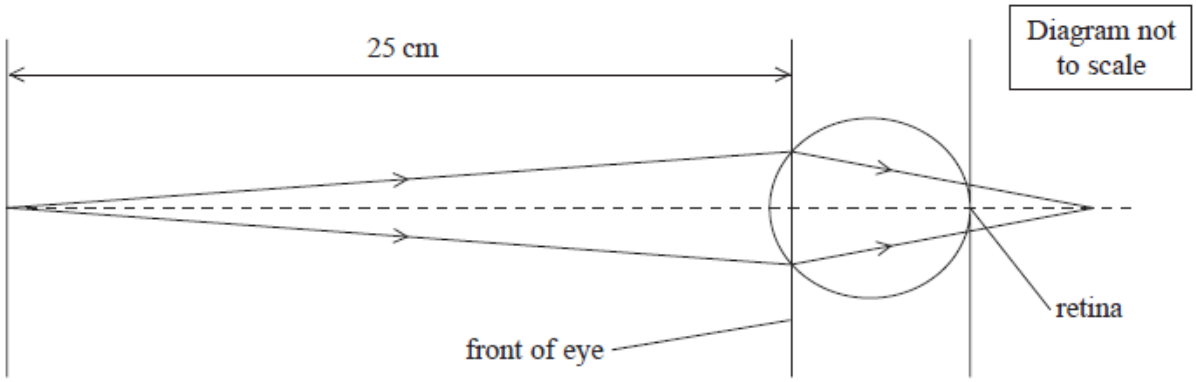
(Total for question = 3 marks)

Q2.

Converging and diverging lenses may be used in glasses to correct problems with eyesight.

A person who is long-sighted cannot clearly see objects that are close to the eye.

Rays of light from an object 25 cm in front of the eye would converge to a point behind the retina as shown in the diagram.



This may be corrected by using an additional converging lens.

State how an additional converging lens would enable the light rays from an object 25 cm in front of the eye to converge at a point on the retina.

(1)

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(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which row of the table shows a base quantity and its base SI unit?

		Quantity	Unit
☒	**A**	charge	C
☒	**B**	length	m
☒	**C**	mass	g
☒	**D**	temperature	°C

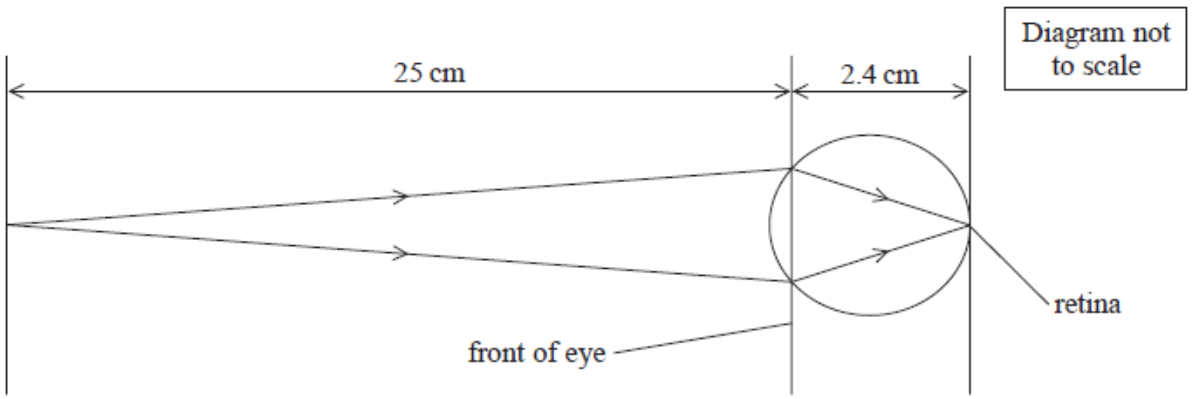
(Total for question = 1 mark)

Q4.

Converging and diverging lenses may be used in glasses to correct problems with eyesight.

The eye acts as a converging lens system.

The diagram shows light rays from an object 25 cm in front of an eye converging to a point on the retina at the back of the eye. The eye has a depth of 2.4 cm.



Calculate the optical power of the eye.

(3)

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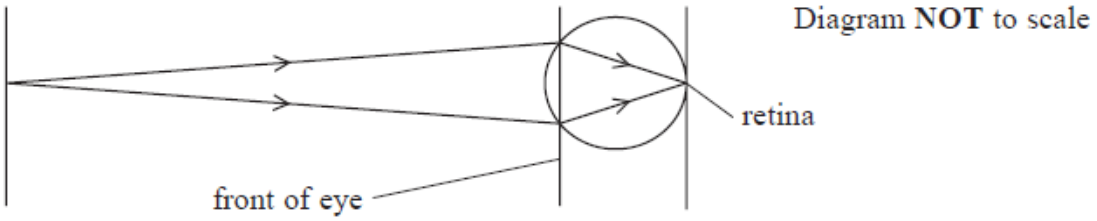
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Power = ...

(Total for question = 3 marks)

Q5.

The human eye acts as a converging lens system that produces an image on the retina at the back of the eye as shown.



A person with eyesight problems may wear either diverging or converging contact lenses.

A short-sighted eye cannot focus on distant objects, because the power of the eye is too great.

One student with short sight cannot focus on objects further than 1.5 m without wearing her contact lenses.

To view distant objects, it is determined that the combined power of her eye and her contact lens should be 41.7 D.

Determine the power and type of lens needed to correct her vision. Assume the equations for thin lens apply to both lenses.

distance from eye lens to retina = 2.4 cm

(4)

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Power = ...

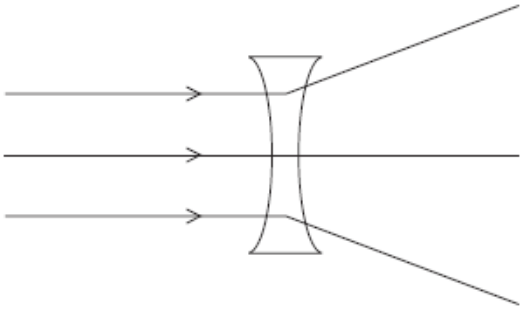
Type of lens .....

(Total for question = 4 marks)

Q6.

Converging and diverging lenses may be used in glasses to correct problems with eyesight.

The diagram shows three parallel rays of light incident on a diverging lens and the path of the rays after passing through the lens. The diagram is drawn to actual size.



Add to the diagram to determine the focal length of the lens.

(2)

Focal length = ...

(Total for question = 2 marks)

Q7.

A camera uses a converging lens to produce an image.

In some cameras, lenses of different focal lengths can be used. A particular camera can use a lens of focal length 50 mm or a lens of focal length 200 mm. Both lenses are made from the same material.

(i) Describe a method to determine an approximate value for the focal length of a converging lens.

(2)

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(ii) Explain why the lens with the shorter focal length is thicker at its centre.

(2)

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(iii) Both photographs show the same scene photographed from the same position.



Photograph 1



Photograph 2

One photograph was taken using the lens of focal length 50 mm and the other was taken using the lens of focal length 200 mm.

Deduce which lens was used to take photograph 2.

(5)

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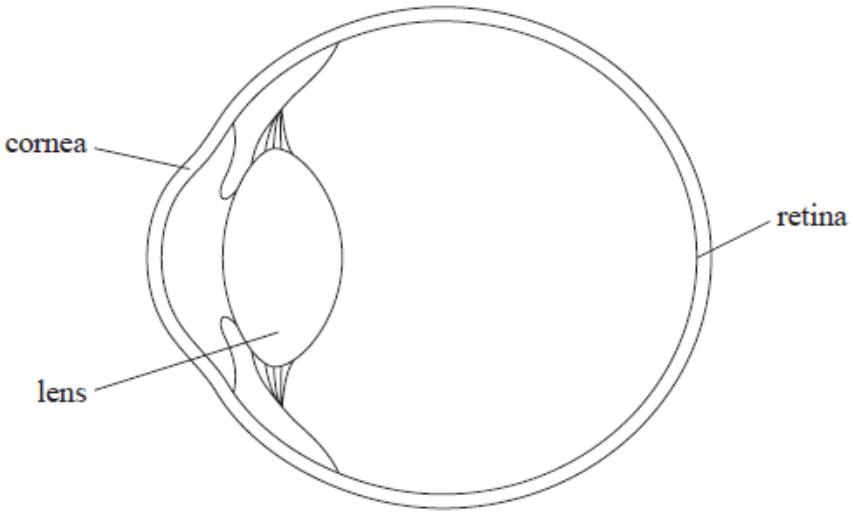
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(Total for question = 9 marks)

Q8.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



People swimming under water often wear goggles. The goggles enable them to see objects under water clearly whereas without goggles objects appear blurred.

Explain why wearing goggles has this effect.

speed of light in water = 2.25×10^8 m s^{-1}

(3)

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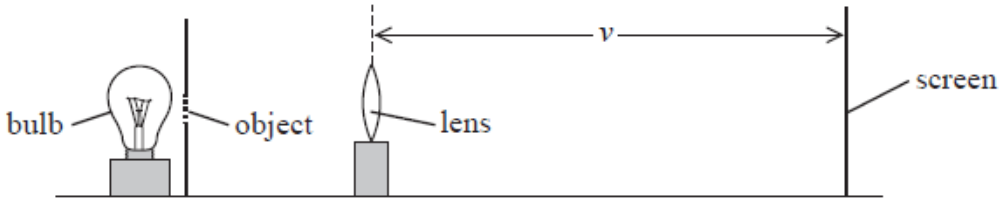
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(Total for question = 3 marks)

Q9.

A student carried out an experiment to determine the focal length of a converging lens. The student used a bulb to illuminate an object as shown. The converging lens produced an image of the object on a screen. The student adjusted the position of the screen until the image was in focus.

He repeated the procedure for different distances between the object and the lens. The distance v from the lens to the screen was measured for each lens position.



The student measured the height h_o of the object and the height h_i of the corresponding image on the screen for each lens position. The magnification m was calculated.

To determine the focal length f of the lens the student used the equation

$$m = \frac{v}{f} - 1$$

If the distance from object to the lens is less than a certain value, no image is produced on the screen.

Explain why.

(3)

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(Total for question = 3 marks)

Q10.

A student investigated how a converging lens can be used to project a magnified image onto a whiteboard.

In a darkened room, the student placed a smartphone 9.0 cm from the converging lens. The phone's display was projected onto the whiteboard. The converging lens was 75.0 cm from the whiteboard when a clear image was produced.

Calculate the focal length of the lens.

(2)

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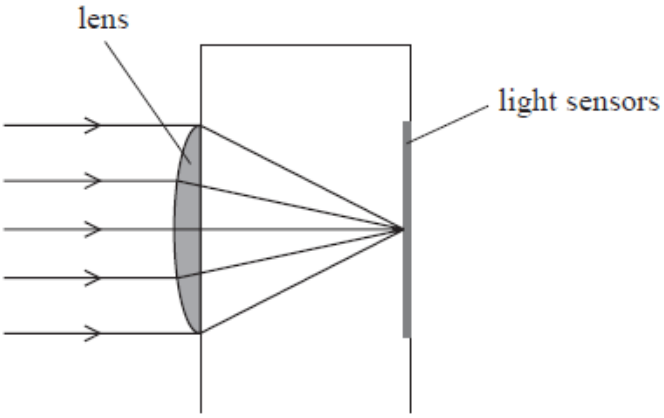
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Focal length = ...

(Total for question = 2 marks)

Q11.

The lens of a mobile phone camera has a focal length of 4.25 mm. Light is focused onto light sensors at the back of the camera, as shown.



The camera is initially focused on an object in the far distance.

Calculate the displacement of the lens that would be required to focus on an object 25.0 cm from the camera.

(4)

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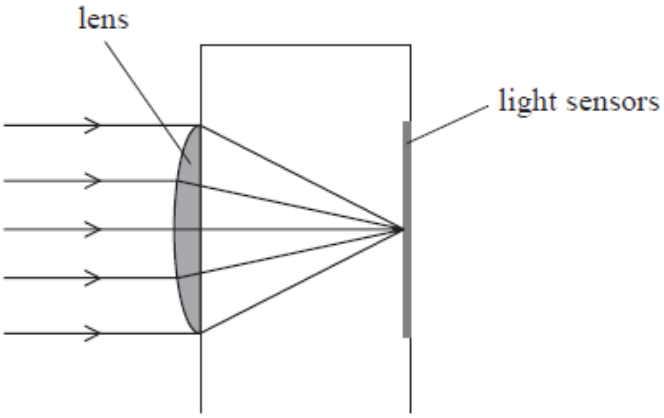
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Displacement of lens = ...

(Total for question = 4 marks)

Q12.

The lens of a mobile phone camera has a focal length of 4.25 mm. Light is focused onto light sensors at the back of the camera, as shown.



State why the lens and the light sensors in a mobile phone camera can be positioned a fixed distance apart.

(1)

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(Total for question = 1 mark)

Q13.

An object is placed in front of a lens.

Which row of the table shows a combination that will produce a real image of the object?

		Focal length of lens / cm	Object distance / cm
☒	**A**	−5	10
☒	**B**	−5	2
☒	**C**	5	10
☒	**D**	5	2

(Total for question = 1 mark)

Q14.

The lens in the eye of an octopus focuses light onto the retina at the back of the eye.

The octopus focuses on objects at different distances from the eye by changing the shape of the eye to move the lens closer or further from the retina.

(i) The power of an octopus lens is 118 D.

Show that the focal length of the lens is about 8.5 mm.

(2)

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(ii) Calculate the shortest distance from the eye at which an object may be focused clearly on the retina.

maximum distance from lens to retina = 2.0 cm

(2)

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Shortest distance from the eye = ...

(iii) The lens in the eye of an octopus is in contact with seawater. The refractive index of freshwater is less than the refractive index of seawater.

Deduce what would happen to the shortest distance from the eye at which an object may be focused clearly if the octopus was in freshwater.

(3)

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(iv) Calculate the speed of light in seawater.

refractive index of seawater = 1.37

(2)

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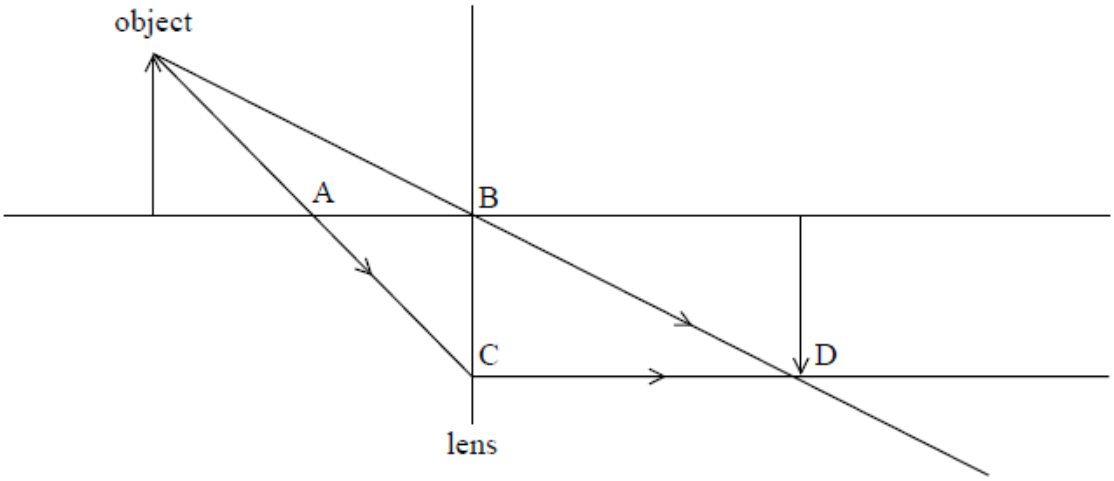
.....

Speed of light in seawater = ...

(Total for question = 9 marks)

Q15.

The diagram shows how an image is formed by an object that is placed a small distance from a thin converging lens.



Which of the labels A, B, C or D represents the focal point of the lens?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q16.

The photograph shows a man wearing a virtual reality (VR) headset.

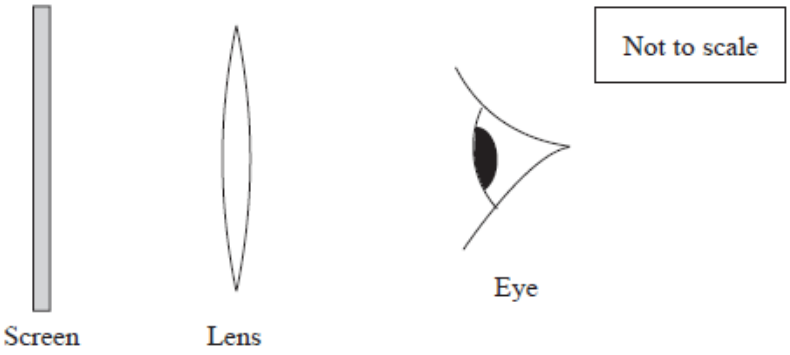


The VR headset gives the illusion of three-dimensional vision.

Inside the VR headset a pair of lenses is used to enable the user to focus on a magnified virtual image of a screen. The lenses can be changed to suit the vision of the user.



In the VR headset the lens is between the eye and the screen, as shown below.



For a particular user of the headset, the image of the screen must be at least 16 cm from the eye and have a magnification of at least 3.0.

Determine whether this would be possible with a lens of focal length 3.8 cm.
Your answer should include a full-scale ray diagram drawn on the grid provided.

(4)

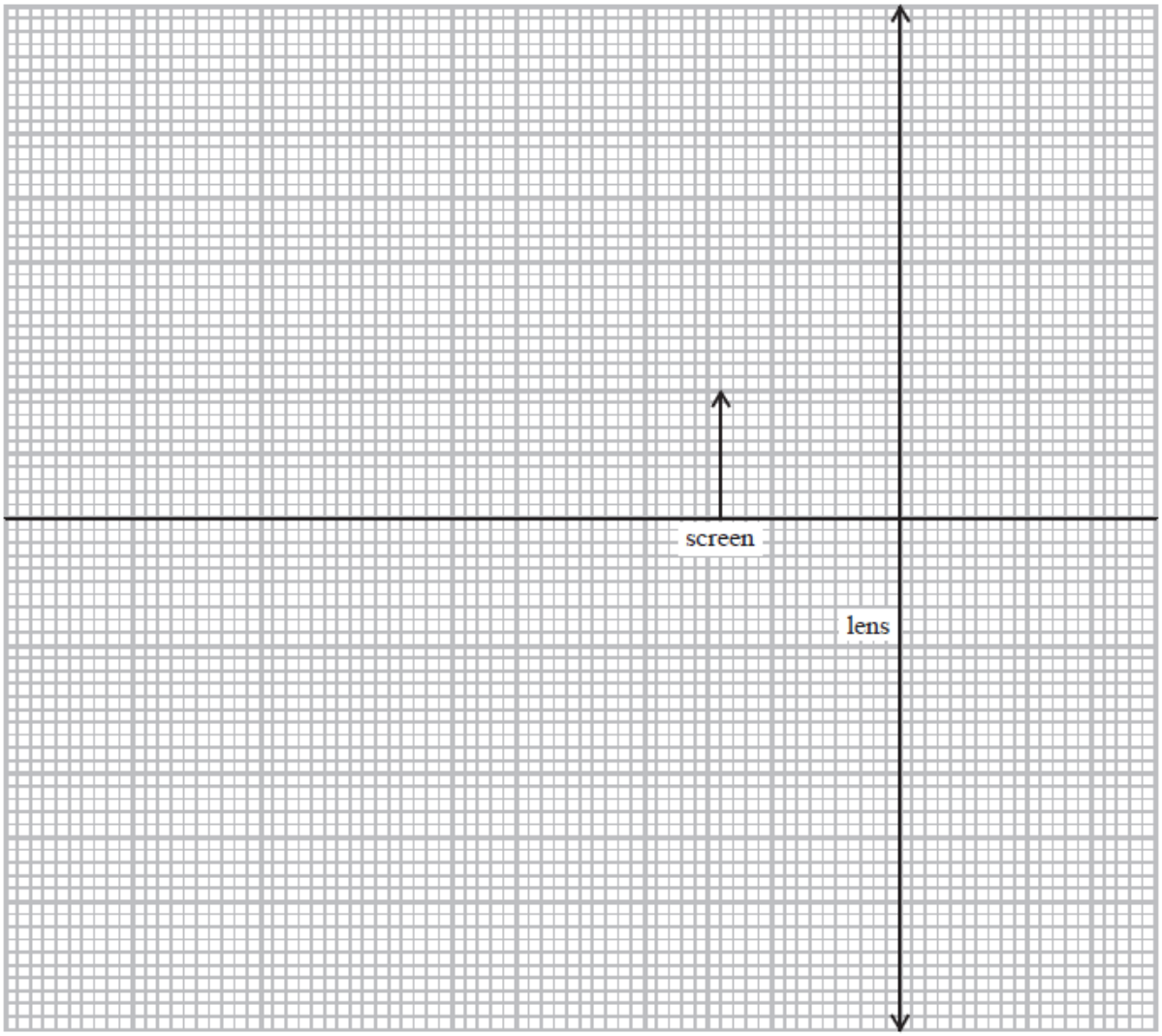
distance from screen to lens = 2.8 cm
distance from lens to eye = 2.2 cm

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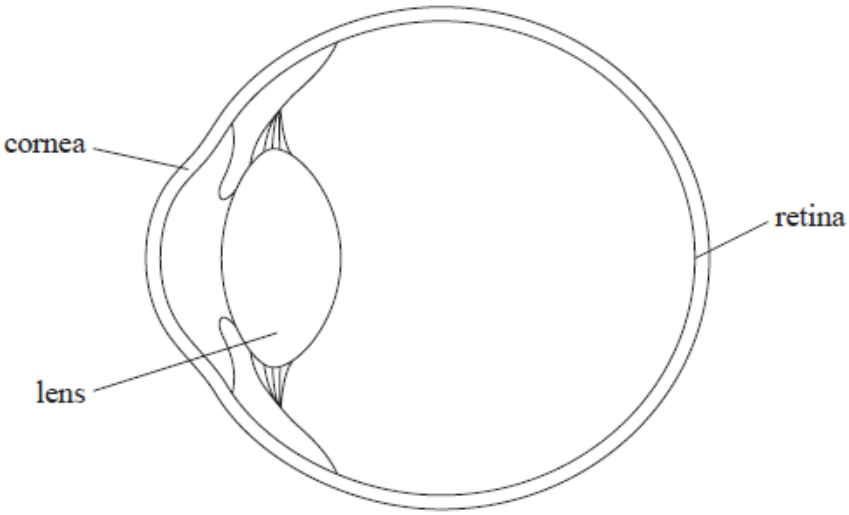
.....



(Total for question = 4 marks)

Q17.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



Light from a point object forms a focused image on the retina.

The cornea and lens may be treated as a single lens of focal length 1.6 cm that is 2.4 cm from the retina.

(i) Calculate the distance from the point object to this single lens when a focused image is formed on the retina.

(2)

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Distance = ...

(ii) A ray of light strikes the front of the cornea at an angle to the normal in air of 15°.

Calculate the angle of the ray to the normal in the cornea.

speed of light in air = 3.00×10^8 m s^{-1}

speed of light in cornea = 2.18×10^8 m s^{-1}

(3)

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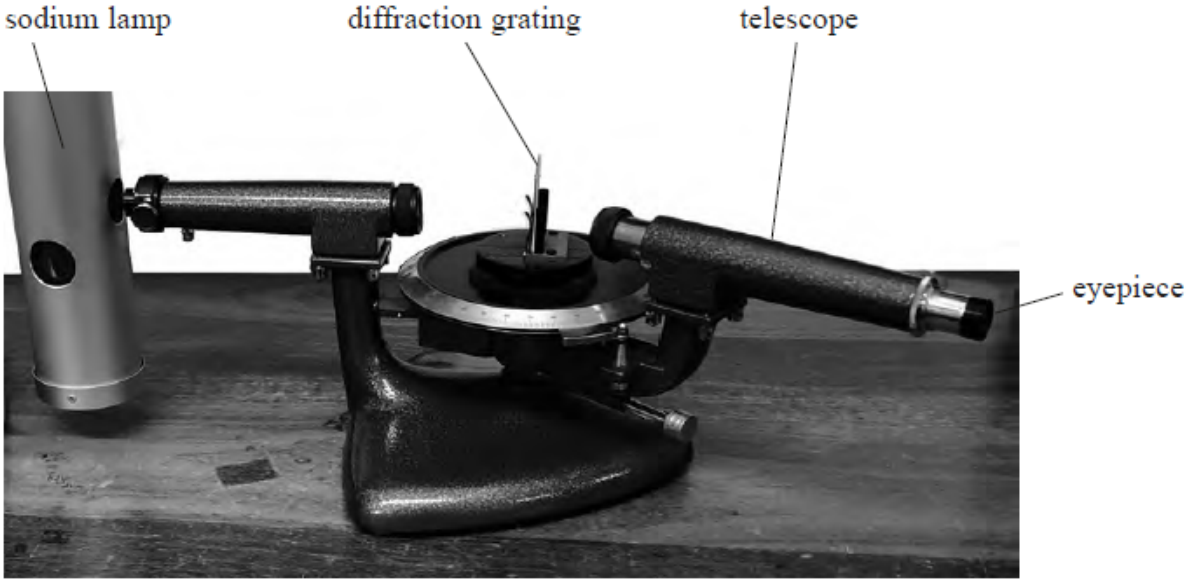
.....

Angle to normal in cornea = ...

(Total for question = 5 marks)

Q18.

The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

In the telescope, light from the grating is focused to make a real image 16.7 mm in front of the eyepiece lens. The eyepiece lens then uses this real image as an object to produce a magnified virtual image for the observer.

Calculate the magnification produced by the eyepiece lens.

focal length of eyepiece lens = 17.9 mm

(3)

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Magnification = ...

(Total for question = 3 marks)

Q19.

The photograph shows a man wearing a virtual reality (VR) headset.



The VR headset gives the illusion of three-dimensional vision.

Inside the VR headset a pair of lenses is used to enable the user to focus on a magnified virtual image of a screen. The lenses can be changed to suit the vision of the user.



Plastic Fresnel lenses are used in the VR headset because they are thinner and lighter than traditional glass lenses.

Instead of the continuous curved surface of a converging lens the Fresnel lens has circular ridges, each with an edge at a different angle to the adjacent ridge, as shown in the simplified cross-section in Figure 1. Figure 2 shows a ray of light entering a section of the lens.

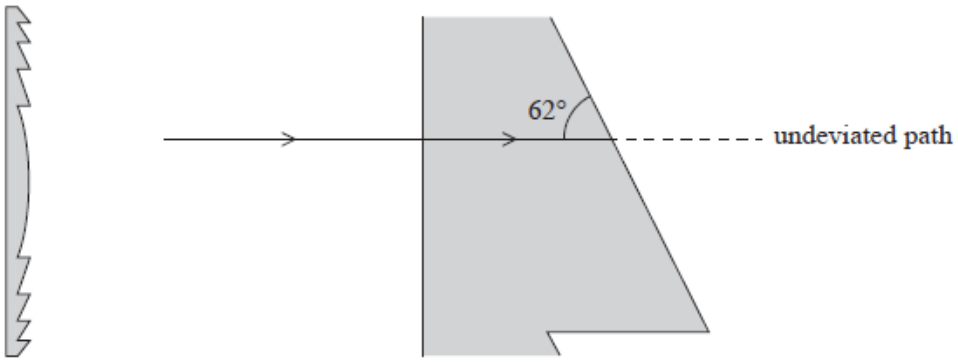


Figure 1 Figure 2

(i) Calculate the angle through which the ray has been deviated as it emerges from the plastic.

(4)

refractive index of plastic = 1.47

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Angle = ...

(ii) Explain how the lens focuses a beam of light travelling parallel to the principal axis.

(3)

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(Total for question = 7 marks)

Q20.

A magnifying glass consists of a converging lens and is used to magnify the details of an object.

A biologist is studying a flower using a magnifying glass. The anther of the flower has a width of 0.2 mm. The magnifying glass is placed 5.0 cm from the flower and an image of the anther is produced that is 3.5 mm wide.

Calculate the power of the lens in the magnifying glass.

(5)

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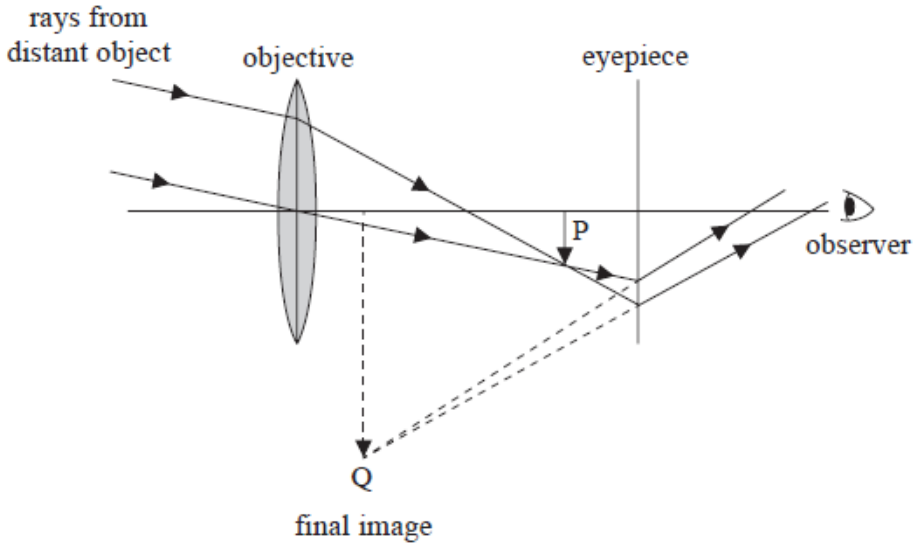
.....

Power of lens = ...

(Total for question = 5 marks)

Q21.

A telescope consists of a convex lens (objective) of power 0.820 D and a second lens (eyepiece) as shown.



The objective produces an image at P. This image becomes the object of the eyepiece, which produces a final image at Q.

Telescopes can be used to observe distant objects such as the Moon.

(i) Explain why the image of the Moon produced at P by the objective lens will be at a distance of about 1200 mm from this lens.

(2)

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(ii) State the properties of the image at P.

(2)

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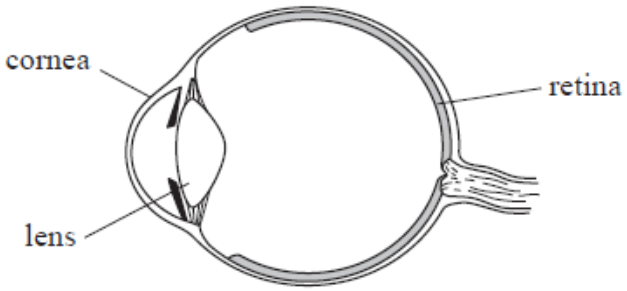
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(Total for question = 4 marks)

Q22.

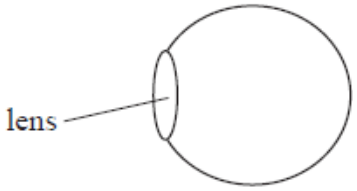
The diagram shows a cross-section through a human eye.



Light from an object is refracted by the cornea and lens to form an image on the retina.

The shape of the lens is altered by muscles in the eye to allow images of objects at different distances to be focused on the retina. The closest position at which people can clearly see an object is called the near point.

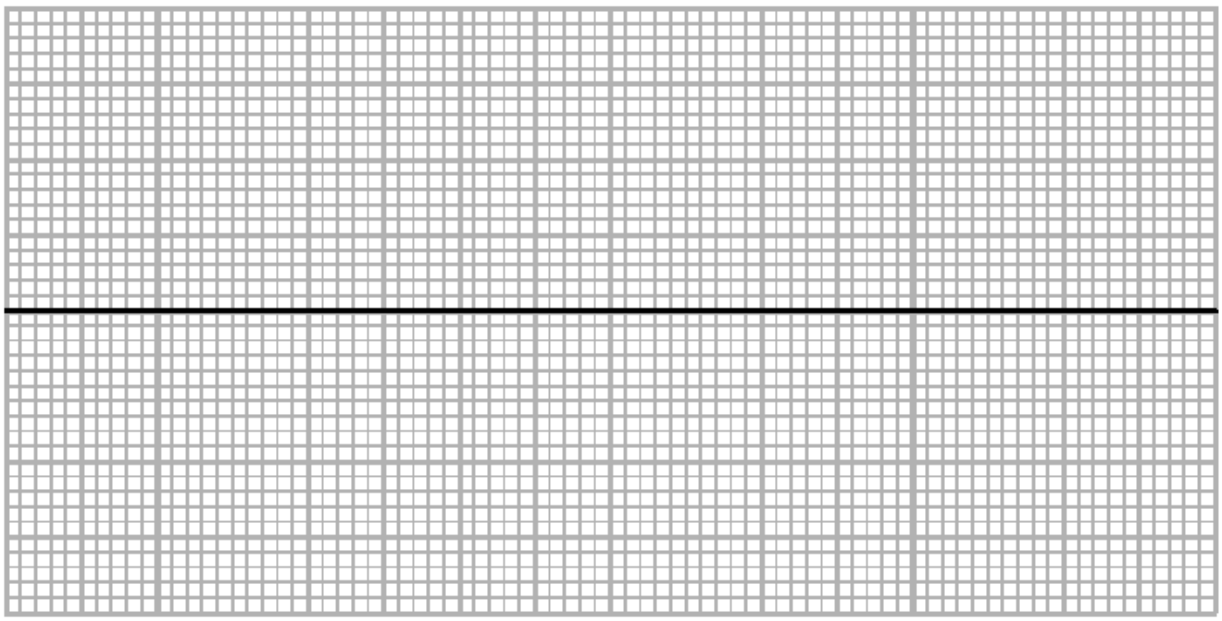
The eye may be modelled as a sphere with a single thin lens as shown. The distance from the centre of the lens to the retina is 2.0 cm.



(i) When the eye of a 10 year-old child is focused on an object that is at the near point, the focal length is 1.5 cm.

Complete a ray diagram to scale, on the grid below, to determine the distance to the near point for the child.

(3)



Distance to near point = ...

(ii) Calculate the magnification for this image.

(2)

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Magnification = ...

Q23.

Smartphones have built-in cameras. A lens on one side of the smartphone is used to form an image on sensors on the opposite side.

A smartphone camera is able to form clear images of objects at distances from the camera between 4.5 cm and infinity.

(a) Sketch a ray diagram to show the formation of a real image for an object close to the phone.

The diagram is not expected to be to scale.

(4)

(b) Estimate the thickness of a smartphone and use this value to determine the power of a lens that could be used to form a clear image for an object that is 4.5 cm away from the lens.

(3)

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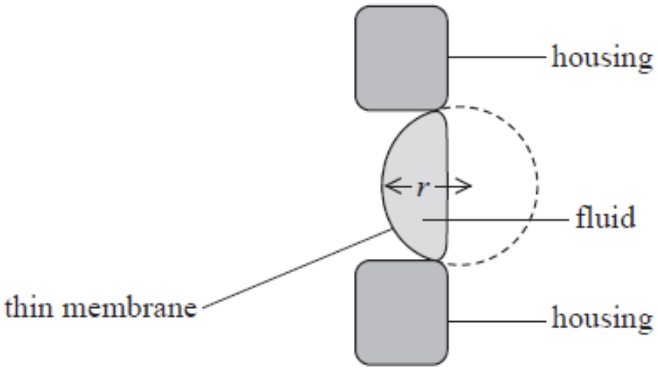
Power = ...

(Total for question = 7 marks)

Q24.

Bar code scanners scan objects at different distances and need a lens that changes shape and hence focal length, in order to produce a focused image. A fluid is sealed within a thin membrane and acts as the shape-changing lens.

A current in a coil of wire is used to change the radius of curvature of the lens. Increasing the current decreases the radius of curvature of the lens and increases the focal length of the lens.



The manufacturer states that the current in the coil should not exceed a maximum value.

Justify the manufacturer's statement.

(4)

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Q25.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The focal length and power of a converging glass lens are determined for the lens in air.
The lens is then immersed in water.

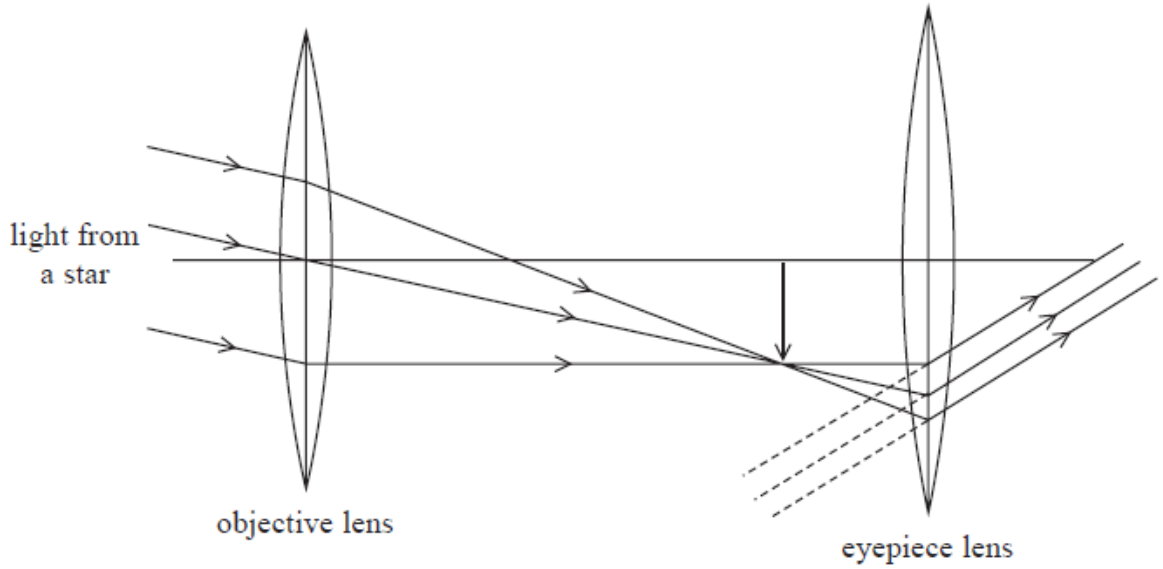
Which row in the table shows how the focal length and power of the lens change?

		Focal length	Power of lens
☒	**A**	decreases	decreases
☒	**B**	decreases	increases
☒	**C**	increases	decreases
☒	**D**	increases	increases

(Total for question = 1 mark)

Q1.

A simple astronomical refracting telescope consists of two converging lenses. Light from a star is brought to a focus by the objective lens and then viewed through an eyepiece lens as shown.



(i) In the arrangement shown, the final image is formed at infinity.

Explain why the separation of the objective and eyepiece lenses is equal to the sum of their focal lengths.

(2)

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(ii) State why the final image is inverted.

(1)

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(Total for question = 3 marks)

Q2.

The photograph shows a man wearing a virtual reality (VR) headset.

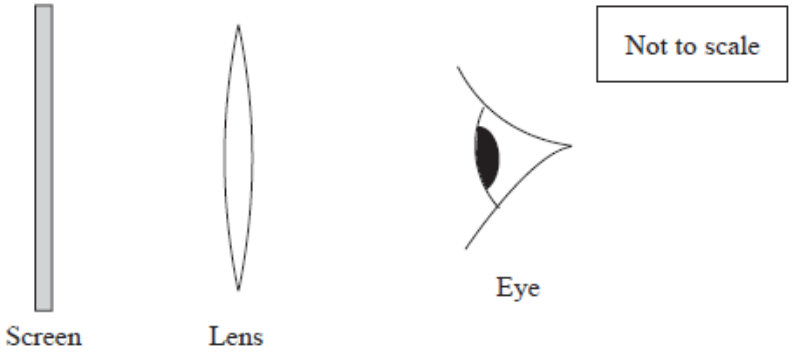


The VR headset gives the illusion of three-dimensional vision.

Inside the VR headset a pair of lenses is used to enable the user to focus on a magnified virtual image of a screen. The lenses can be changed to suit the vision of the user.



In the VR headset the lens is between the eye and the screen, as shown below.



For a particular user of the headset, the image of the screen must be at least 16 cm from the eye and have a magnification of at least 3.0.

Determine whether this would be possible with a lens of focal length 3.8 cm.
Your answer should include a full-scale ray diagram drawn on the grid provided.

(4)

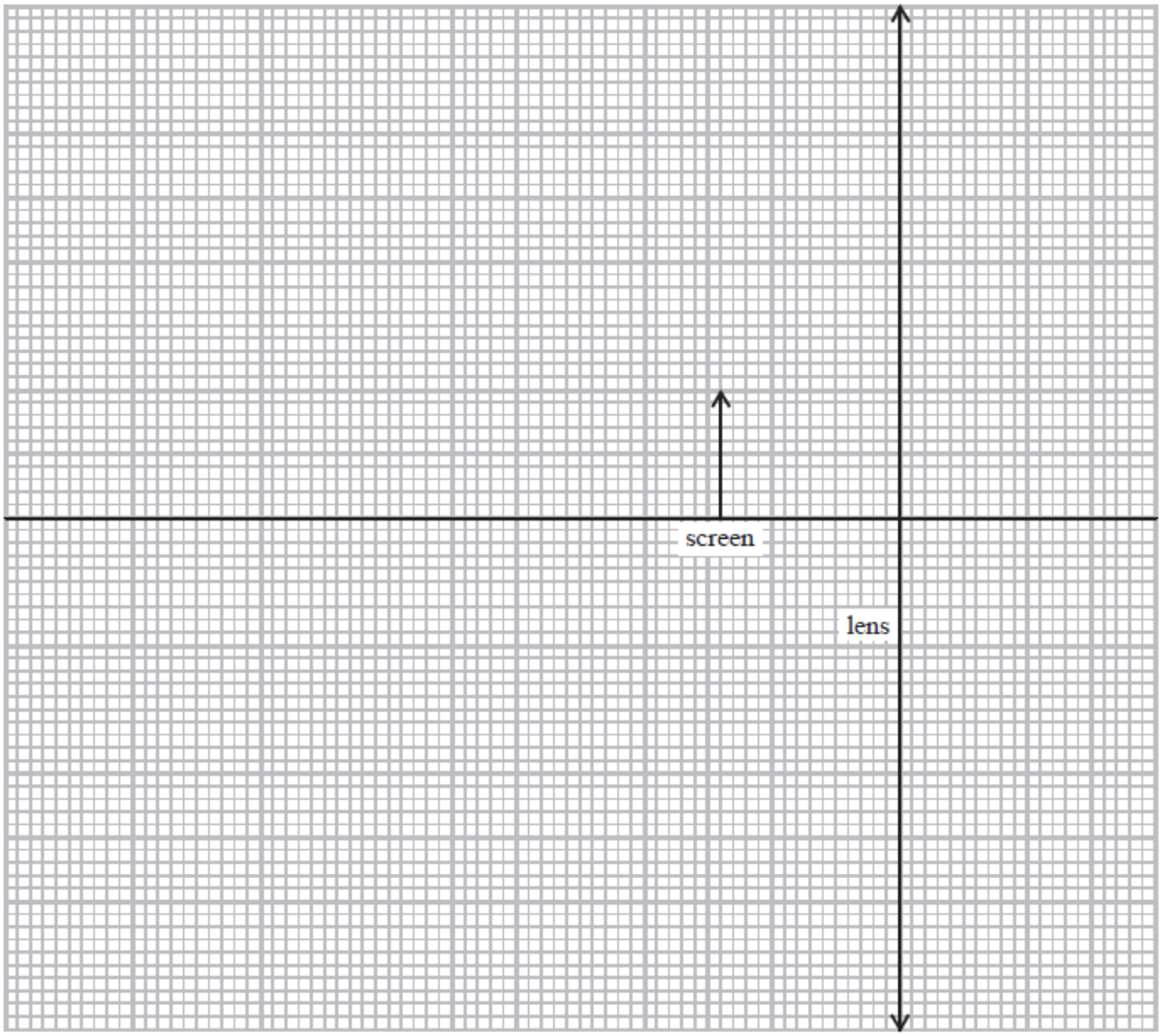
distance from screen to lens = 2.8 cm
distance from lens to eye = 2.2 cm

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(Total for question = 4 marks)

Q3.

Smartphones have built-in cameras. A lens on one side of the smartphone is used to form an image on sensors on the opposite side.

A smartphone camera is able to form clear images of objects at distances from the camera between 4.5 cm and infinity.

(a) Sketch a ray diagram to show the formation of a real image for an object close to the phone.

The diagram is not expected to be to scale.

(4)

(b) Estimate the thickness of a smartphone and use this value to determine the power of a lens that could be used to form a clear image for an object that is 4.5 cm away from the lens.

(3)

.....

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.....

.....

Power = ...

(Total for question = 7 marks)

Q1.

The power of the lens in the human eye changes as the lens changes shape. This enables a person to see objects at different distances clearly. To change the shape, muscles in the eye put the lens under stress.

A teacher was modelling the human eye. He placed an object 60 cm from a converging lens system. A real image of the object was observed with a magnification of 0.5

The converging lenses that were available to the teacher had powers of 2D, 3D and 4D.

Deduce which lens, or combination of lenses, the teacher used.

(4)

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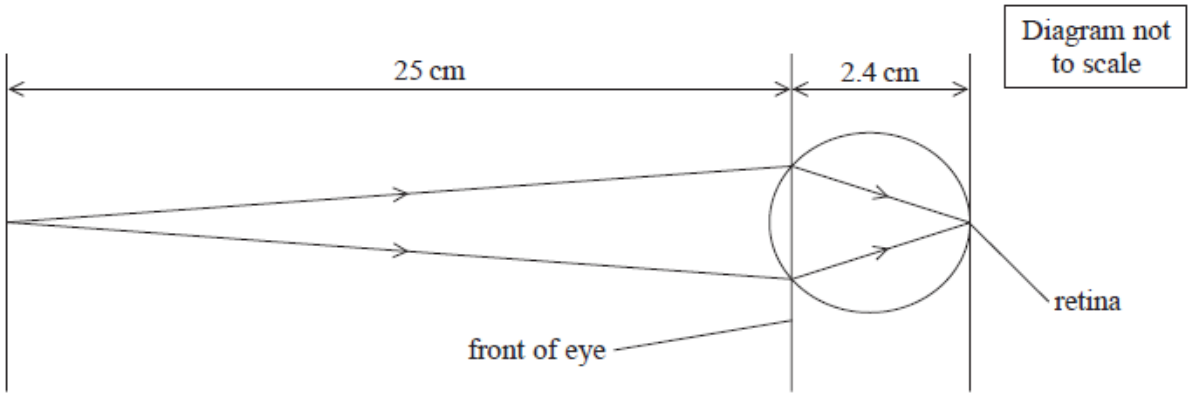
(Total for question = 4 marks)

Q2.

Converging and diverging lenses may be used in glasses to correct problems with eyesight.

The eye acts as a converging lens system.

The diagram shows light rays from an object 25 cm in front of an eye converging to a point on the retina at the back of the eye. The eye has a depth of 2.4 cm.



Calculate the optical power of the eye.

(3)

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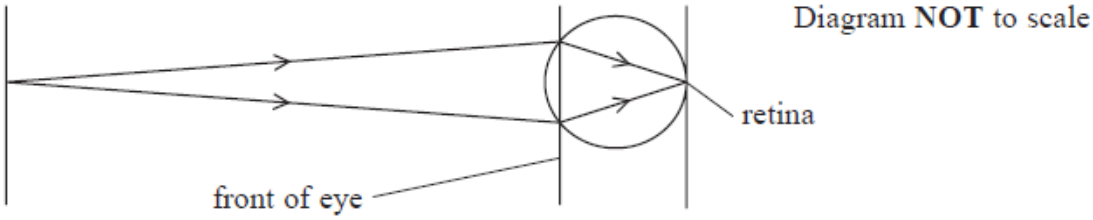
.....

Power = ...

(Total for question = 3 marks)

Q3.

The human eye acts as a converging lens system that produces an image on the retina at the back of the eye as shown.



A person with eyesight problems may wear either diverging or converging contact lenses.

A short-sighted eye cannot focus on distant objects, because the power of the eye is too great.

One student with short sight cannot focus on objects further than 1.5 m without wearing her contact lenses.

To view distant objects, it is determined that the combined power of her eye and her contact lens should be 41.7 D.

Determine the power and type of lens needed to correct her vision. Assume the equations for thin lens apply to both lenses.

distance from eye lens to retina = 2.4 cm

(4)

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Power = ...

Type of lens .....

(Total for question = 4 marks)

Q4.

A camera uses a converging lens to produce an image.

In some cameras, lenses of different focal lengths can be used. A particular camera can use a lens of focal length 50 mm or a lens of focal length 200 mm. Both lenses are made from the same material.

(i) Describe a method to determine an approximate value for the focal length of a converging lens.

(2)

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(ii) Explain why the lens with the shorter focal length is thicker at its centre.

(2)

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(iii) Both photographs show the same scene photographed from the same position.



Photograph 1



Photograph 2

One photograph was taken using the lens of focal length 50 mm and the other was taken using the lens of focal length 200 mm.

Deduce which lens was used to take photograph 2.

(5)

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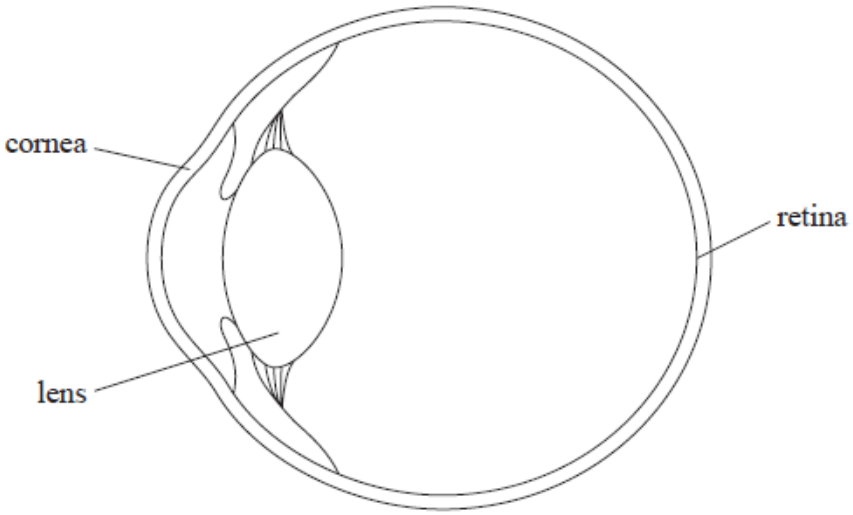
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(Total for question = 9 marks)

Q5.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



People swimming under water often wear goggles. The goggles enable them to see objects under water clearly whereas without goggles objects appear blurred.

Explain why wearing goggles has this effect.

speed of light in water = 2.25×10^8 m s^{-1}

(3)

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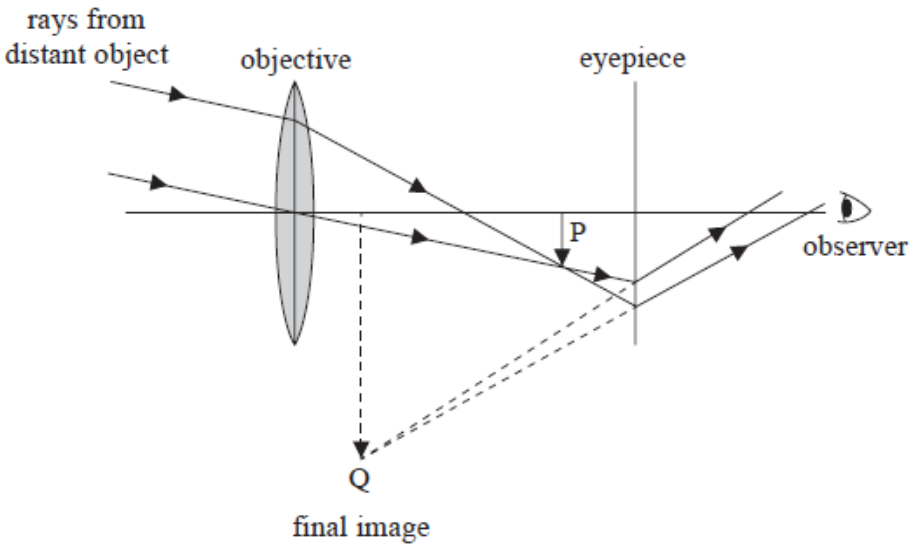
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(Total for question = 3 marks)

Q6.

A telescope consists of a convex lens (objective) of power 0.820 D and a second lens (eyepiece) as shown.



The objective produces an image at P. This image becomes the object of the eyepiece, which produces a final image at Q.

Show that the focal length of the objective lens is about 1200 mm.

(2)

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(Total for question = 2 marks)

Q7.

The photograph shows a child's nature observation kit used for observing small creatures such as flies.



The lid has a built-in lens and an additional optional lens to allow the magnification to be increased.



The photographs below show the appearance of a fly using no lens, a single lens and two lenses respectively.







A student reads that the power of a combination of lenses is equal to the sum of the powers of the individual lenses.

$$\text{power}_{\text{combination}} = \text{power}_{\text{lens1}} + \text{power}_{\text{lens2}}$$

The student investigates this relationship using the lenses in the observation kit.

The student records the method and measurements as shown below.

Method

Set up a bulb on one side of the laboratory.
Hold the lens near the opposite wall and vary the distance from the wall until a clear image of the bulb is seen on the wall.
With the other hand, use a ruler to measure the distance of the lens from the clear image formed.
This is the focal length.

Results

Lens	Focal length/cm
Lens in the lid	12
Optional lens	17.5
Combination of both lenses	7

The distance between the light and the opposite wall was 6 m.

(i) Explain **one** way of improving the value obtained for the focal length of the lens.

(2)

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(ii) Determine whether the data from this experiment supports the conclusion.

$$\text{power}_{\text{combination}} = \text{power}_{\text{lens1}} + \text{power}_{\text{lens2}}$$

Support your answer with a calculation.

(4)

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(Total for question = 6 marks)

Q8.

The lens in the eye of an octopus focuses light onto the retina at the back of the eye.

The octopus focuses on objects at different distances from the eye by changing the shape of the eye to move the lens closer or further from the retina.

(i) The power of an octopus lens is 118 D.

Show that the focal length of the lens is about 8.5 mm.

(2)

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(ii) Calculate the shortest distance from the eye at which an object may be focused clearly on the retina.

maximum distance from lens to retina = 2.0 cm

(2)

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Shortest distance from the eye = ...

(iii) The lens in the eye of an octopus is in contact with seawater. The refractive index of freshwater is less than the refractive index of seawater.

Deduce what would happen to the shortest distance from the eye at which an object may be focused clearly if the octopus was in freshwater.

(3)

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(iv) Calculate the speed of light in seawater.

refractive index of seawater = 1.37

(2)

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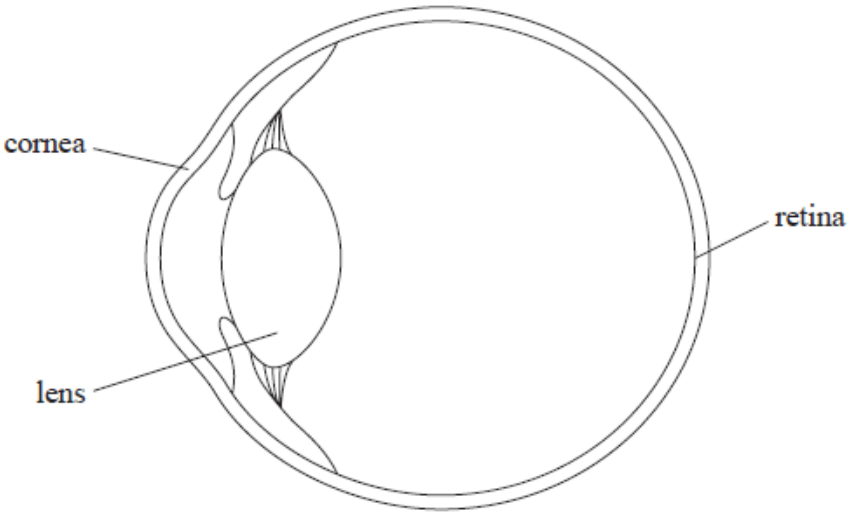
.....

Speed of light in seawater = ...

(Total for question = 9 marks)

Q9.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



It is suggested that the cornea provides 80% of the focusing power of the eye.

Determine whether this is correct.

focal length of cornea = 2.23 cm

focal length of lens for near object = 5.27 cm

(4)

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(Total for question = 4 marks)

Q10.

A magnifying glass consists of a converging lens and is used to magnify the details of an object.

A biologist is studying a flower using a magnifying glass. The anther of the flower has a width of 0.2 mm. The magnifying glass is placed 5.0 cm from the flower and an image of the anther is

produced that is 3.5 mm wide.

Calculate the power of the lens in the magnifying glass.

(5)

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Power of lens = ...

(Total for question = 5 marks)

Q1.

The power of the lens in the human eye changes as the lens changes shape. This enables a person to see objects at different distances clearly. To change the shape, muscles in the eye put the lens under stress.

A teacher was modelling the human eye. He placed an object 60 cm from a converging lens system. A real image of the object was observed with a magnification of 0.5

The converging lenses that were available to the teacher had powers of 2D, 3D and 4D.

Deduce which lens, or combination of lenses, the teacher used.

(4)

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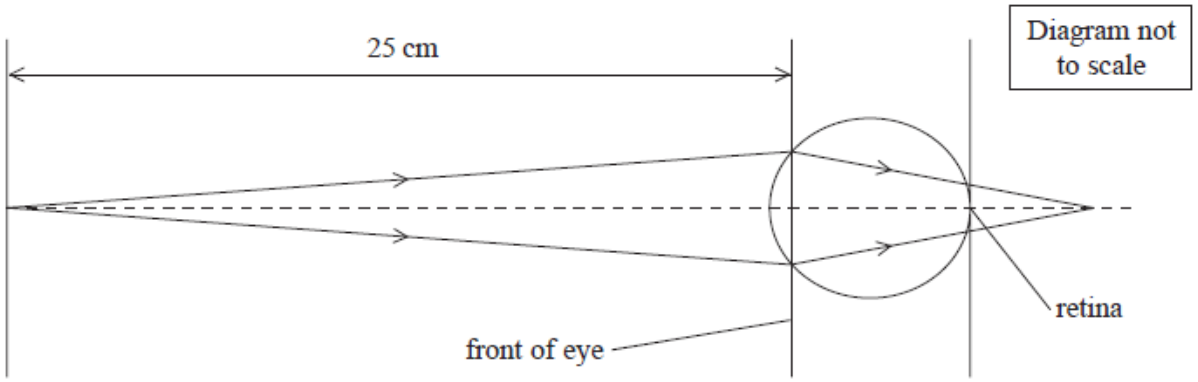
(Total for question = 4 marks)

Q2.

Converging and diverging lenses may be used in glasses to correct problems with eyesight.

A person who is long-sighted cannot clearly see objects that are close to the eye.

Rays of light from an object 25 cm in front of the eye would converge to a point behind the retina as shown in the diagram.



This may be corrected by using an additional converging lens.

State how an additional converging lens would enable the light rays from an object 25 cm in front of the eye to converge at a point on the retina.

(1)

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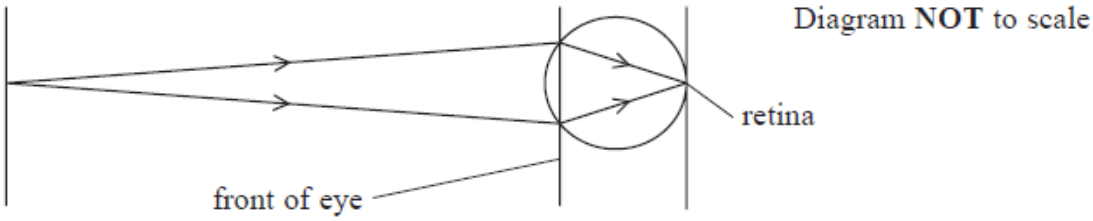
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(Total for question = 1 mark)

Q3.

The human eye acts as a converging lens system that produces an image on the retina at the back of the eye as shown.



A person with eyesight problems may wear either diverging or converging contact lenses.

A short-sighted eye cannot focus on distant objects, because the power of the eye is too great.

One student with short sight cannot focus on objects further than 1.5 m without wearing her contact lenses.

To view distant objects, it is determined that the combined power of her eye and her contact lens should be 41.7 D.

Determine the power and type of lens needed to correct her vision. Assume the equations for thin lens apply to both lenses.

distance from eye lens to retina = 2.4 cm

(4)

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Power = ...

Type of lens .....

(Total for question = 4 marks)

Q4.

A camera uses a converging lens to produce an image.

In some cameras, lenses of different focal lengths can be used. A particular camera can use a lens of focal length 50 mm or a lens of focal length 200 mm. Both lenses are made from the same material.

(i) Describe a method to determine an approximate value for the focal length of a converging lens.

(2)

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(ii) Explain why the lens with the shorter focal length is thicker at its centre.

(2)

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(iii) Both photographs show the same scene photographed from the same position.



Photograph 1



Photograph 2

One photograph was taken using the lens of focal length 50 mm and the other was taken using the lens of focal length 200 mm.

Deduce which lens was used to take photograph 2.

(5)

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(Total for question = 9 marks)

Q5.

The photograph shows a child's nature observation kit used for observing small creatures such

as flies.



The lid has a built-in lens and an additional optional lens to allow the magnification to be increased.



The photographs below show the appearance of a fly using no lens, a single lens and two lenses respectively.







A student reads that the power of a combination of lenses is equal to the sum of the powers of the individual lenses.

$$\text{power}_{\text{combination}} = \text{power}_{\text{lens1}} + \text{power}_{\text{lens2}}$$

The student investigates this relationship using the lenses in the observation kit.

The student records the method and measurements as shown below.

Method

Set up a bulb on one side of the laboratory.
Hold the lens near the opposite wall and vary the distance from the wall until a clear image of the bulb is seen on the wall.
With the other hand, use a ruler to measure the distance of the lens from the clear image formed.
This is the focal length.

Results

Lens	Focal length/cm
Lens in the lid	12
Optional lens	17.5
Combination of both lenses	7

The distance between the light and the opposite wall was 6 m.

(i) Explain **one** way of improving the value obtained for the focal length of the lens.

(2)

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(ii) Determine whether the data from this experiment supports the conclusion.

$$\text{power}_{\text{combination}} = \text{power}_{\text{lens1}} + \text{power}_{\text{lens2}}$$

Support your answer with a calculation.

(4)

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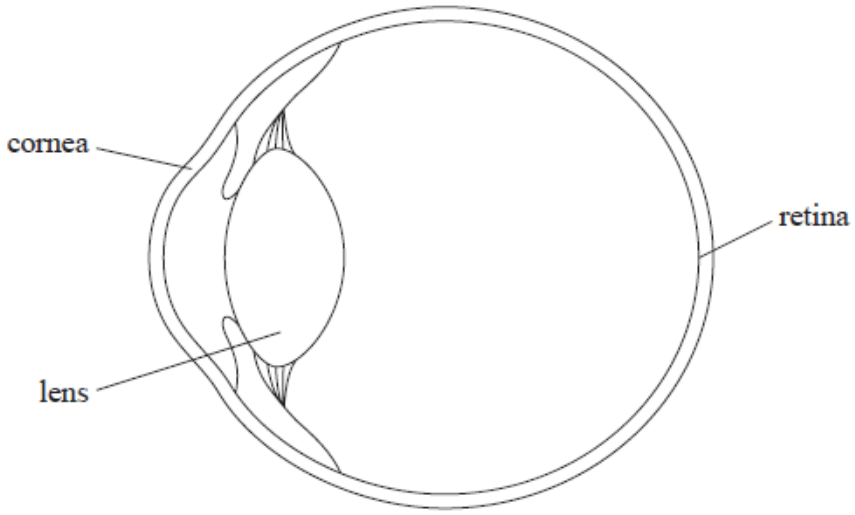
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(Total for question = 6 marks)

Q6.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



It is suggested that the cornea provides 80% of the focusing power of the eye.

Determine whether this is correct.

focal length of cornea = 2.23 cm

focal length of lens for near object = 5.27 cm

(4)

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(Total for question = 4 marks)

Q7.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

A system of lenses consists of a converging lens and a diverging lens in contact.

The magnitude of the power of the converging lens is 9.4 D and the magnitude of the power of the diverging lens is 4.2 D.

Which of the following is the power of this system of lenses?

☒ **A** 13.6 D

☒ **B** 5.2 D

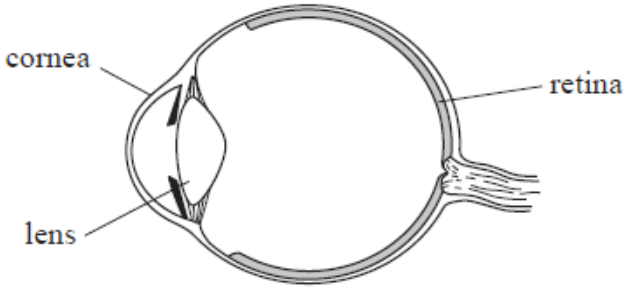
☒ **C** −5.2 D

☒ **D** −13.6 D

(Total for question = 1 mark)

Q8.

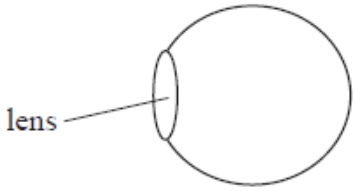
The diagram shows a cross-section through a human eye.



Light from an object is refracted by the cornea and lens to form an image on the retina.

The shape of the lens is altered by muscles in the eye to allow images of objects at different distances to be focused on the retina. The closest position at which people can clearly see an object is called the near point.

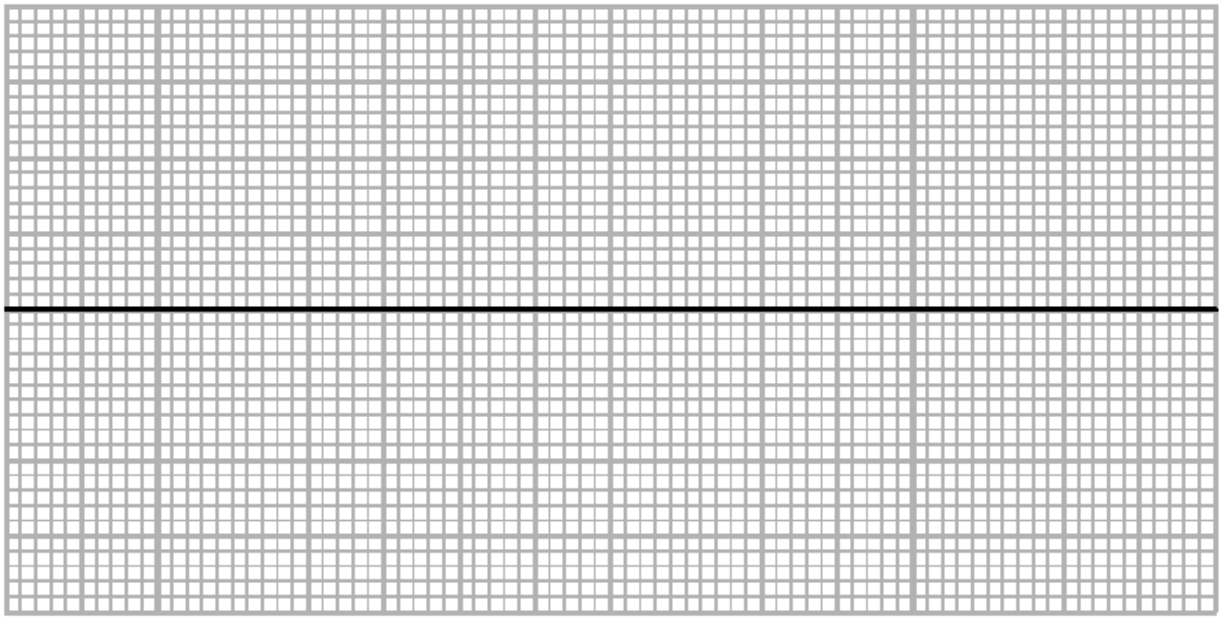
The eye may be modelled as a sphere with a single thin lens as shown. The distance from the centre of the lens to the retina is 2.0 cm.



(i) When the eye of a 10 year-old child is focused on an object that is at the near point, the focal length is 1.5 cm.

Complete a ray diagram to scale, on the grid below, to determine the distance to the near point for the child.

(3)



Distance to near point = ...

(ii) Calculate the magnification for this image.

(2)

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Magnification = ...

Q9.

A photographer uses a light meter to measure the intensity of light entering a camera.

A simple light meter consists of a light dependent resistor (LDR) connected in a circuit.

The resistance of an LDR depends on the intensity of light incident on the LDR.

Explain how the change in resistance may be modelled in terms of conduction electrons.

(4)

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(Total for question = 4 marks)

Q1.

Q1.

The power of the lens in the human eye changes as the lens changes shape. This enables a person to see objects at different distances clearly. To change the shape, muscles in the eye put the lens under stress.

A teacher was modelling the human eye. He placed an object 60 cm from a converging lens system. A real image of the object was observed with a magnification of 0.5

The converging lenses that were available to the teacher had powers of 2D, 3D and 4D.

Deduce which lens, or combination of lenses, the teacher used.

(4)

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(Total for question = 4 marks)

Q2.

A student investigated how a converging lens can be used to project a magnified image onto a whiteboard.

In a darkened room, the student placed a smartphone 9.0 cm from the converging lens. The phone's display was projected onto the whiteboard. The converging lens was 75.0 cm from the whiteboard when a clear image was produced.

The image projected onto the whiteboard was real.

State what is meant by a real image.

(1)

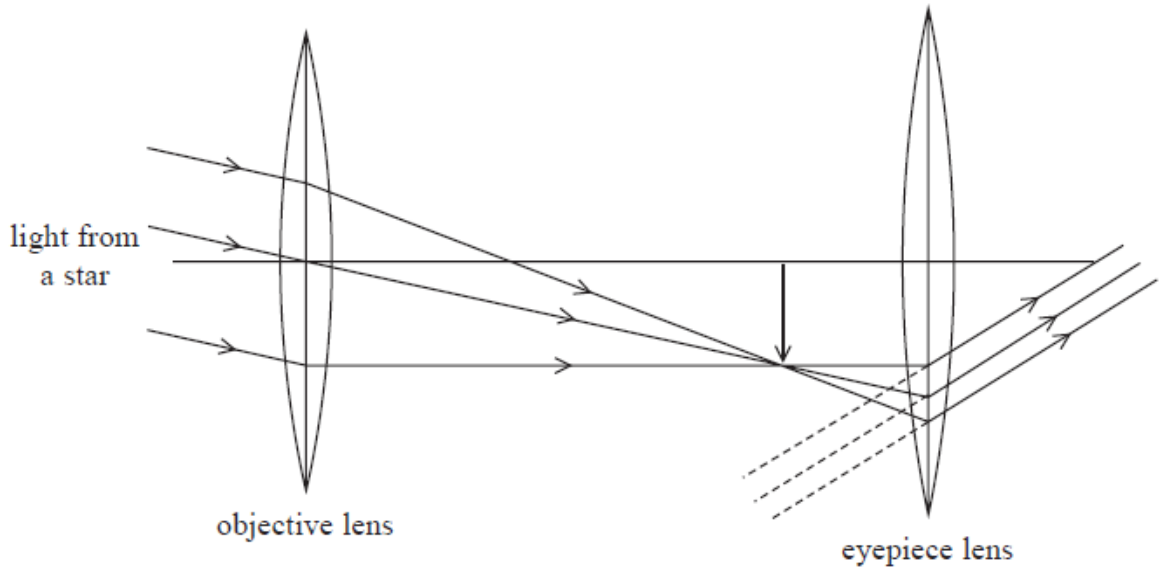
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(Total for question = 1 mark)

Q3.

A simple astronomical refracting telescope consists of two converging lenses. Light from a star is brought to a focus by the objective lens and then viewed through an eyepiece lens as shown.



(i) In the arrangement shown, the final image is formed at infinity.

Explain why the separation of the objective and eyepiece lenses is equal to the sum of their focal lengths.

(2)

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(ii) State why the final image is inverted.

(1)

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(Total for question = 3 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which row of the table shows a base quantity and its base SI unit?

		Quantity	Unit
☒	**A**	charge	C
☒	**B**	length	m
☒	**C**	mass	g
☒	**D**	temperature	°C

(Total for question = 1 mark)

Q5.

Magnifying 'bug boxes' are used to observe small insects. One type consists of a clear plastic pot with a snap-on lid.



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The lid acts as a converging lens of focal length 8.5 cm.

An insect inside the box appears to be 3.5 times bigger when viewed through the lid.

(i) Draw a ray diagram to show the formation of the image by the lens when used in this way.

(3)

(ii) Calculate the distance of the insect from the lid.

(3)

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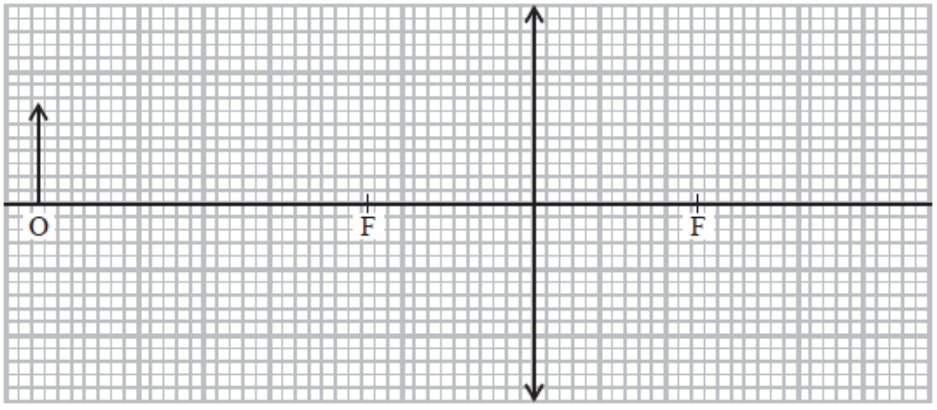
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(Total for question = 6 marks)

Q6.

A camera uses a converging lens to produce an image.

The diagram represents an object O and a converging lens.



(i) Complete the ray diagram to determine the position of the image.

(3)

(ii) Determine the magnification of this image.

(2)

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Magnification = ...

(iii) State, with justification, whether the image is real or virtual.

(1)

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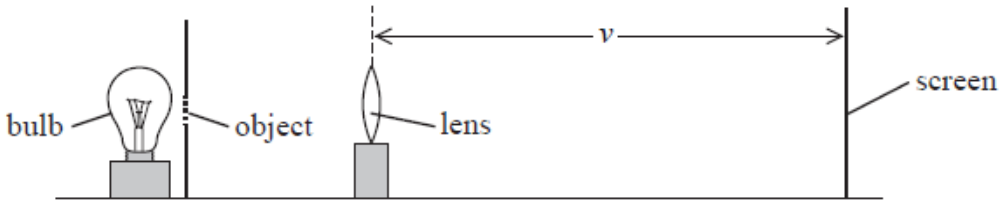
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(Total for question = 6 marks)

Q7.

A student carried out an experiment to determine the focal length of a converging lens. The student used a bulb to illuminate an object as shown. The converging lens produced an image of the object on a screen. The student adjusted the position of the screen until the image was in focus.

He repeated the procedure for different distances between the object and the lens. The distance v from the lens to the screen was measured for each lens position.



The student measured the height h_o of the object and the height h_i of the corresponding image on the screen for each lens position. The magnification m was calculated.

To determine the focal length f of the lens the student used the equation

$$m = \frac{v}{f} - 1$$

If the distance from object to the lens is less than a certain value, no image is produced on the screen.

Explain why.

(3)

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(Total for question = 3 marks)

Q8.

An object is placed in front of a lens.

Which row of the table shows a combination that will produce a real image of the object?

	Focal length of lens / cm	Object distance / cm
☒ **A**	−5	10
☒ **B**	−5	2
☒ **C**	5	10
☒ **D**	5	2

(Total for question = 1 mark)

Q9.

The photograph shows a man wearing a virtual reality (VR) headset.

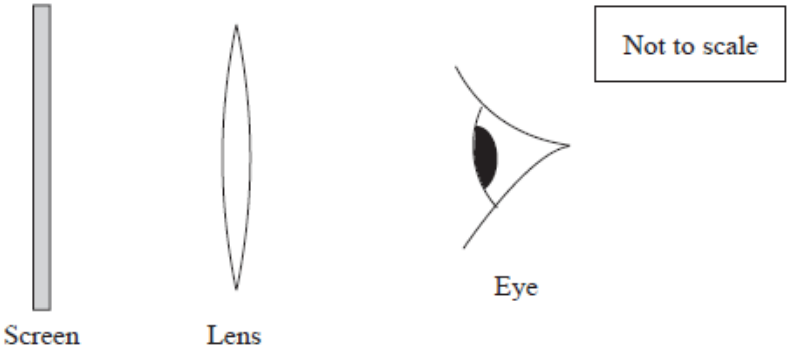


The VR headset gives the illusion of three-dimensional vision.

Inside the VR headset a pair of lenses is used to enable the user to focus on a magnified virtual image of a screen. The lenses can be changed to suit the vision of the user.



In the VR headset the lens is between the eye and the screen, as shown below.



For a particular user of the headset, the image of the screen must be at least 16 cm from the eye and have a magnification of at least 3.0.

Determine whether this would be possible with a lens of focal length 3.8 cm.
Your answer should include a full-scale ray diagram drawn on the grid provided.

(4)

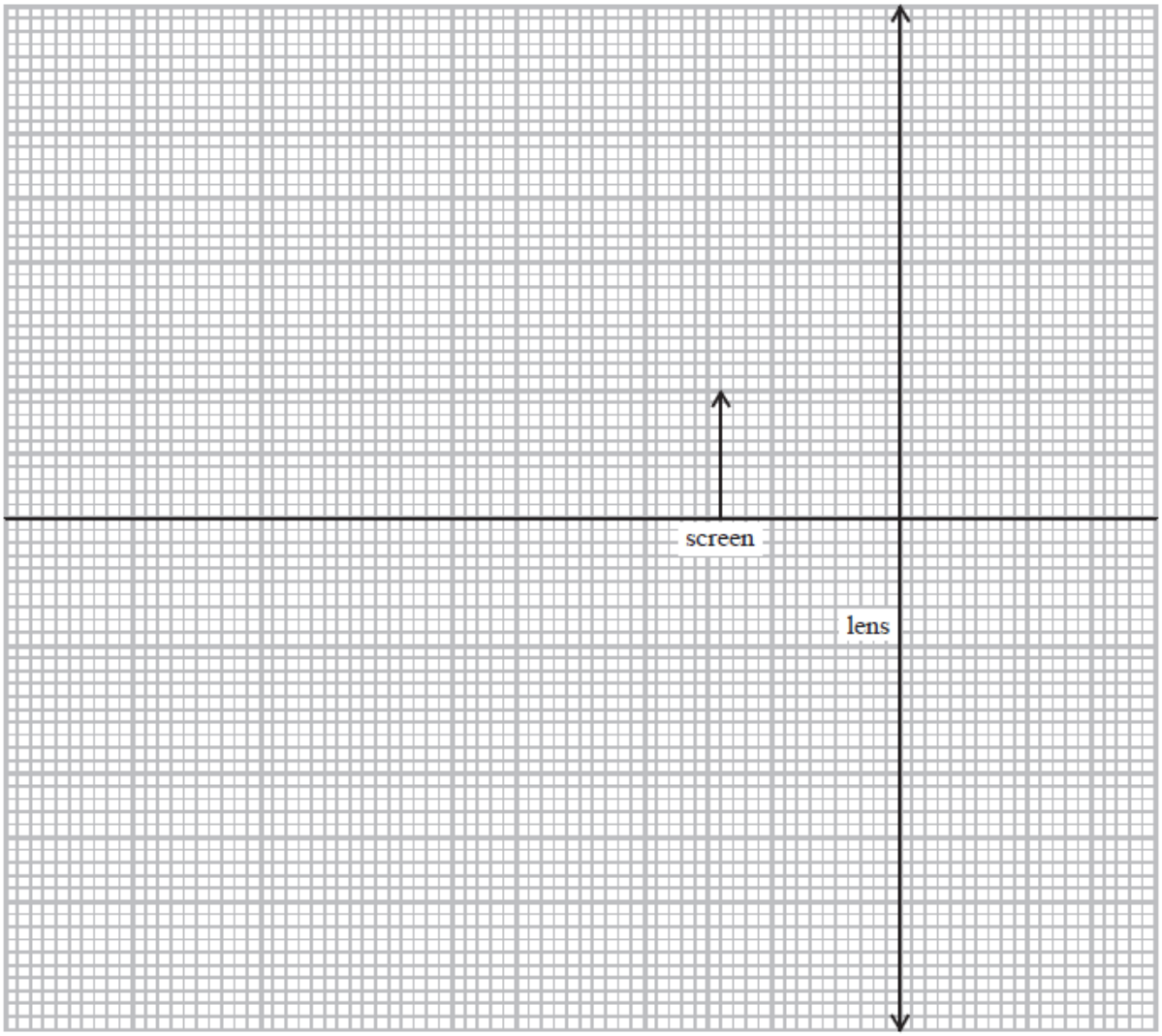
distance from screen to lens = 2.8 cm
distance from lens to eye = 2.2 cm

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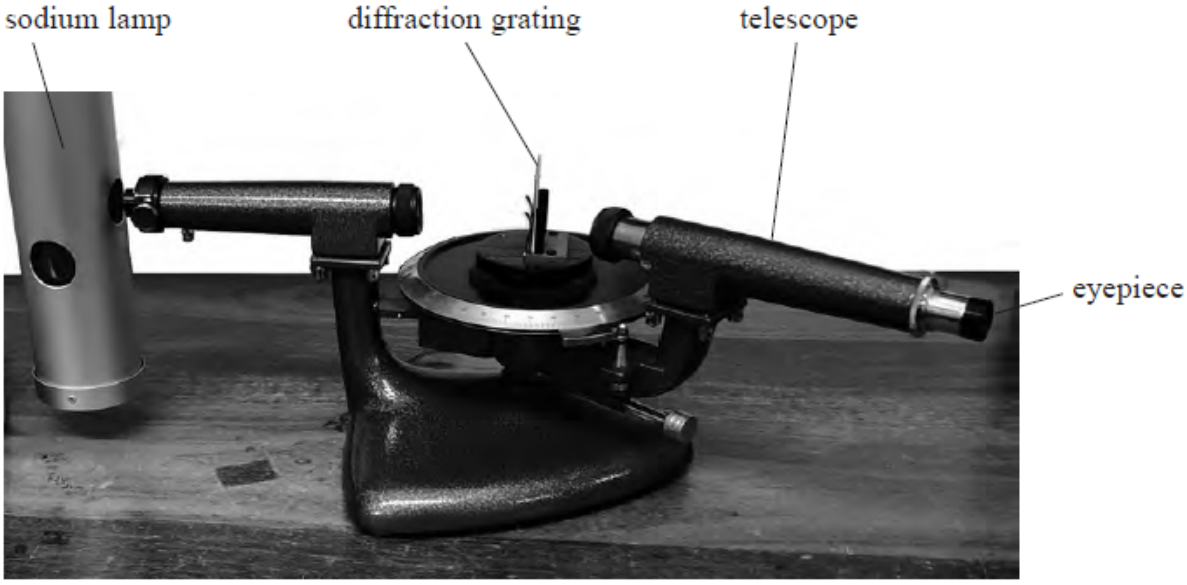
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(Total for question = 4 marks)

Q10.

The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

In the telescope, light from the grating is focused to make a real image 16.7 mm in front of the eyepiece lens. The eyepiece lens then uses this real image as an object to produce a magnified virtual image for the observer.

Calculate the magnification produced by the eyepiece lens.

focal length of eyepiece lens = 17.9 mm

(3)

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Magnification = ...

(Total for question = 3 marks)

Q11.

A diverging lens is used to produce an image of a real object.

Select the row of the table that correctly identifies the nature of the image produced.

☐ **A**	Real	Upright
☐ **B**	Real	Inverted
☐ **C**	Virtual	Upright
☐ **D**	Virtual	Inverted

(Total for question = 1 mark)

Q12.

A converging lens is used as a magnifying glass. An image is produced that is 30 cm away from the lens and twice as big as the object.

Choose the row that correctly identifies the nature of the image and the object distance.

	Nature of image	Object distance/cm
☐ **A**	real	15
☐ **B**	real	60
☐ **C**	virtual	15
☐ **D**	virtual	60

(Total for question = 1 mark)

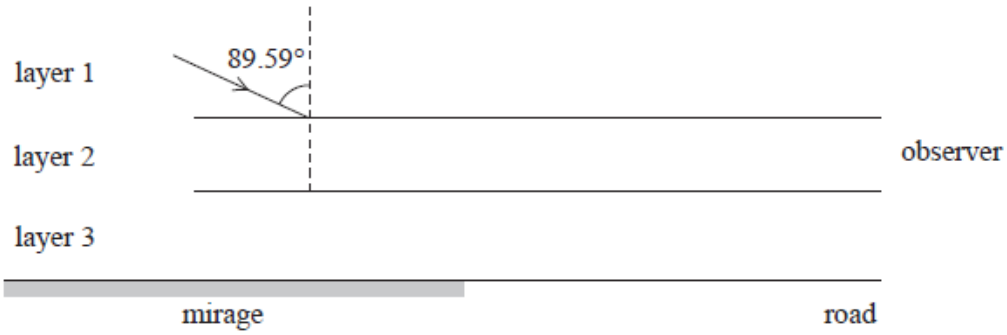
Q13.

On sunny days a mirage can sometimes be observed when a virtual image of the sky is seen on the surface of a road.



The Sun's rays heat up the surface of the road. The heated road then heats the surrounding air so that the layer of air just above the road is at a higher temperature than the air above it. Warm air has a lower refractive index than cool air.

The diagram represents a simple model which is sometimes used to explain how a mirage is formed. The three layers, each with a different refractive index, represent air at three different temperatures. Layer 3 represents the air at the highest temperature closest to the road. A light ray is shown incident at the interface between layer 1 and layer 2.



	refractive index
layer 1	1.00032
layer 2	1.00030
layer 3	1.00028

critical angle for light travelling from layer 1 to layer 2 = 89.64°
critical angle for light travelling from layer 2 to layer 3 = 89.64°

Use the information to discuss whether the observer sees a mirage on the road in the position shown.

(6)

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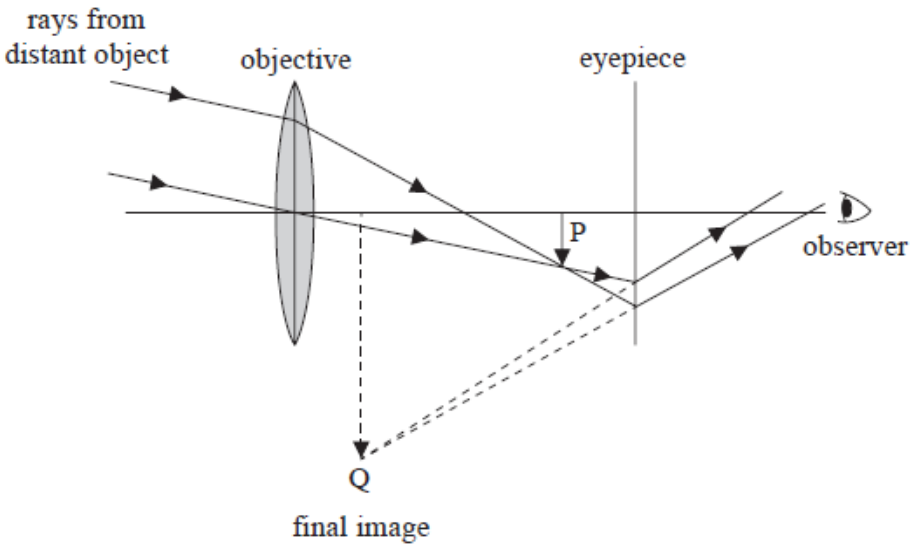
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(Total for question = 6 marks)

Q14.

A telescope consists of a convex lens (objective) of power 0.820 D and a second lens (eyepiece) as shown.



The objective produces an image at P. This image becomes the object of the eyepiece, which produces a final image at Q.

Telescopes can be used to observe distant objects such as the Moon.

(i) Explain why the image of the Moon produced at P by the objective lens will be at a distance of about 1200 mm from this lens.

(2)

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(ii) State the properties of the image at P.

(2)

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(Total for question = 4 marks)

Q15.

Smartphones have built-in cameras. A lens on one side of the smartphone is used to form an image on sensors on the opposite side.

A smartphone camera is able to form clear images of objects at distances from the camera between 4.5 cm and infinity.

(a) Sketch a ray diagram to show the formation of a real image for an object close to the phone.

The diagram is not expected to be to scale.

(4)

(b) Estimate the thickness of a smartphone and use this value to determine the power of a lens that could be used to form a clear image for an object that is 4.5 cm away from the lens.

(3)

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Power = ...

(Total for question = 7 marks)

Q1.

The power of the lens in the human eye changes as the lens changes shape. This enables a person to see objects at different distances clearly. To change the shape, muscles in the eye put the lens under stress.

A teacher was modelling the human eye. He placed an object 60 cm from a converging lens system. A real image of the object was observed with a magnification of 0.5

The converging lenses that were available to the teacher had powers of 2D, 3D and 4D.

Deduce which lens, or combination of lenses, the teacher used.

(4)

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(Total for question = 4 marks)

Q2.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which row of the table shows a base quantity and its base SI unit?

		Quantity	Unit
☒	**A**	charge	C
☒	**B**	length	m
☒	**C**	mass	g
☒	**D**	temperature	°C

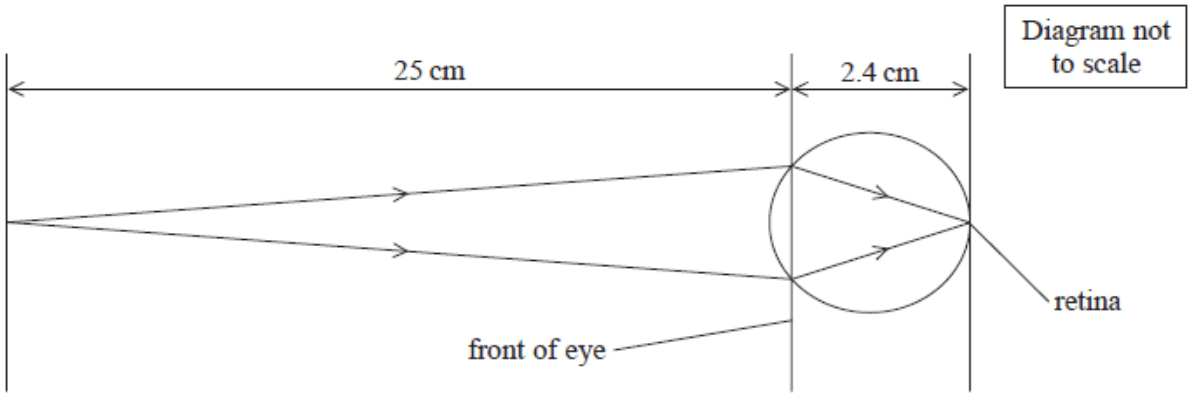
(Total for question = 1 mark)

Q3.

Converging and diverging lenses may be used in glasses to correct problems with eyesight.

The eye acts as a converging lens system.

The diagram shows light rays from an object 25 cm in front of an eye converging to a point on the retina at the back of the eye. The eye has a depth of 2.4 cm.



Calculate the optical power of the eye.

(3)

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Power = ...

(Total for question = 3 marks)

Q4.

The photograph shows a child's nature observation kit used for observing small creatures such as flies.



The lid has a built-in lens and an additional optional lens to allow the magnification to be increased.



The photographs below show the appearance of a fly using no lens, a single lens and two lenses respectively.







A student reads that the power of a combination of lenses is equal to the sum of the powers of the individual lenses.

$$\text{power}_{\text{combination}} = \text{power}_{\text{lens1}} + \text{power}_{\text{lens2}}$$

The student investigates this relationship using the lenses in the observation kit.

The student records the method and measurements as shown below.

Method

Set up a bulb on one side of the laboratory.
Hold the lens near the opposite wall and vary the distance from the wall until a clear image of the bulb is seen on the wall.
With the other hand, use a ruler to measure the distance of the lens from the clear image formed.
This is the focal length.

Results

Lens	Focal length/cm
Lens in the lid	12
Optional lens	17.5
Combination of both lenses	7

The distance between the light and the opposite wall was 6 m.

The distance of an object from the combined lenses is 5.0 cm.

Calculate the magnification of the lens.

Focal length = 7.0 cm.

(3)

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Magnification = ...

(Total for question = 3 marks)

Q5.

Magnifying 'bug boxes' are used to observe small insects. One type consists of a clear plastic pot with a snap-on lid.



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The lid acts as a converging lens of focal length 8.5 cm.

An insect inside the box appears to be 3.5 times bigger when viewed through the lid.

(i) Draw a ray diagram to show the formation of the image by the lens when used in this way.

(3)

(ii) Calculate the distance of the insect from the lid.

(3)

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(Total for question = 6 marks)

Q6.

The photograph shows a type of drink known as stout.



When the drink is poured, it contains many spherical bubbles of gas which rise and form the foamy 'head' at the top of the drink. The manufacturers of the drink state "It takes 120 seconds for the head to form".

For the smallest bubbles, the uniform upward velocity can be calculated using the equation

$$v = \frac{2(\rho_{\text{stout}} - \rho_{\text{gas}})r^2 g}{9\eta}$$

(i) Derive this equation by considering the forces acting on a bubble.

(3)

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(ii) State an assumption you have made.

(1)

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(iii) Evaluate the statement from the manufacturers that it takes 120 seconds for the head to form.

You should consider the time for a bubble to travel from the bottom of the glass to the top.

height of glass = 11.5 cm
density of gas = 1.22 kg m^{-3}
density of stout = 1.01×10^3 kg m^{-3}

viscosity of stout = 2.06×10^{-3} Pa s
diameter of bubble = 122 μm

(4)

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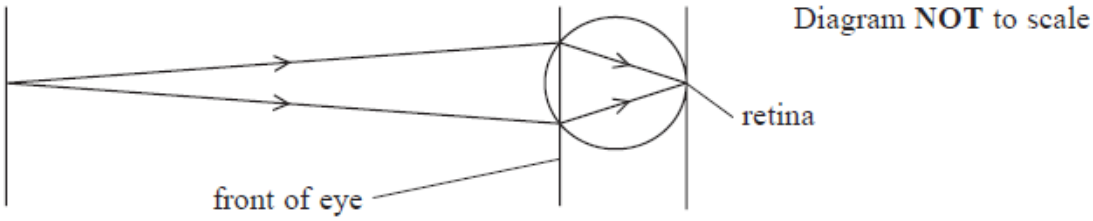
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Q7.

The human eye acts as a converging lens system that produces an image on the retina at the back of the eye as shown.



A person with eyesight problems may wear either diverging or converging contact lenses.

A short-sighted eye cannot focus on distant objects, because the power of the eye is too great.

One student with short sight cannot focus on objects further than 1.5 m without wearing her contact lenses.

To view distant objects, it is determined that the combined power of her eye and her contact lens should be 41.7 D.

Determine the power and type of lens needed to correct her vision. Assume the equations for thin lens apply to both lenses.

distance from eye lens to retina = 2.4 cm

(4)

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Power = ...

Type of lens .....

(Total for question = 4 marks)

Q8.

A camera uses a converging lens to produce an image.

In some cameras, lenses of different focal lengths can be used. A particular camera can use a lens of focal length 50 mm or a lens of focal length 200 mm. Both lenses are made from the same material.

(i) Describe a method to determine an approximate value for the focal length of a converging lens.

(2)

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(ii) Explain why the lens with the shorter focal length is thicker at its centre.

(2)

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(iii) Both photographs show the same scene photographed from the same position.



Photograph 1



Photograph 2

One photograph was taken using the lens of focal length 50 mm and the other was taken using the lens of focal length 200 mm.

Deduce which lens was used to take photograph 2.

(5)

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(Total for question = 9 marks)

Q9.

A converging lens can be used to produce a real image on a screen.

A converging lens of focal length 15.0 cm is used to project an image of an illuminated object onto a screen. The object is a circle of diameter 4.0 mm and the image must be as large as possible on a screen of size 0.75 m by 1.25 m.

Calculate the distance between the lens and the screen for this image to be displayed.

(3)

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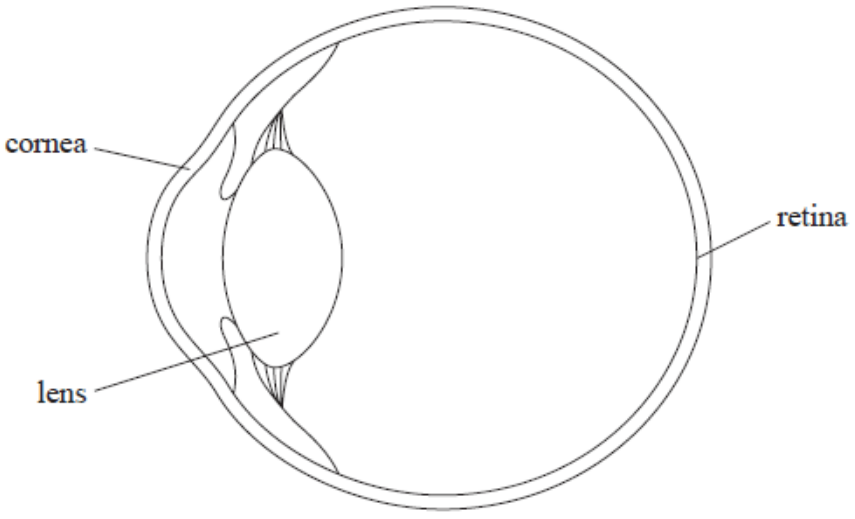
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Distance between lens and screen = ...

(Total for question = 3 marks)

Q10.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



People swimming under water often wear goggles. The goggles enable them to see objects under water clearly whereas without goggles objects appear blurred.

Explain why wearing goggles has this effect.

speed of light in water = 2.25×10^8 m s^{-1}

(3)

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(Total for question = 3 marks)

Q11.

A student investigated how a converging lens can be used to project a magnified image onto a whiteboard.

In a darkened room, the student placed a smartphone 9.0 cm from the converging lens. The phone's display was projected onto the whiteboard. The converging lens was 75.0 cm from the whiteboard when a clear image was produced.

Calculate the focal length of the lens.

(2)

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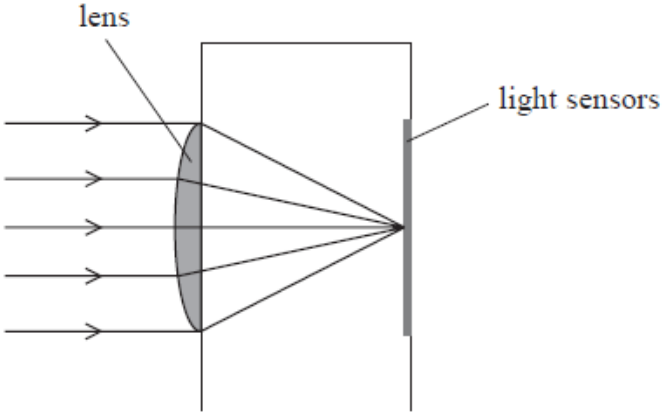
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Focal length = ...

(Total for question = 2 marks)

Q12.

The lens of a mobile phone camera has a focal length of 4.25 mm. Light is focused onto light sensors at the back of the camera, as shown.



The camera is initially focused on an object in the far distance.

Calculate the displacement of the lens that would be required to focus on an object 25.0 cm from the camera.

(4)

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Displacement of lens = ...

(Total for question = 4 marks)

Q13.

The lens in the eye of an octopus focuses light onto the retina at the back of the eye.

The octopus focuses on objects at different distances from the eye by changing the shape of the eye to move the lens closer or further from the retina.

(i) The power of an octopus lens is 118 D.

Show that the focal length of the lens is about 8.5 mm.

(2)

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(ii) Calculate the shortest distance from the eye at which an object may be focused clearly on the retina.

maximum distance from lens to retina = 2.0 cm

(2)

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Shortest distance from the eye = ...

(iii) The lens in the eye of an octopus is in contact with seawater. The refractive index of freshwater is less than the refractive index of seawater.

Deduce what would happen to the shortest distance from the eye at which an object may be focused clearly if the octopus was in freshwater.

(3)

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(iv) Calculate the speed of light in seawater.

refractive index of seawater = 1.37

(2)

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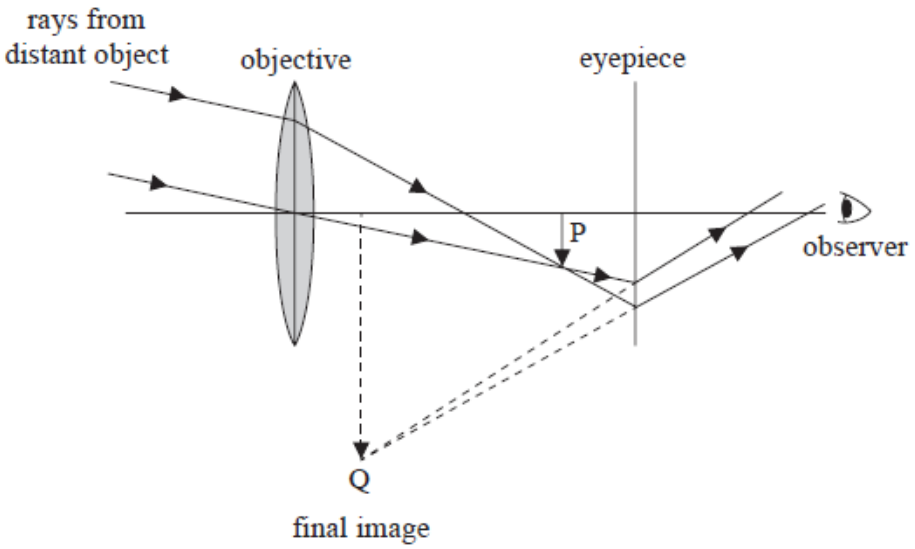
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Speed of light in seawater = ...

(Total for question = 9 marks)

Q14.

A telescope consists of a convex lens (objective) of power 0.820 D and a second lens (eyepiece) as shown.



The objective produces an image at P. This image becomes the object of the eyepiece, which produces a final image at Q.

The eyepiece is at a distance of 100 mm from the image at P. To give a reasonable magnification, the final image at Q should be a virtual image at a distance of 300 mm from the eyepiece.

The following lenses are available:

diverging lens focal length 150 mm,
converging lens focal length 150 mm,
diverging lens focal length 100 mm,
converging lens focal length 100 mm.

Deduce which lens should be used for the eyepiece.

(3)

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(Total for question = 3 marks)

Q15.

The distance of the near point from the eye increases as people get older. Because of this, older people use reading glasses to enable objects closer than the near point to be seen clearly.

A person wants to buy reading glasses so that they can read text clearly at a distance of 27.5 cm from their eye. The minimum focal length for this person's eye is 1.93 cm and the distance from the centre of the lens to the retina is 2.0 cm.

The available powers of lenses are +1.0 D, +1.5 D, +2.0 D, +2.5 D, +3.0 D and +3.5 D.

Show that the appropriate lens needed has a power of +2.0 D. You may ignore the distance between the lens of the glasses and the eye.

(4)

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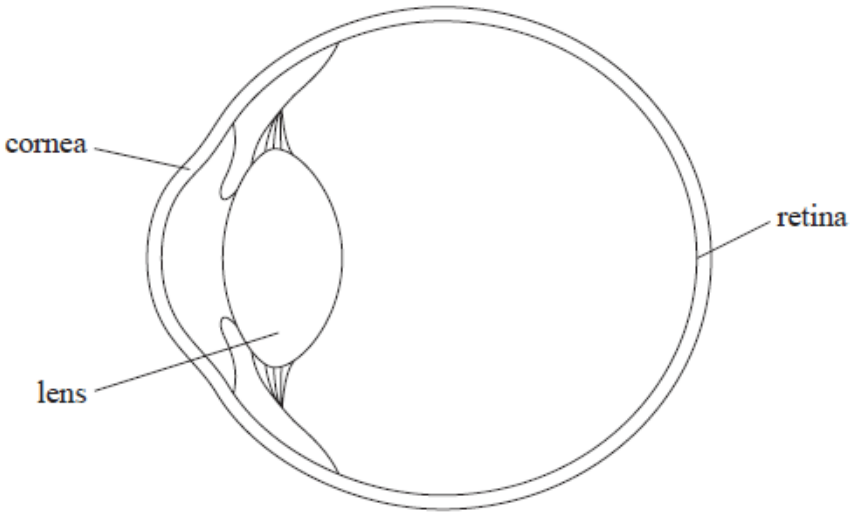
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Q16.

Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



Light from a point object forms a focused image on the retina.

The cornea and lens may be treated as a single lens of focal length 1.6 cm that is 2.4 cm from the retina.

(i) Calculate the distance from the point object to this single lens when a focused image is formed on the retina.

(2)

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Distance = ...

(ii) A ray of light strikes the front of the cornea at an angle to the normal in air of 15°.

Calculate the angle of the ray to the normal in the cornea.

speed of light in air = 3.00×10^8 m s^{-1}

speed of light in cornea = 2.18×10^8 m s^{-1}

(3)

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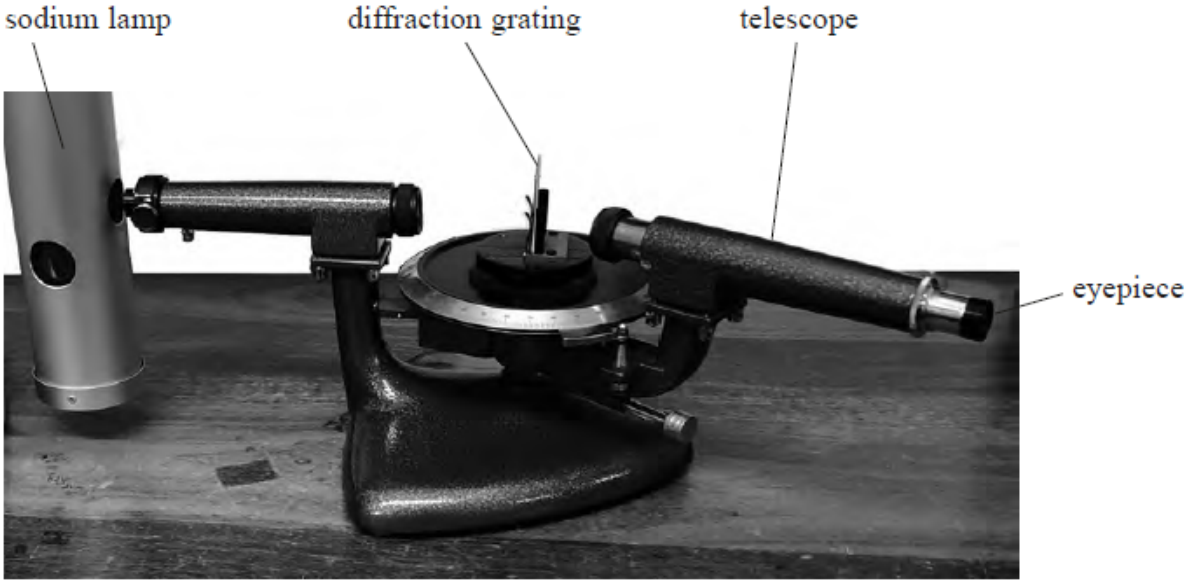
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Angle to normal in cornea = ...

(Total for question = 5 marks)

Q17.

The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

In the telescope, light from the grating is focused to make a real image 16.7 mm in front of the eyepiece lens. The eyepiece lens then uses this real image as an object to produce a magnified virtual image for the observer.

Calculate the magnification produced by the eyepiece lens.

focal length of eyepiece lens = 17.9 mm

(3)

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Magnification = ...

(Total for question = 3 marks)

Q18.

A magnifying glass consists of a converging lens and is used to magnify the details of an object.

A biologist is studying a flower using a magnifying glass. The anther of the flower has a width of 0.2 mm. The magnifying glass is placed 5.0 cm from the flower and an image of the anther is produced that is 3.5 mm wide.

Calculate the power of the lens in the magnifying glass.

(5)

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Power of lens = ...

(Total for question = 5 marks)

Q19.

A converging lens has a focal length of less than 20 cm. The lens can be used to produce real images of an illuminated object. You are required to investigate how the image distance from the lens depends upon the object distance from the lens. Your method should lead to a graphical method to determine the focal length of the lens.

(a) Describe how you would obtain the data.

(4)

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(b) Explain how you would use your results to determine a value for the focal length of the lens.

(3)

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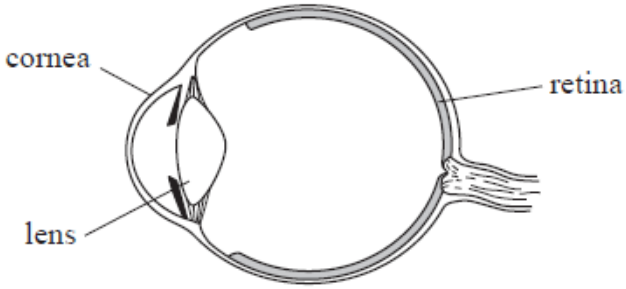
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(Total for question = 7 marks)

Q20.

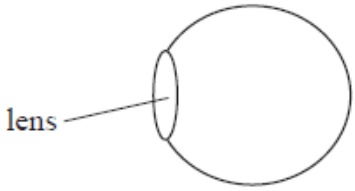
The diagram shows a cross-section through a human eye.



Light from an object is refracted by the cornea and lens to form an image on the retina.

The shape of the lens is altered by muscles in the eye to allow images of objects at different distances to be focused on the retina. The closest position at which people can clearly see an object is called the near point.

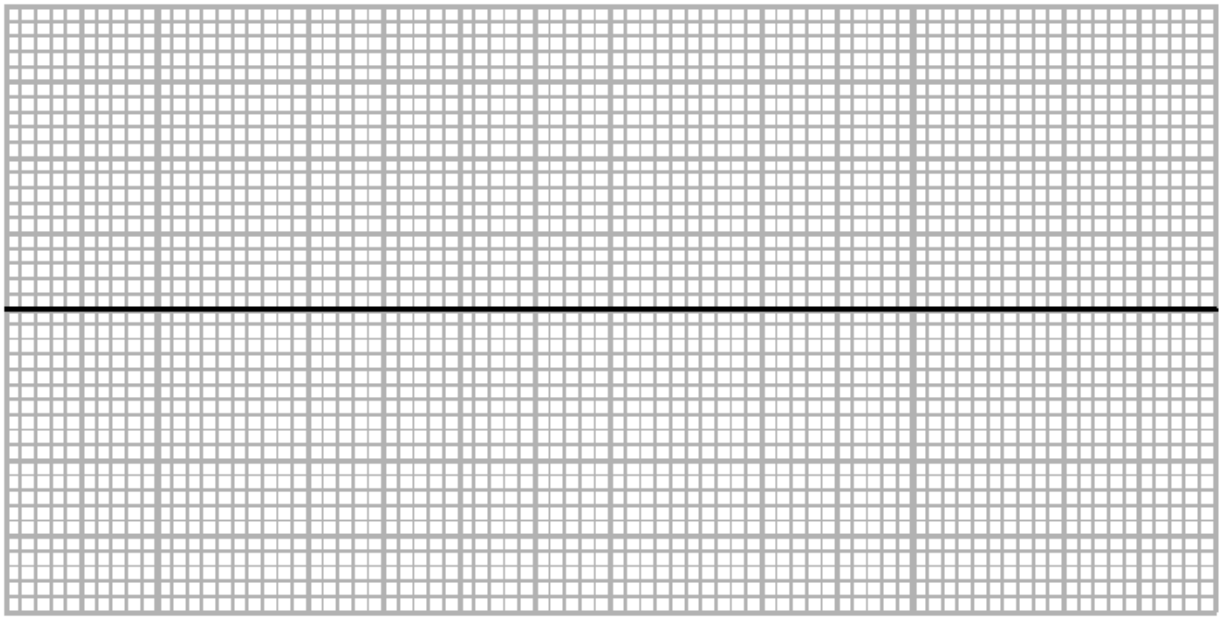
The eye may be modelled as a sphere with a single thin lens as shown. The distance from the centre of the lens to the retina is 2.0 cm.



(i) When the eye of a 10 year-old child is focused on an object that is at the near point, the focal length is 1.5 cm.

Complete a ray diagram to scale, on the grid below, to determine the distance to the near point for the child.

(3)



Distance to near point = ...

(ii) Calculate the magnification for this image.

(2)

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Magnification = ...

Q1.

The photograph shows a child's nature observation kit used for observing small creatures such as flies.



The lid has a built-in lens and an additional optional lens to allow the magnification to be increased.



The photographs below show the appearance of a fly using no lens, a single lens and two lenses respectively.







A student reads that the power of a combination of lenses is equal to the sum of the powers of the individual lenses.

$$\text{power}_{\text{combination}} = \text{power}_{\text{lens1}} + \text{power}_{\text{lens2}}$$

The student investigates this relationship using the lenses in the observation kit.

The student records the method and measurements as shown below.

Method

Set up a bulb on one side of the laboratory.
Hold the lens near the opposite wall and vary the distance from the wall until a clear image of the bulb is seen on the wall.
With the other hand, use a ruler to measure the distance of the lens from the clear image formed.
This is the focal length.

Results

Lens	Focal length/cm
Lens in the lid	12
Optional lens	17.5
Combination of both lenses	7

The distance between the light and the opposite wall was 6 m.

The distance of an object from the combined lenses is 5.0 cm.

Calculate the magnification of the lens.

Focal length = 7.0 cm.

(3)

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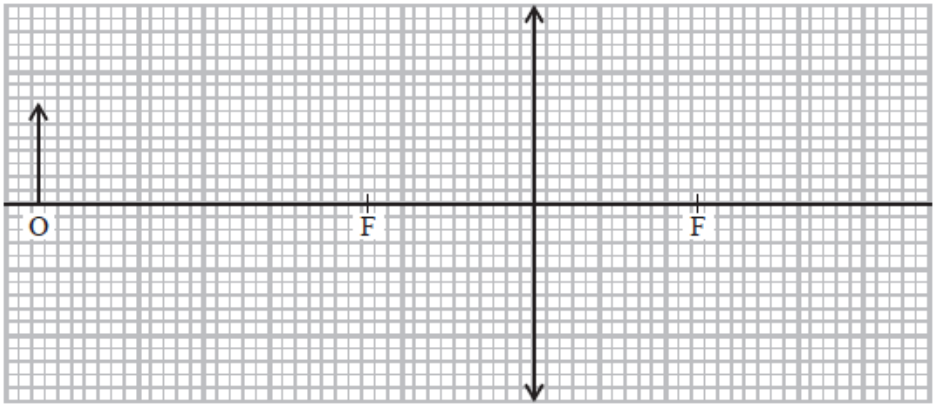
Magnification = ...

(Total for question = 3 marks)

Q2.

A camera uses a converging lens to produce an image.

The diagram represents an object O and a converging lens.



(i) Complete the ray diagram to determine the position of the image.

(3)

(ii) Determine the magnification of this image.

(2)

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Magnification = ...

(iii) State, with justification, whether the image is real or virtual.

(1)

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(Total for question = 6 marks)

Q3.

The photograph shows a type of drink known as stout.



When the drink is poured, it contains many spherical bubbles of gas which rise and form the foamy 'head' at the top of the drink. The manufacturers of the drink state "It takes 120 seconds for the head to form".

For the smallest bubbles, the uniform upward velocity can be calculated using the equation

$$v = \frac{2(\rho_{\text{stout}} - \rho_{\text{gas}})r^2 g}{9\eta}$$

(i) Derive this equation by considering the forces acting on a bubble.

(3)

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(ii) State an assumption you have made.

(1)

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(iii) Evaluate the statement from the manufacturers that it takes 120 seconds for the head to form.

You should consider the time for a bubble to travel from the bottom of the glass to the top.

height of glass = 11.5 cm
density of gas = 1.22 kg m^{-3}
density of stout = 1.01 × 10^3 kg m^{-3}

viscosity of stout = 2.06×10^{-3} Pa s
diameter of bubble = 122 μm

(4)

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Q4.

A camera uses a converging lens to produce an image.

In some cameras, lenses of different focal lengths can be used. A particular camera can use a lens of focal length 50 mm or a lens of focal length 200 mm. Both lenses are made from the same material.

(i) Describe a method to determine an approximate value for the focal length of a converging lens.

(2)

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(ii) Explain why the lens with the shorter focal length is thicker at its centre.

(2)

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(iii) Both photographs show the same scene photographed from the same position.



Photograph 1



Photograph 2

One photograph was taken using the lens of focal length 50 mm and the other was taken using the lens of focal length 200 mm.

Deduce which lens was used to take photograph 2.

(5)

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(Total for question = 9 marks)

Q5.

A converging lens can be used to produce a real image on a screen.

A converging lens of focal length 15.0 cm is used to project an image of an illuminated object

onto a screen. The object is a circle of diameter 4.0 mm and the image must be as large as possible on a screen of size 0.75 m by 1.25 m.

Calculate the distance between the lens and the screen for this image to be displayed.

(3)

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Distance between lens and screen = ...

(Total for question = 3 marks)

Q6.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

An object is placed 6.5 cm from a lens of focal length 3.9 cm. An image is formed 9.8 cm behind the lens.

Which of the following expressions is equal to the magnification?

☐ **A** $\frac{3.9}{6.5}$

☐ **B** $\frac{6.5}{9.8}$

☐ **C** $\frac{6.5}{3.9}$

☐ **D** $\frac{9.8}{6.5}$

(Total for question = 1 mark)

Q7.

The photograph shows a man wearing a virtual reality (VR) headset.

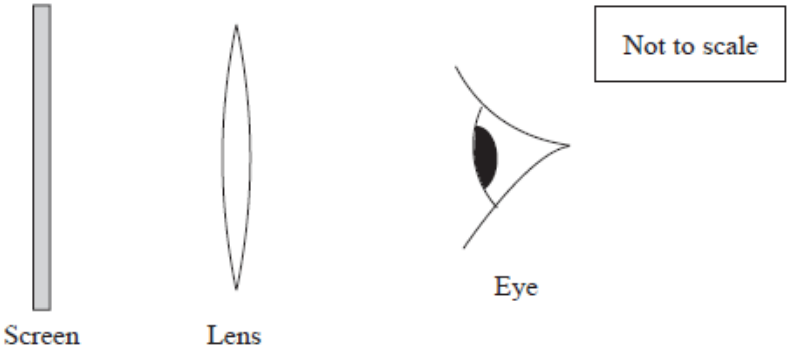


The VR headset gives the illusion of three-dimensional vision.

Inside the VR headset a pair of lenses is used to enable the user to focus on a magnified virtual image of a screen. The lenses can be changed to suit the vision of the user.



In the VR headset the lens is between the eye and the screen, as shown below.



For a particular user of the headset, the image of the screen must be at least 16 cm from the eye and have a magnification of at least 3.0.

Determine whether this would be possible with a lens of focal length 3.8 cm.
Your answer should include a full-scale ray diagram drawn on the grid provided.

(4)

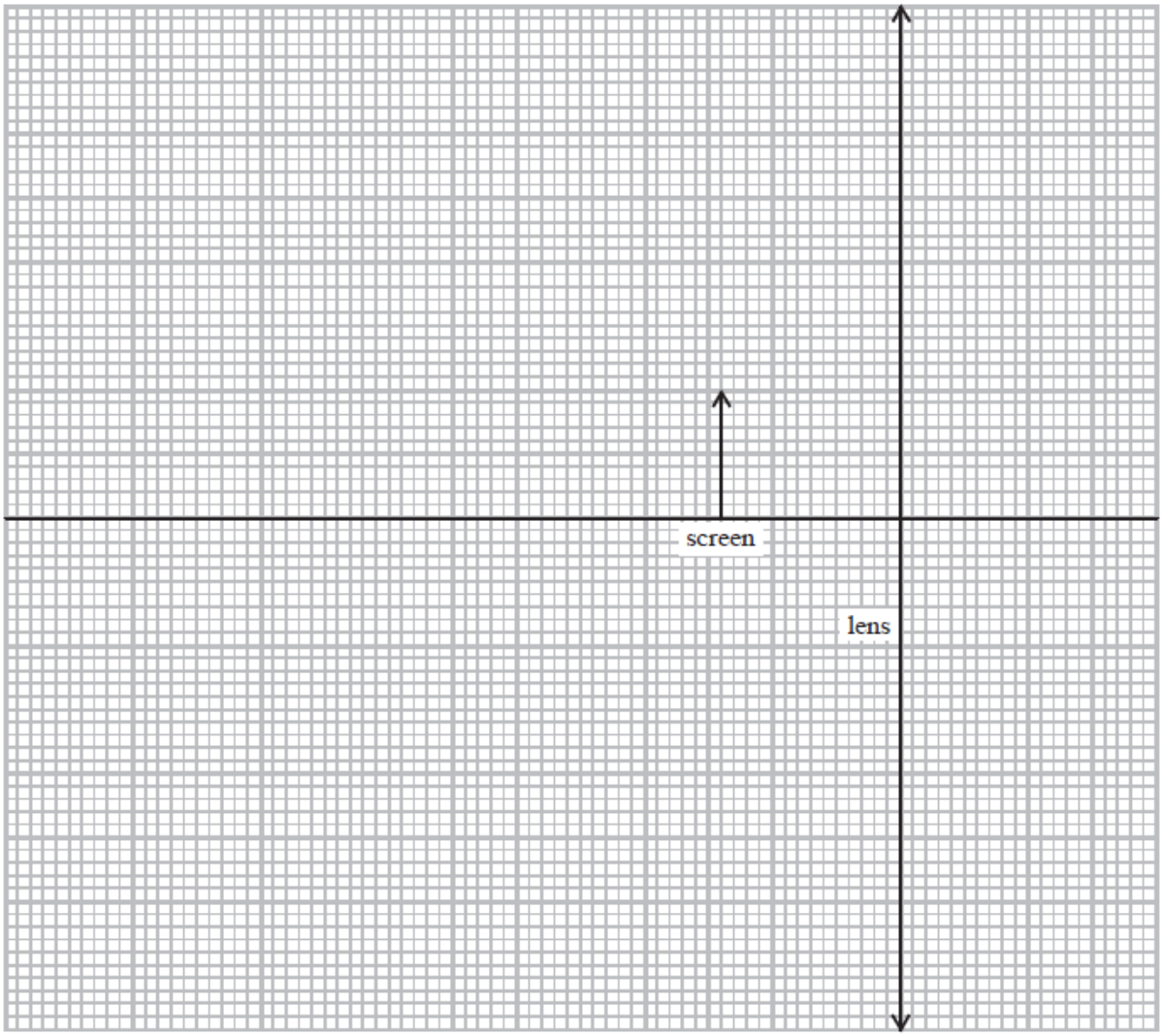
distance from screen to lens = 2.8 cm
distance from lens to eye = 2.2 cm

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(Total for question = 4 marks)

Q8.

An object is placed 6.5 cm away from a lens of focal length 3.9 cm. An image is formed 9.8 cm from the lens.

Which of the following is the magnification?

(1)

☒ **A** 0.60

☒ **B** 0.66

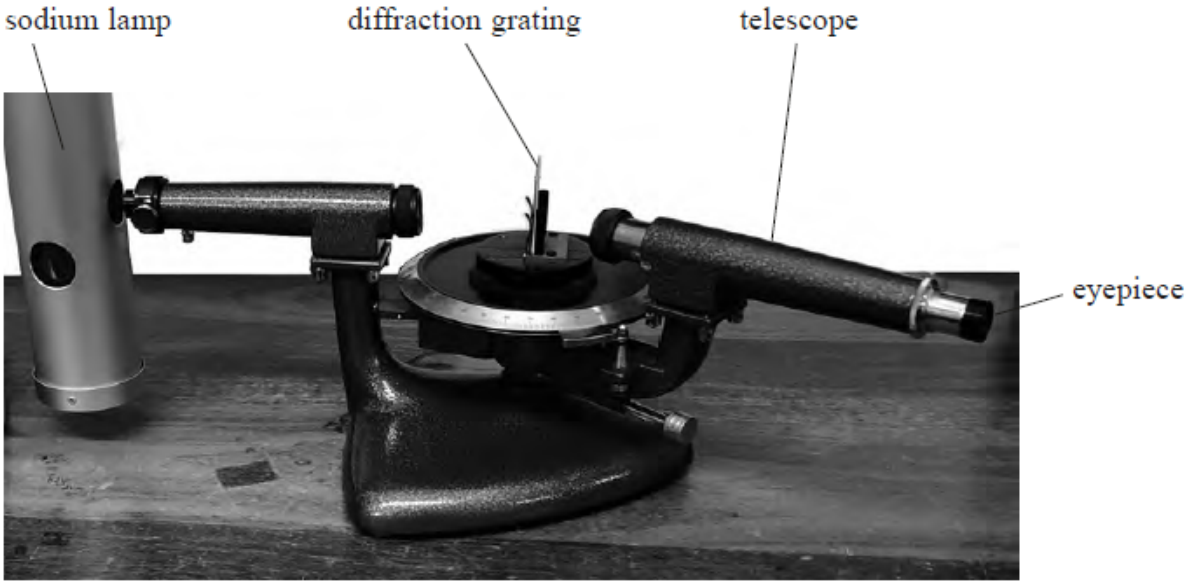
☒ **C** 1.5

☒ **D** 1.7

(Total for question = 1 mark)

Q9.

The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

In the telescope, light from the grating is focused to make a real image 16.7 mm in front of the eyepiece lens. The eyepiece lens then uses this real image as an object to produce a magnified virtual image for the observer.

Calculate the magnification produced by the eyepiece lens.

focal length of eyepiece lens = 17.9 mm

(3)

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Magnification = ...

(Total for question = 3 marks)

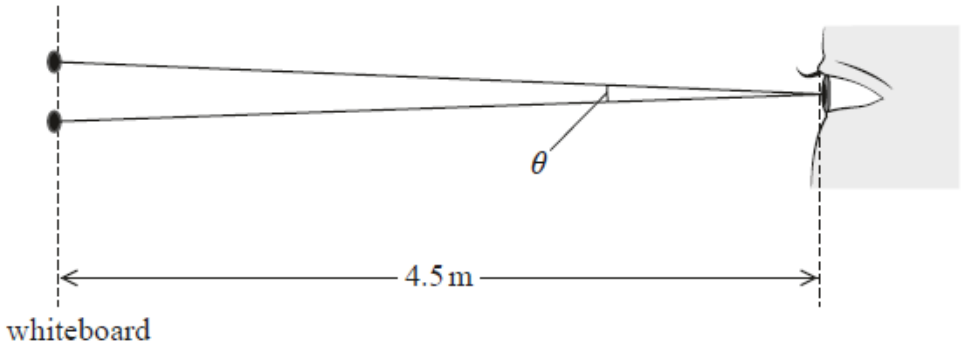
Q10.

A student investigated how a converging lens can be used to project a magnified image onto a whiteboard.

In a darkened room, the student placed a smartphone 9.0 cm from the converging lens. The phone's display was projected onto the whiteboard. The converging lens was 75.0 cm from the whiteboard when a clear image was produced.

The display on the phone contained two dots that were 5.0 mm apart. The student stood 4.5 m from the whiteboard and viewed the image of the dots.

Rays of light from the images of the two dots on the whiteboard were incident at the student's eye with an angle θ between them as shown.



The student could distinguish the two dots if the angle θ was greater than 0.0003 radians.

Deduce whether the student could distinguish the two dots clearly.

(5)

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(Total for question = 5 marks)

Q11.

A converging lens is used as a magnifying glass. An image is produced that is 30 cm away from the lens and twice as big as the object.

Choose the row that correctly identifies the nature of the image and the object distance.

	Nature of image	Object distance/cm
☒ **A**	real	15
☒ **B**	real	60
☒ **C**	virtual	15
☒ **D**	virtual	60

(Total for question = 1 mark)

Q12.

A magnifying glass consists of a converging lens and is used to magnify the details of an object.

A biologist is studying a flower using a magnifying glass. The anther of the flower has a width of 0.2 mm. The magnifying glass is placed 5.0 cm from the flower and an image of the anther is produced that is 3.5 mm wide.

Calculate the power of the lens in the magnifying glass.

(5)

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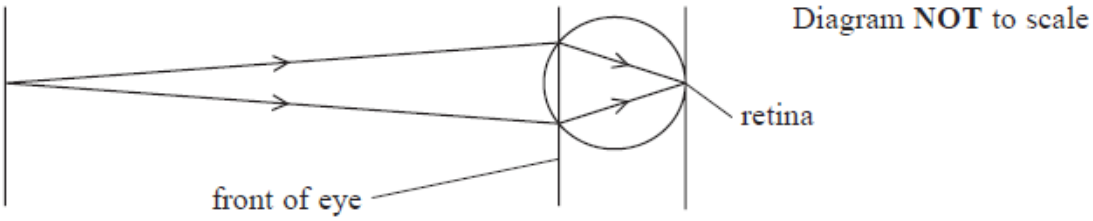
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Power of lens = ...

(Total for question = 5 marks)

Q13.

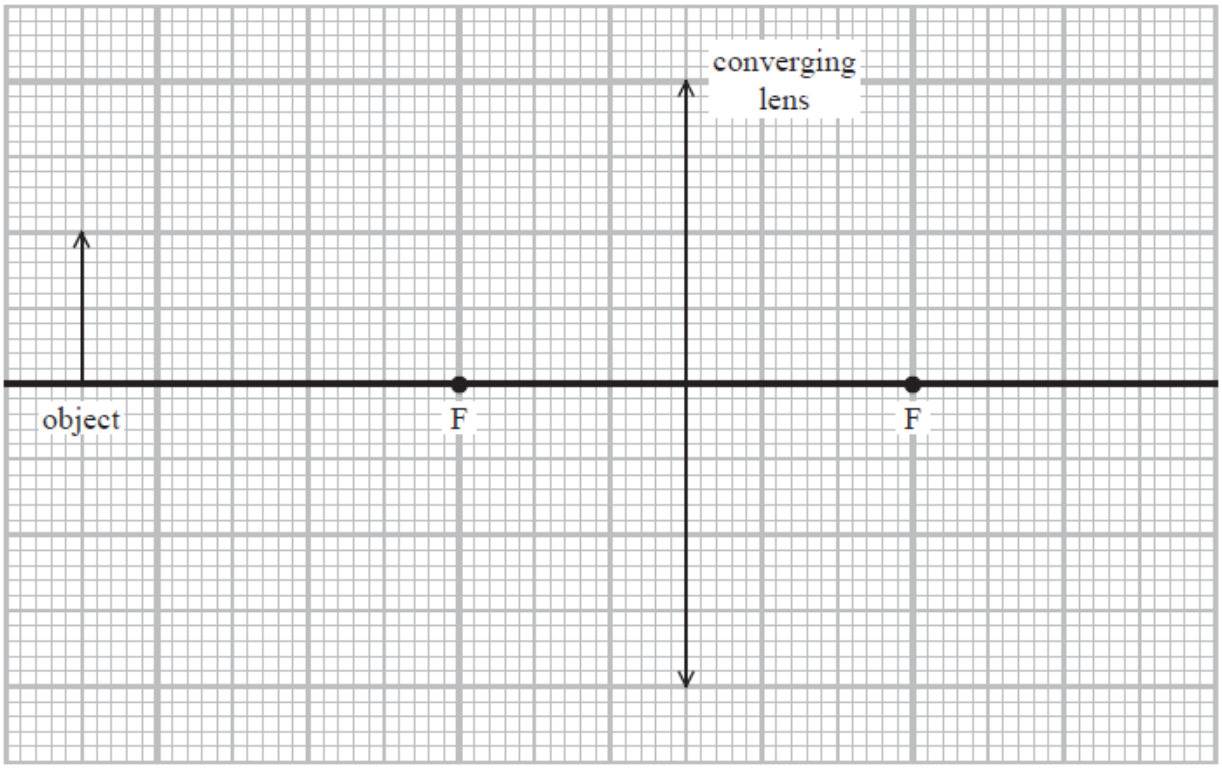
The human eye acts as a converging lens system that produces an image on the retina at the back of the eye as shown.



A person with eyesight problems may wear either diverging or converging contact lenses.

The diagram below shows an object in front of a converging lens.

F is the principal focus.



Determine the position and magnification of the image produced by the lens, by completing a ray diagram.

(4)

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Magnification = ...

(Total for question = 4 marks)

Q14.

Some sunglasses have lenses made from polarising filters.

You are given two pairs of identical sunglasses.

Devise a simple test to determine whether the sunglasses use polarising lenses.

(2)

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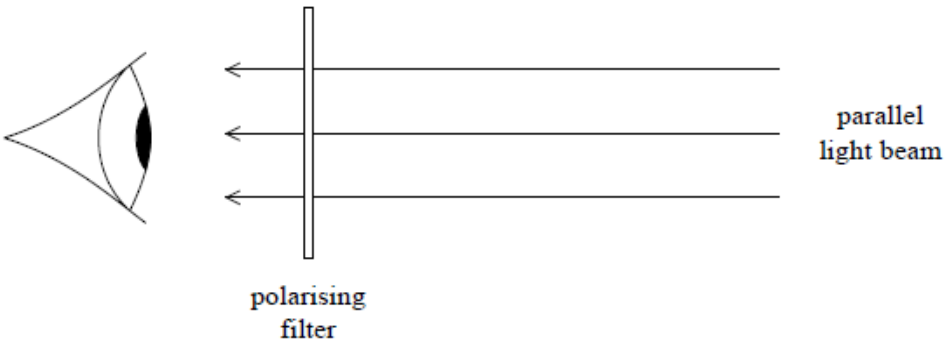
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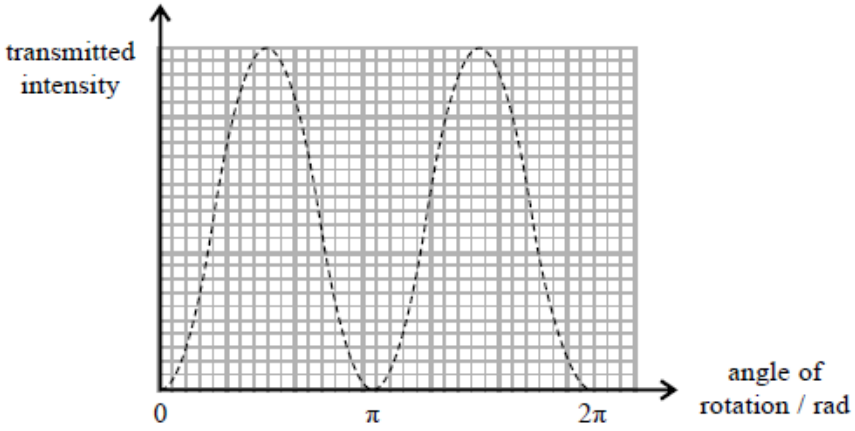
(Total for question = 2 marks)

Q15.

A student observes a parallel beam of light through a polarising filter.



The polarising filter is rotated through 2π rad in its own plane. The intensity of the light transmitted through the filter varies as shown.



* Explain the observed variation in intensity of the transmitted beam.

(6)

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(Total for question = 6 marks)