Reflection, Refraction and Lenses

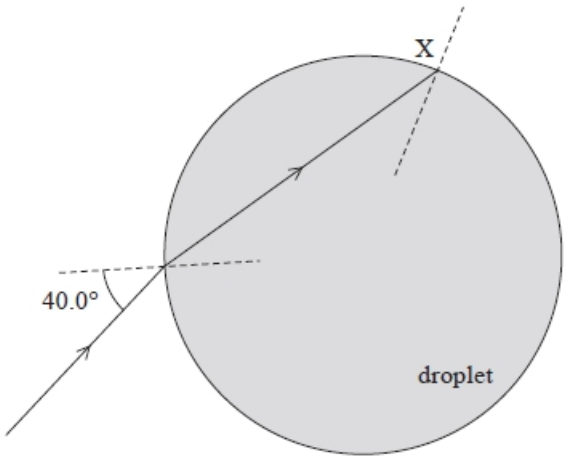
Q1.

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.

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.

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(Total for question = 4 marks)

Q3.

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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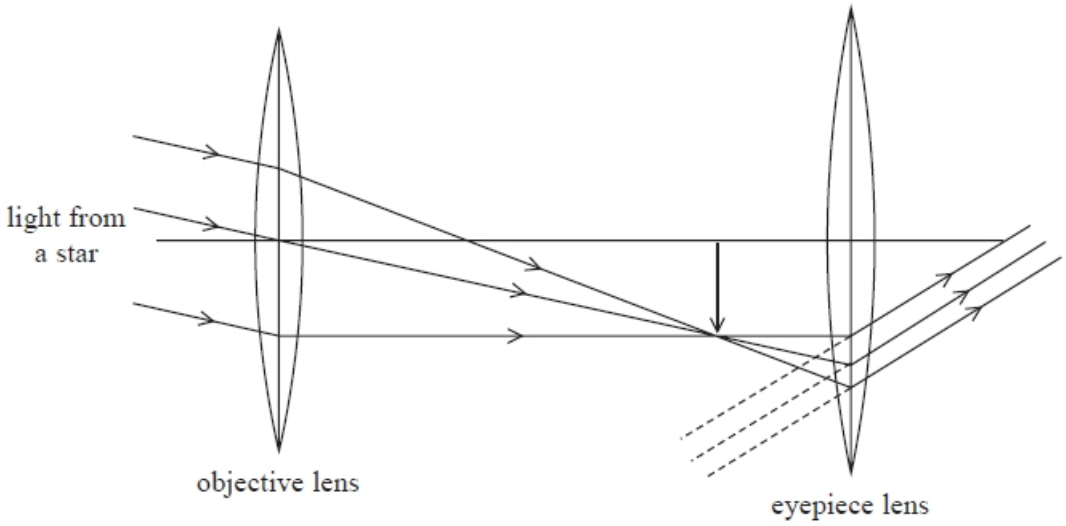
(Total for question = 1 mark)

Q4.

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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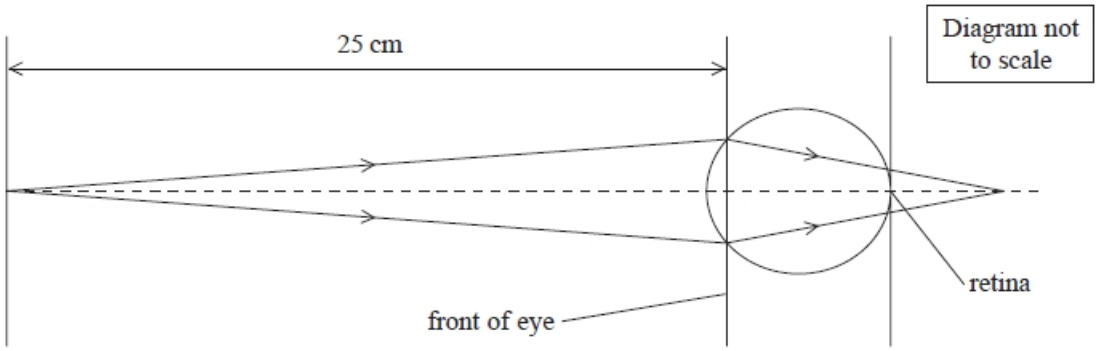
(Total for question = 3 marks)

Q5.

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)

Q6.

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** $\sin C = \frac{n_g}{n_w}$

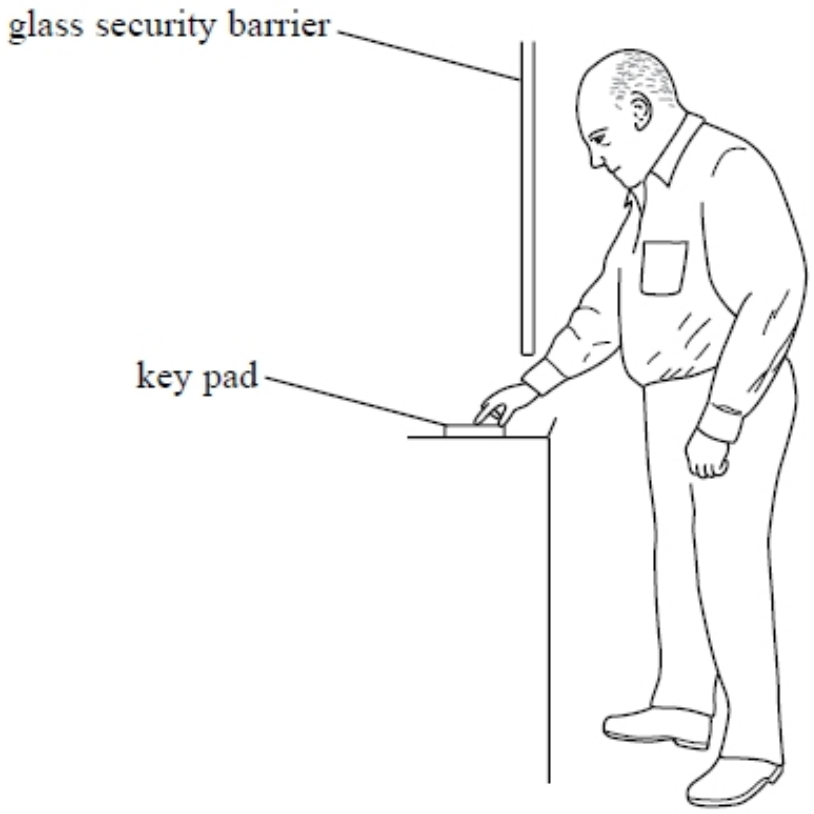
☒ **D** $\sin C = \frac{1}{n_w}$

(Total for question = 1 mark)

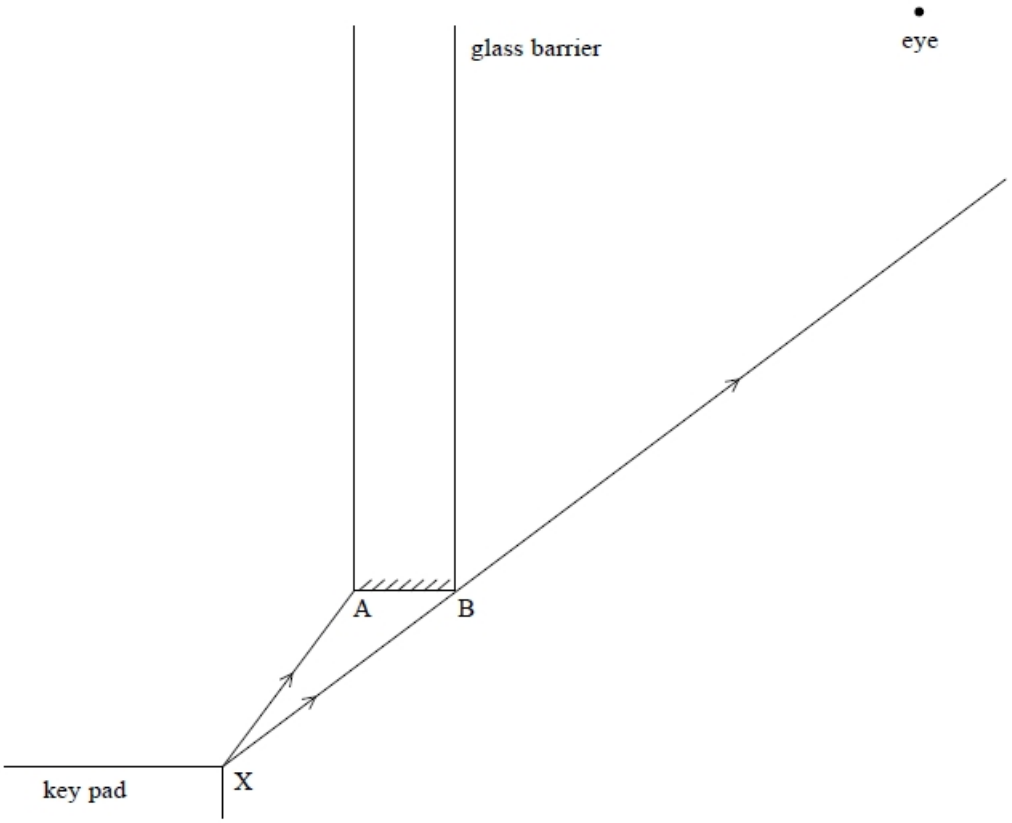
Q7.

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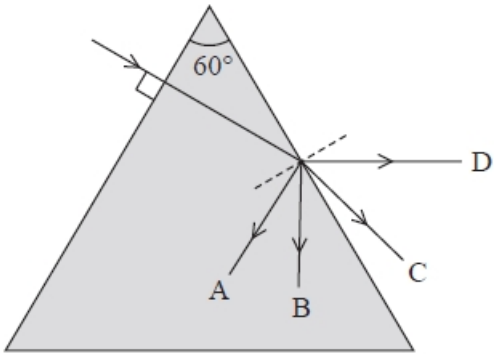
(ii) Add to the diagram to show that light travelling initially along the path XA does not reach the eye of the motorist.

(1)

(Total for question = 4 marks)

Q8.

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

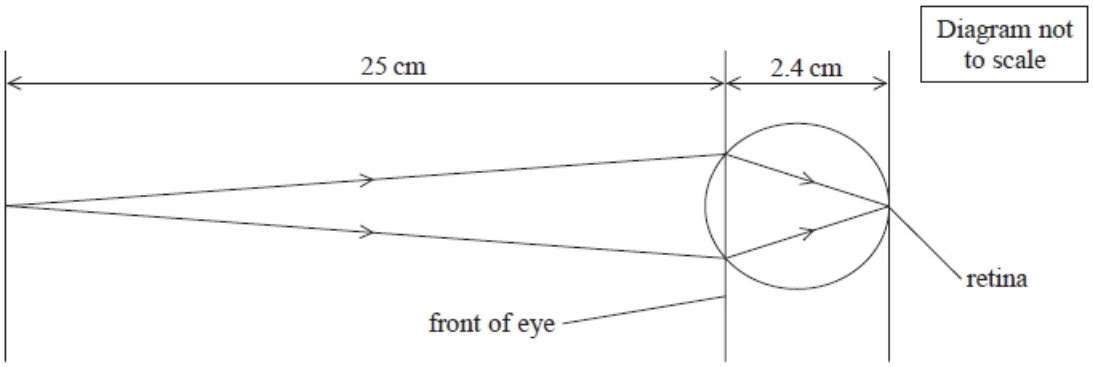
(Total for question = 1 mark)

Q9.

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)

Q10.

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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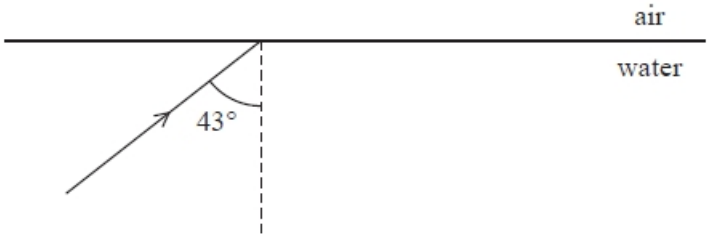
Magnification = ...

(Total for question = 3 marks)

Q11.

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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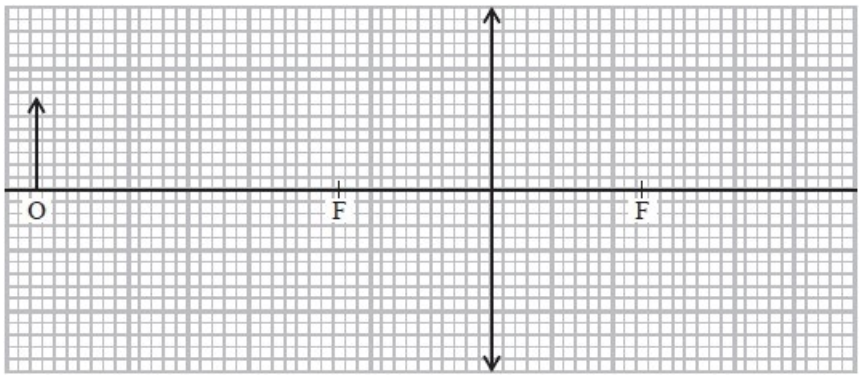
(Total for question = # marks)

Q12.

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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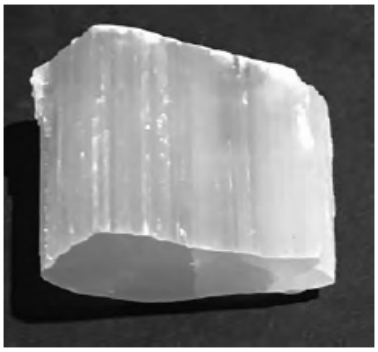
(Total for question = 6 marks)

Q13.

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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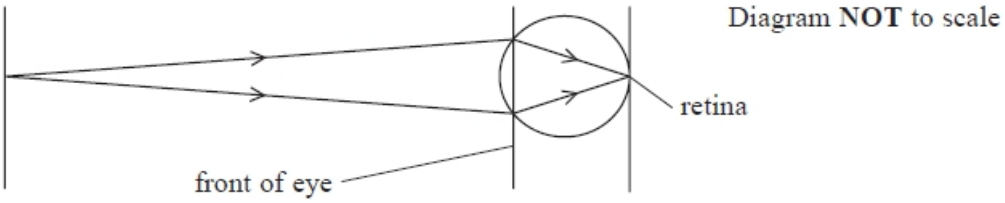
Critical angle for light in selenite = ...

(Total for question = 3 marks)

Q14.

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 = ...

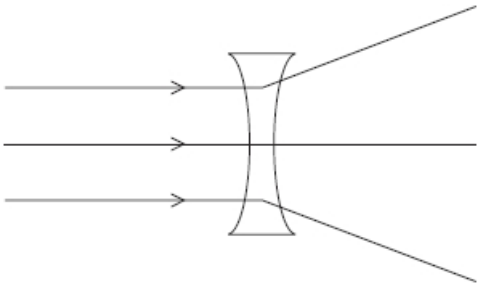
Type of lens .....

(Total for question = 4 marks)

Q15.

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)

Q16.

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.

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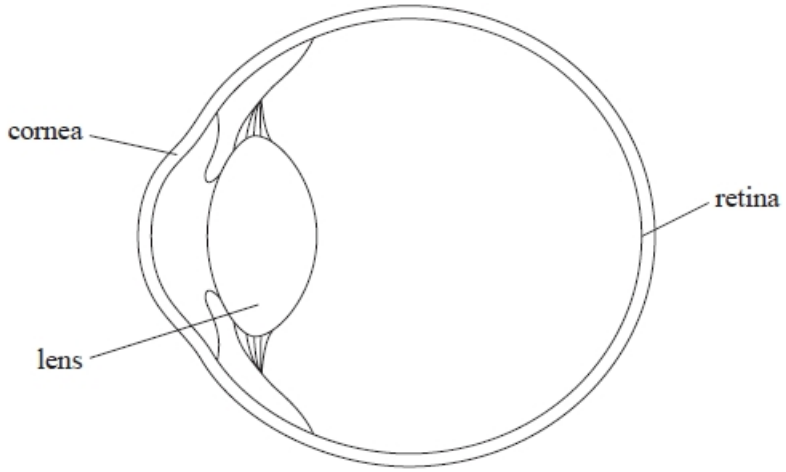
(Total for question = 9 marks)

Q17.

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



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)

Q18.

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** $\frac{6.5}{3.9}$

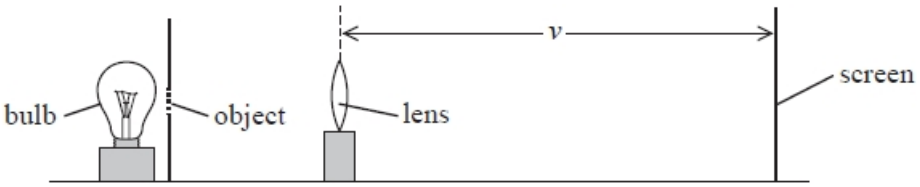
☒ **D** $\frac{9.8}{6.5}$

(Total for question = 1 mark)

Q19.

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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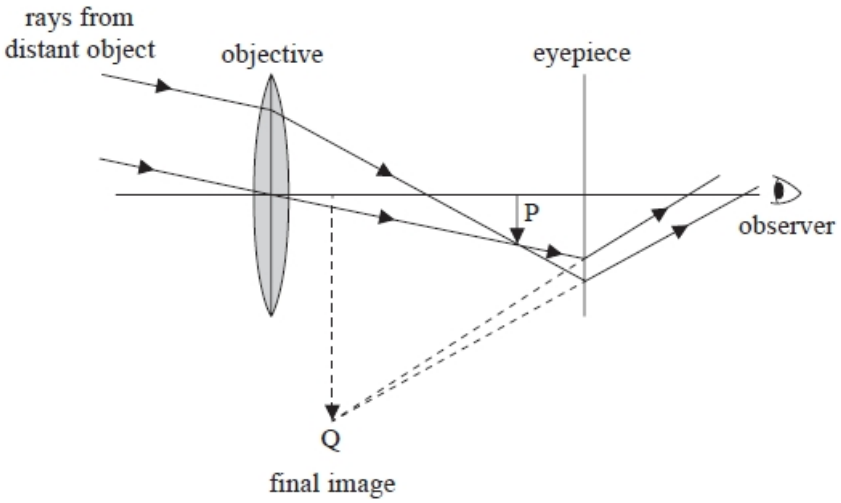
(Total for question = 3 marks)

Q20.

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)

Q21.

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)

Q22.

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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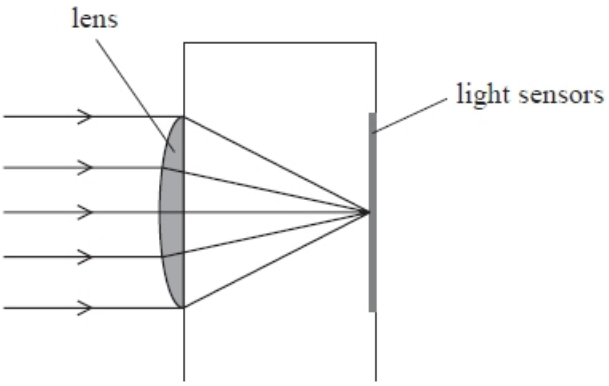
Focal length = ...

(Total for question = 2 marks)

Q23.

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)

Q24.

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)

Q25.

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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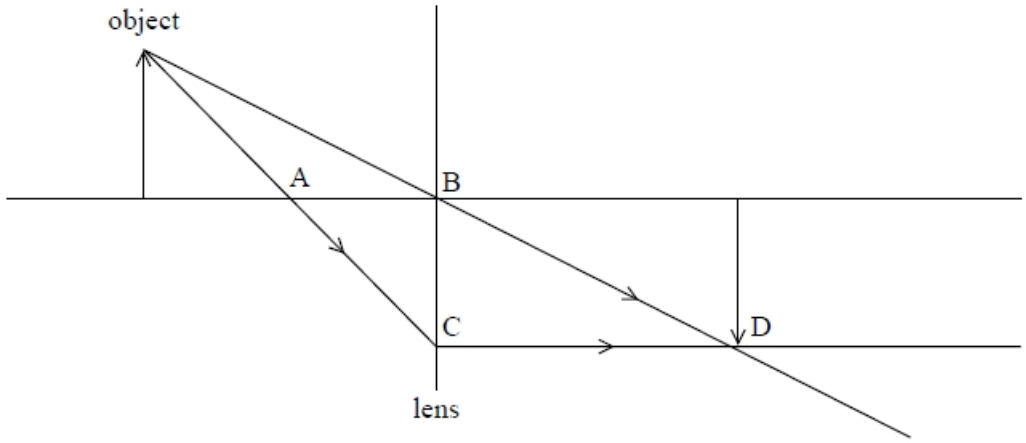
Speed of light in seawater = ...

(Total for question = 9 marks)

Q26.

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)

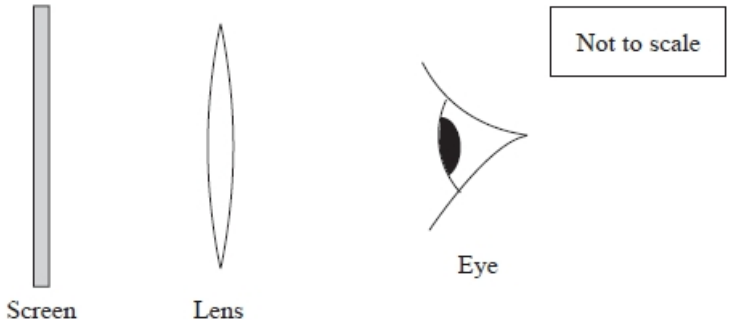
Q27.

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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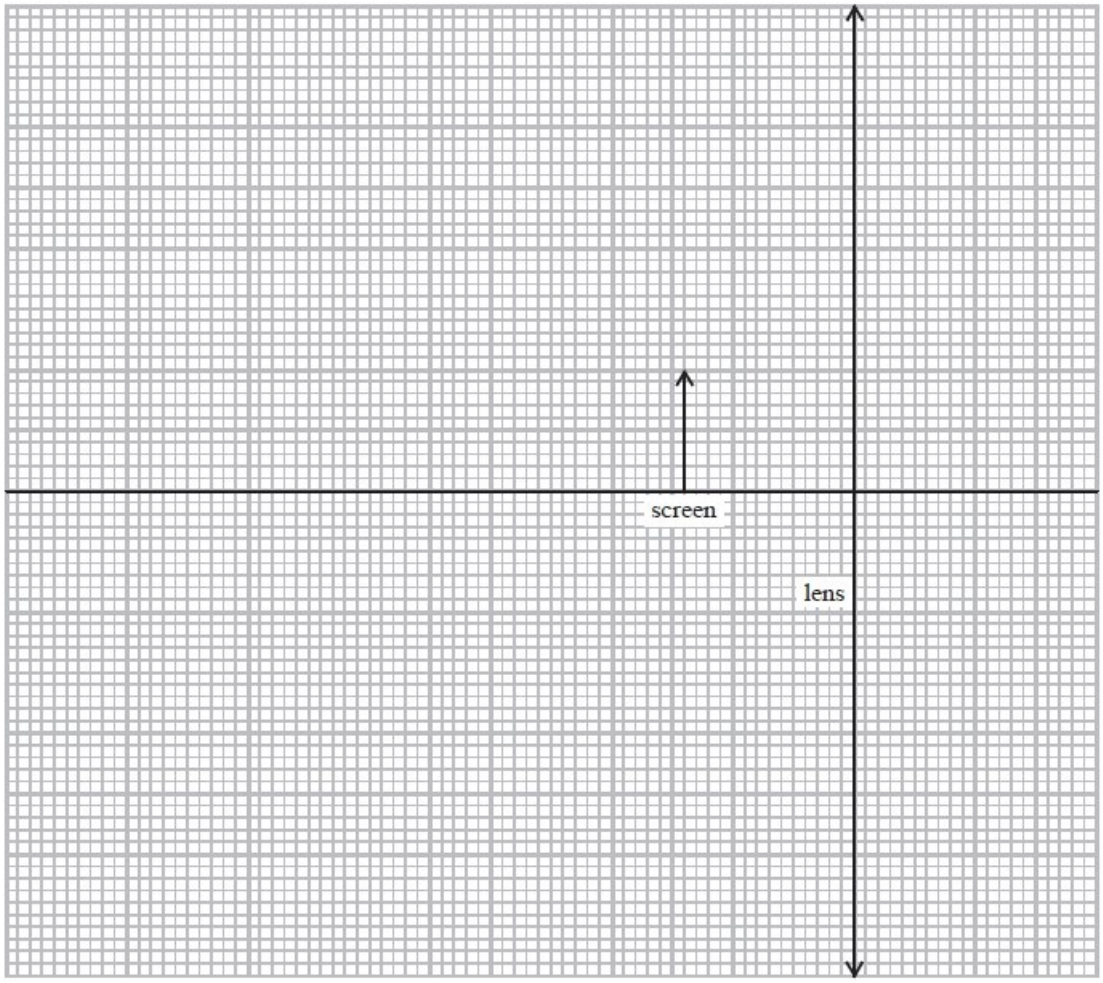


(Total for question = 4 marks)

Q28.

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

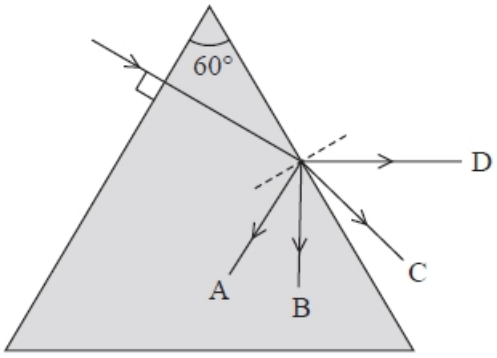
Select the row of the table that correctly identifies the nature of the image produced.

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

(Total for question = 1 mark)

Q29.

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**

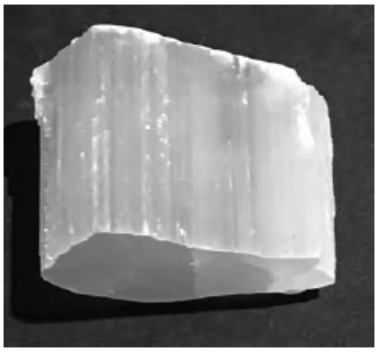
☒ **C**

☒ **D**

(Total for question = 1 mark)

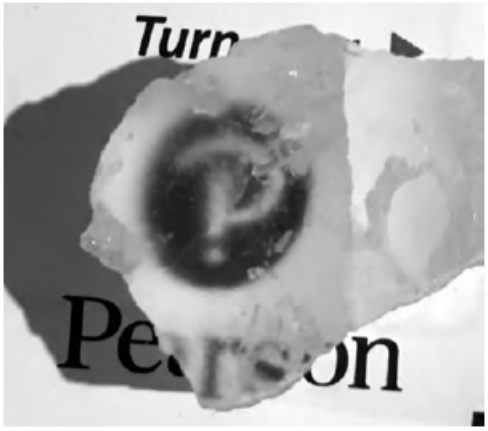
Q30.

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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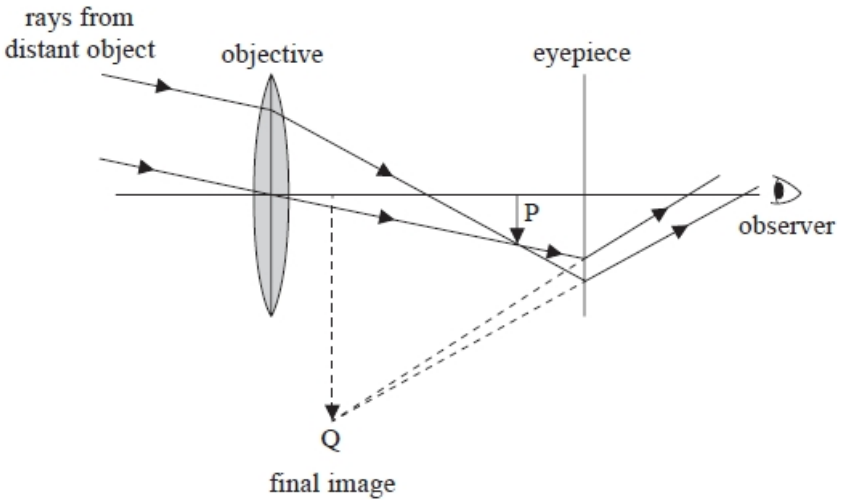
(Total for question = 2 marks)

Q31.

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)

Q32.

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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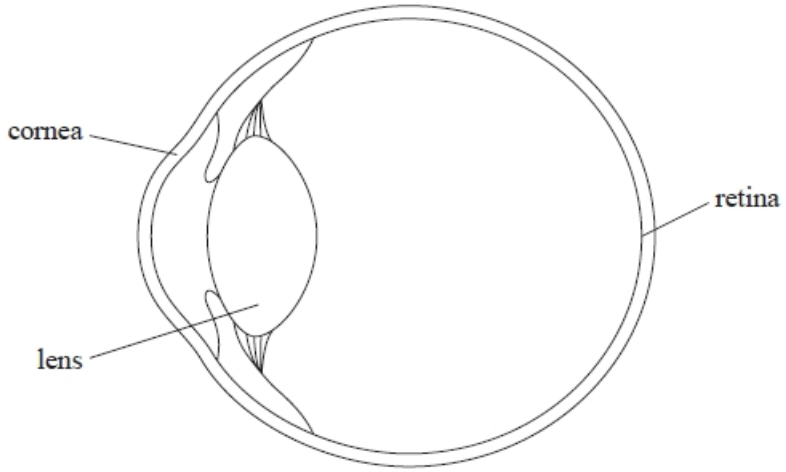
Q33.

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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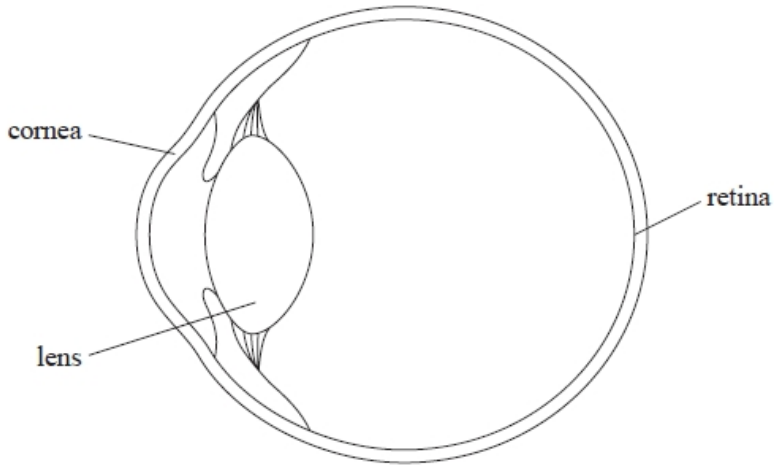
Angle to normal in cornea = ...

(Total for question = 5 marks)

Q34.

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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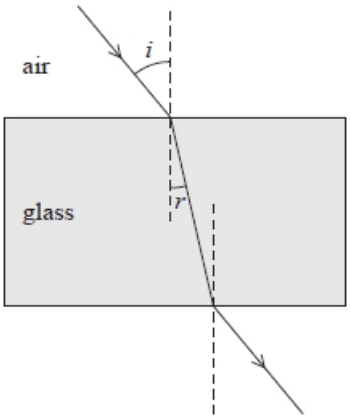
(Total for question = 4 marks)

Q35.

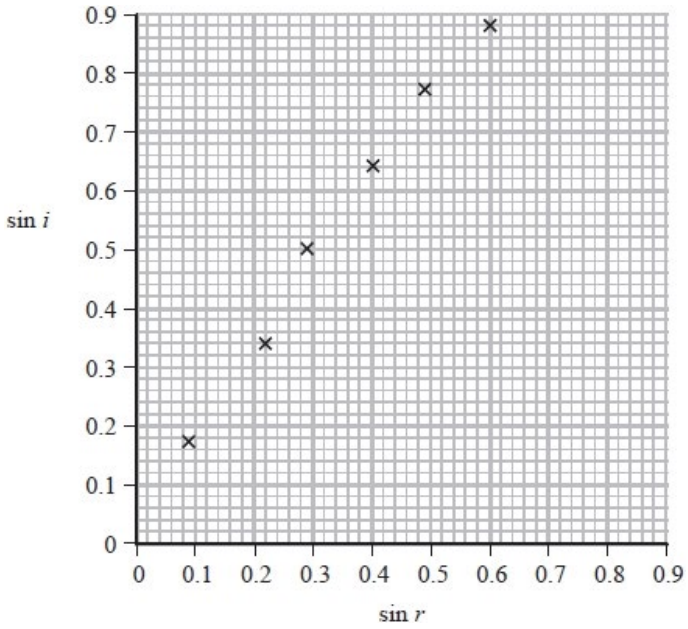
A student is carrying out an experiment to identify which type of glass a rectangular block is made from.

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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Type of glass .....

(Total for question = 4 marks)

Q36.

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

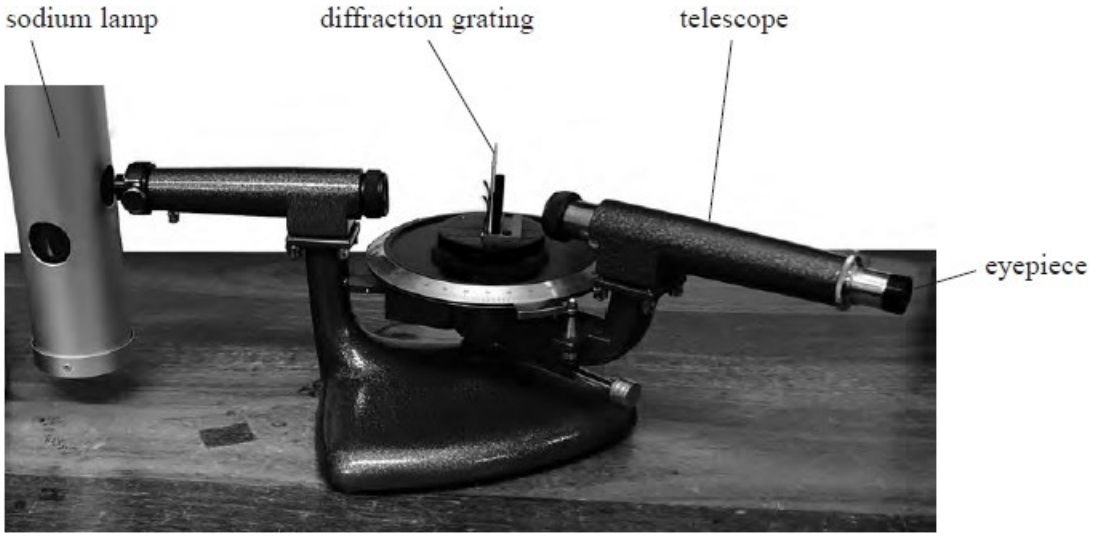
☒ **C** 1.5

☒ **D** 1.7

(Total for question = 1 mark)

Q37.

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)

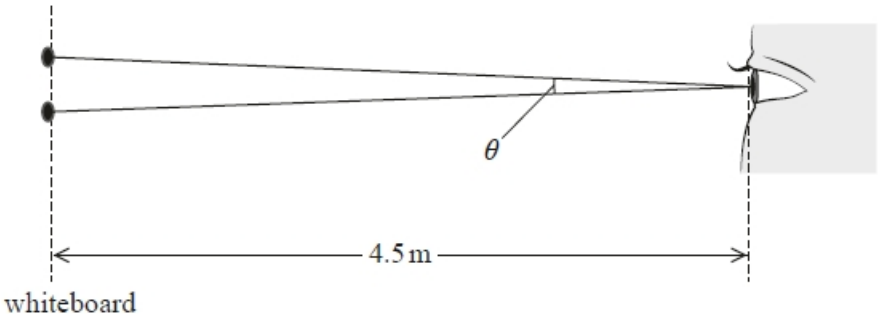
Q38.

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.

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(Total for question = 5 marks)

Q39.

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.

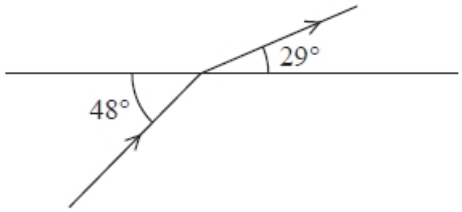
Choose the row that correctly identifies the nature of the image and the object distance.

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

(Total for question = 1 mark)

Q40.

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)

Q41.

A wave of wavelength λ and frequency *f* is travelling in a medium with wave speed v_1.
The wave passes into another medium with wave speed v_2.

The wavelength of the wave in the second medium is

☒ **A** $\frac{v_1}{f}$

☒ **B** $\frac{v_2}{f}$

☒ **C** $\frac{v_1}{v_2 f}$

☒ **D** $\frac{v_2 f}{v_1}$

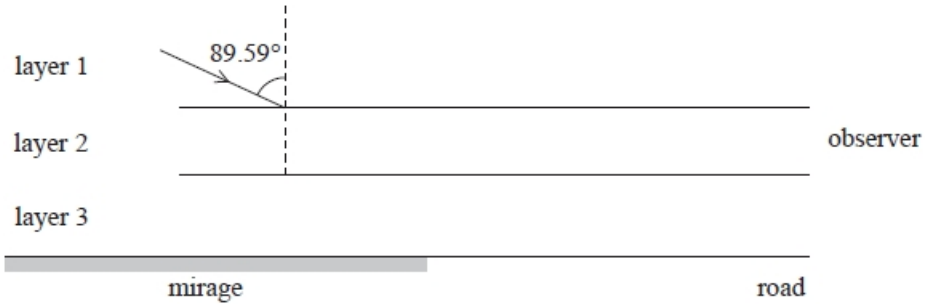
(Total for question = 1 mark)

Q42.

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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(Total for question = 6 marks)

Q43.

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

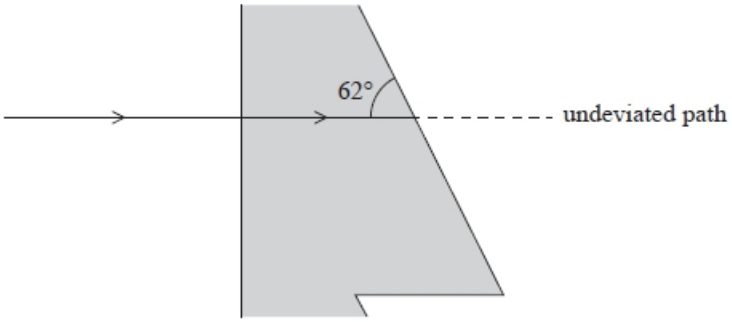

Figure 2

(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)

Q44.

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.

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Power of lens = ...

(Total for question = 5 marks)

Q45.

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

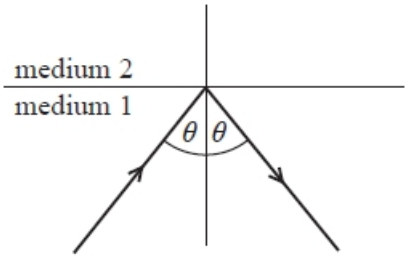
☒ **C** −5.2 D

☒ **D** −13.6 D

(Total for question = 1 mark)

Q46.

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**	$\theta > C$	$n_2 < n_1$

(Total for question = 1 mark)

Q47.

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.

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

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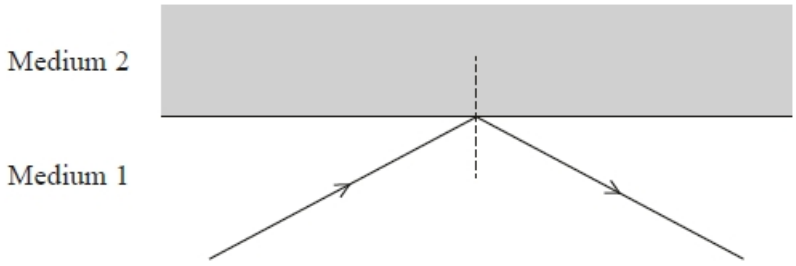
(Total for question = 7 marks)

Q48.

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

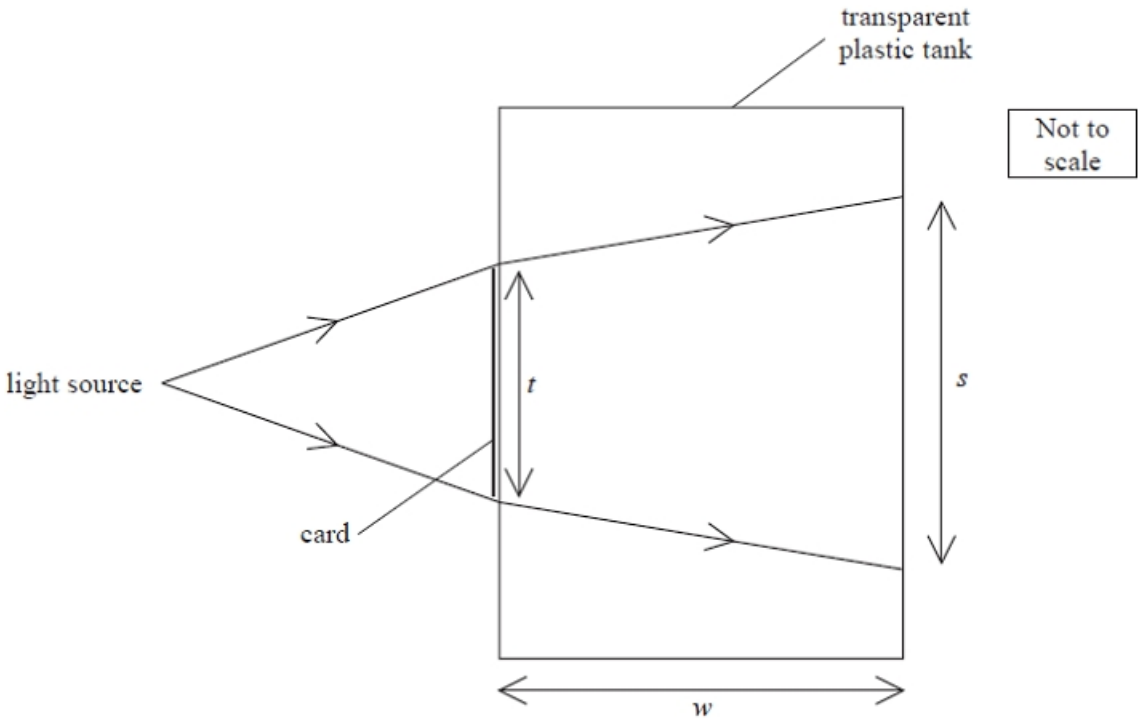
Which row of the table is correct for this situation?

☒	**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)

Q49.

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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(Total for question = 3 marks)

Q50.

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)

Q51.

A student carried out an experiment to determine the focal length of a converging lens.

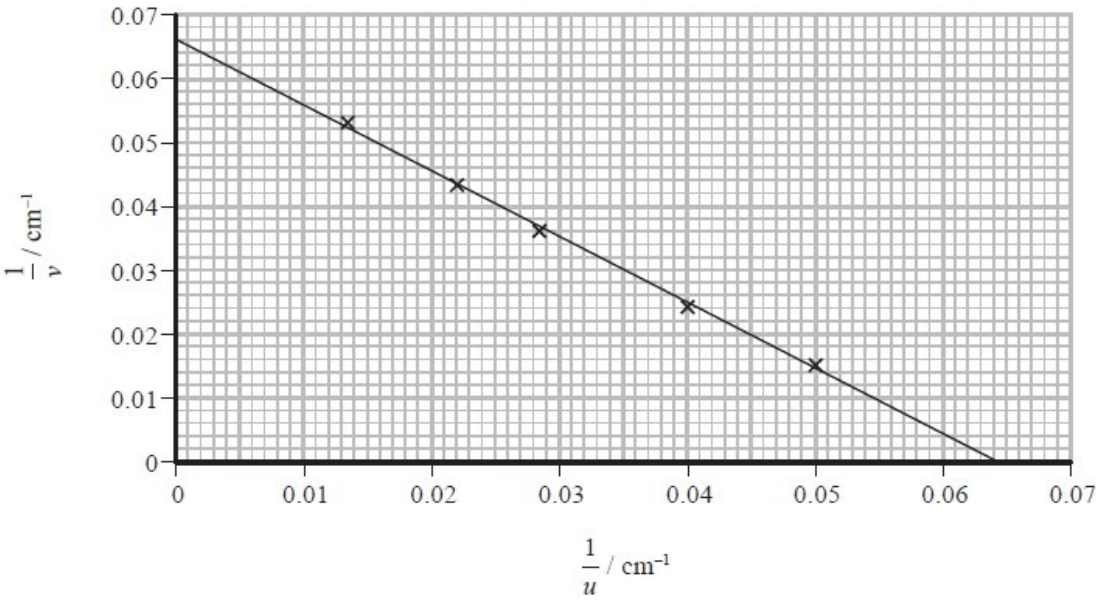
He placed the lens a distance *u* from an illuminated object. He placed a screen on the other side of the lens and moved the screen until a sharp image of the object was produced. He measured the corresponding image distance *v*.

The student repeated the procedure for four more values of *u*.

In his lab report he wrote:

"I made an initial determination of the focal length of the lens and concluded that it was about 15 cm. When I plotted a graph it confirmed my initial determination of the lens focal length."

The student's graph is shown.



Comment on whether the student's data is consistent with his initial determination of the focal length of the lens.

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(Total for question = 5 marks)

Q52.

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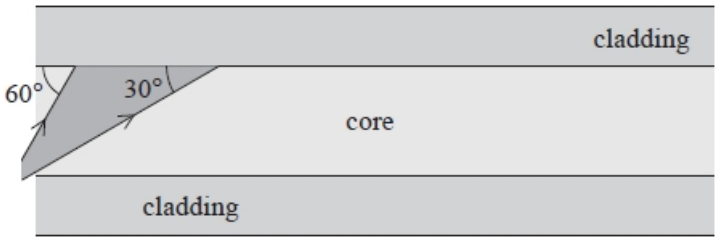
(b) The diagram shows a diverging beam of light incident on the boundary between the core and the cladding. One side of the beam strikes the boundary at 60° and the other side at 30° as shown.



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)

Q53.

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)

Mark Scheme – Reflection, Refraction and Lenses

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $n = \frac{c}{v}$ (1) • Use of $n_1 sin\theta_1 = n_2 sin\theta_2$ (1) • Uses $\sin C = \frac{1}{n}$ (1) • Comparison of $C = 50°$ with 30° and conclusion (1)	Example of Calculation $n_{\text{(air-water)}} = \frac{3.0 \times 10^8}{2.25 \times 10^8} = 1.33$ $\sin 40 = 1.33 \sin\theta_2 \quad \theta_2 = 29°$ At X: $\sin C = \frac{1}{1.33}$ $C = 49° > 29°$ so refracted	4

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • Use of $P = P_1 + P_2 = 5\text{D}$ therefore use one lens with power of 2 (D) and one with power of 3 (D) (1)	Example of Calculation $v = 0.5 \text{ x } 0.6 \text{ m} = 0.3 \text{ m}$ $\frac{1}{f} = \frac{1}{0.6 \text{ m}} + \frac{1}{0.3 \text{ m}}$ $f = 0.2 \text{ m}$ $P = 1/0.2 \text{ m} = 5\text{D}$	4

Q3.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Light rays pass through the image **Or** Light rays converge to a point where the image is formed (1)		1

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Object/star is at infinity, so (intermediate) image formed at focal length of objective lens (1) • (Final image at infinity), so object (intermediate image) must be at focal length of eyepiece lens (1) **Or** • Objective lens, $1/v + 1/u = 1/f$, and u = infinity, so $v = f$ • Eyepiece lens, $1/v + 1/u = 1/f$, v = infinity so $u = f$	Appropriate references to parallel rays may be equivalent to object/image at infinity Example Objective: $1/v + 1/u = 1/f$, $u = \infty$, so $1/v + 1/\infty = 1/f$ $1/v + 0 = 1/f$ $v = f$ Eyepiece: $1/v + 1/u = 1/f$, $v = \infty$, so $1/\infty + 1/u = 1/f$ $0 + 1/u = 1/f$ $u = f$ Note: If both lenses are considered, $1/v + 1/u = 1/f$ does not have to be quoted twice	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• The rays cross over after the objective lens **Or** (1) • The objective lens inverts the image **Or** • The image formed by the eyepiece lens is on the same side as its object, so remains the same way up		1

Q5.

Question Number	Acceptable Answers	Additional guidance	Mark
	• increases the power (of the eye) **Or** to decrease the image distance **Or** to shorten the focal length (of the eye and lens) **Or** to the eye it makes the rays appear to come from an object further away (1)	If a candidate states that the image is formed at the focal point or that the retina is at the focal point do not award this mark	1

Q6.

Question Number	Answers	Mark
	The only correct answer is B ***A*** *is incorrect because the relative refractive index for light travelling from glass to water is required* ***C*** *is incorrect because the relative refractive index for light travelling from glass to water is required* ***D*** *is incorrect because the relative refractive index for light travelling from glass to water is required*	**1**

Q7.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• measure angle of incidence at edge (53°) **(1)** • use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **(1)** • value of angle in glass = 32° **(1)**	±1° tolerance Allow ecf for candidate's value Example of calculation: $1 \times \sin 53° = 1.5 \times \sin\theta_2$ $\theta_2 = 32°$	**3**
(ii)	• show refraction towards normal entering glass and how refraction away from normal exiting glass **(1)**		**1**

Q8.

Question Number	Answer	Mark
	B $\frac{1}{\sin 35}$	**1**
	Incorrect Answers: A – incorrect arrangement of equation C – incorrect arrangement of equation D – incorrect arrangement of equation	

Q9.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ (1) • Use of $P=\frac{1}{f}$ (1) • P = 46 D / Dioptre / dioptre (1)	Accept MP2 if you see $\frac{1}{25}$ or $\frac{1}{2.4}$ for $\frac{1}{f}$ Example of Calculation $\frac{1}{0.25}+\frac{1}{0.024}=46$ D	3

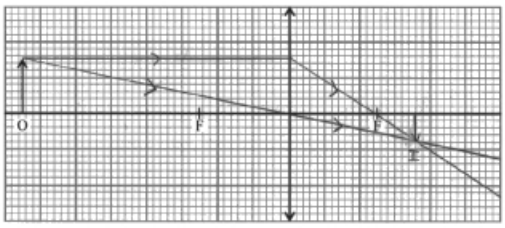
Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• use of $1/v + 1/u = 1/f$ **(1)** • use of magnification = v/u **(1)** • magnification = 3.5 **(1)**	Example of calculation $1/v = 1/7.0 – 1/5.0$ v = 17.5 cm M = 17.5 / 5.0 = 3.5	**3**

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $n = c/v$ (1) • use of sin $C = 1/n$ (1) • C = 48.8° so TIR does not occur (1)	Example of calculation $n = (3.00 \times 10^8 \text{ m s}^{-1}) / (2.25 \times 10^8 \text{ m s}^{-1})$ $n = 1.33$ sin C = 1 / n = 1 / 1.33 C = 48.8°	**(3)**

Q12.

Question Number	Acceptable Answers		Additional guidance	
(i)	• One ray correctly drawn • Second ray correctly drawn • Completes diagram with image at position 3.6 to 3.8 cm and height of 0.7 to 0.8 cm	(1) (1) (1)		3
(ii)	• Use of $m = \frac{v}{u}$ **or** $m = \frac{image\ height}{object\ height}$ using values from (a)(i) • Magnification of 0.47 to 0.53	(1) (1)	Example of Calculation $m = \frac{v}{u} = \frac{3.7}{7.5} = 0.5$	2
(iii)	• Real **and** image on different side of converging lens to object **Or** rays pass through the image	(1)		1

Q13.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• the angle of incidence in an (optically) denser medium at which the angle of refraction (in the less dense medium) is 90° **Or** • the greatest angle of incidence in an (optically) denser medium at which there is an emergent ray (into the less dense medium) **Or** • the greatest angle of incidence in an (optically) denser medium at which there is a refracted ray (in the less dense medium)	(1)	Other equivalent answers may be given Do not accept answers stating or implying that the critical angle is the smallest angle at which total internal reflection occur, e.g., 'The smallest angle at which t.i.r. takes place', but do not automatically exclude answers on the basis of mentioning internal reflection alone without the inclusion of 'total' 'The greatest angle before t.i.r. takes place' is not sufficient	1
(ii)	• Use of $\sin C = 1 / n$ • $C = 41°$	(1) (1)	Example of calculation $\sin C = 1/1.52$ $C = 41.1°$	2

Q14.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and $P = \frac{1}{f}$ • Use of $P = P_1 + P_2$ • (−) 0.6 D • Diverging	MP4 dependent on MP3 <u>Example of calculation</u> Power of eye $P = \frac{1}{1.5\ (m)} + \frac{1}{0.024(m)} = 42.3$ D P of spectacles = 41.7 (D) – 42.3 (D) = -0.6 D diverging	4

Q15.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Two straight lines drawn extrapolated from diverging rays meeting at a single point on the principal axis (1) • focal length = (-) 2.3 to 2.4 cm (1)	Accept dotted or solid lines	2

Q16.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Focus image of distant/far object on to a screen (1) • Measure distance from lens to screen (1) **Or** • Use <u>parallel</u> rays of light (1) • Measure distance from lens to the point where the rays converge (1)	MP2 dependent on MP1	2
(ii)	• Greater <u>refraction</u> (1) • To converge (parallel) rays at a point closer to the lens (1)		2
(iii)	• Photograph 2 has a greater magnification (1) • so v is greater (1) • since u is constant (1) • So f is greater (1) • Hence photograph 2 taken with lens of focal length 200 mm (1)	MP5 dependent on MP2 and MP4	5

Q17.

Question Number	Acceptable answers		Additional guidance	Mark
	• difference in speed for air to cornea much greater than difference in speed from water to cornea **Or** lower refractive index for water to cornea (= 1.03)	(1)	MP1: Seeing values of refractive index as 1.03 and 1.38 is not enough, a comparison is required.	3
	• so less refraction **Or** so power of eye/cornea reduced **Or** so focal length of eye/cornea increased	(1)		
	• if goggles worn the interface is with air and refraction is as normal **Or** if goggles worn the interface is with air and image focused on retina	(1)		

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is **D** because magnification is numerically equal to image distance divided by object distance A is not correct because magnification is numerically equal to image distance divided by object distance, but this is focal length divided by object distance B is not correct because magnification is numerically equal to image distance divided by object distance, but this is object distance divided by image distance C is not correct because magnification is numerically equal to image distance divided by object distance, but this is object distance divided by focal length		1

Q19.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Only a real image will be produced on a screen **(1)** • The object cannot be closer than *f* for a real image **(1)** • Because light diverges after passing through the lens **(1)** **OR** • If object closer than *f* rays still diverge after passing though lens **(1)** • So a virtual image is formed **(1)** • which cannot be seen on a screen. **(1)**		3

Q20.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $P = \frac{1}{f}$	**(1)**	Example of calculation 0.82 D = 1/*f*	
	• 1220 (mm)	**(1)**	*f* = 1 / 0.82 D = 1.22 m Accept 122 (cm)	2

Q21.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to: **EITHER** • holding the lens steady in your hand would be difficult and would make the distance measurement inaccurate **(1)** • so the lens should be in a holder on a stable surface to make the measurement accurate **(1)** **OR** • holding the ruler steady parallel to the principal axis would be difficult and make the distance measurement inaccurate **(1)** • so the ruler should be on a stable surface to make the measurement accurate **(1)** **OR** • focal length is image distance when object distance is infinite **(1)** • this is not at infinity so lens formula should be used **(1)**	These marks can be awarded only for answers in the context of the method described in the question. Reference to use of an optical bench is acceptable. Reference to use of a clamp is acceptable.	**2**
(ii)	• use of power = 1/focal length **(1)** • calculates at least two powers correctly **(1)** • analyses data to compare powers or focal lengths **(1)** • draws a conclusion that is consistent with calculated values about how well the relationship is supported **(1)**	This is a comparison, so use of cm not penalised if used for all and unit D is not required. MP3 calculates combined power and uses it to calculate focal length for the combination and compares this with the measured value of focal length. Example of calculation: $P = 1/f$ power $_{lid} = 1/0.12 = 8.3$ D power $_{optional} = 1/0.175 = 5.7$ D power $_{combined} = 1/0.07 = 14$ D $8.3 + 5.7 = 14$ D	**4**

Q22.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • $f = 8.0 \times 10^{-2}$ m (1)	Example of calculation $\frac{1}{f} = \frac{1}{0.09\text{ m}} + \frac{1}{0.75\text{ m}}$ $f = 8.00 \times 10^{-2}$m	**2**

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
	• Lens displacement is so minimal that v doesn't change much **Or** $u >> v$ so Δv doesn't change much **Or** $u >> f$ so displacement doesn't change much **Or** $u >> v$ so v approx. equal to f **Or** most object distances can be considered to be at infinity so will focus at about f (1)		1

Q24.

Question Number	Answer	Mark
	The onlv correct answer is C because 10 cm is more than the focal length from a converging lens A diverging lenses do not form real images from real objects B diverging lenses do not form real images from real objects D an object at less than the focal length from a converging lens will form a virtual image	1

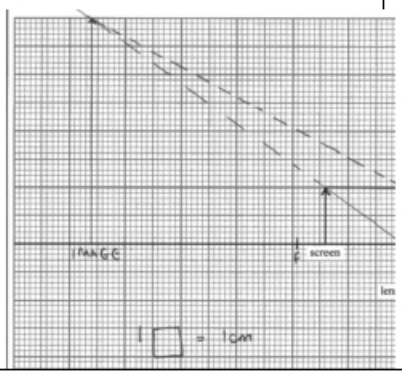
Q25.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $P = 1/f$ • $f = 8.47$ (mm)	(1) (1)	Example of calculation $f = 1 / 118$ D = 8.47 mm	2
(ii)	• Use of $1/v + 1/u = 1/f$ (allow u and v reversed, but not f) • $u = 14.8$ mm (ecf for f from 19(a)(i))	(1) (1)	Example of calculation 1/20 mm + $1/u$ = 1/8.5 mm u = 14.8 mm	2
(iii)	• (Freshwater has a lower refractive index than seawater, so) there will be greater refraction of light on entering the lens • This means that the power of the lens is greater in freshwater **Or** this means that the focal length is less in freshwater • This means that the shortest distance will be decreased	(1) (1) (1)		3
(iv)	• Use of $n = c/v$ • $v = 2.2 \times 10^8$ m s^{-1}	(1) (1)	Example of calculation $1.37 = 3.00 \times 10^8$ m s^{-1} / v $v = 2.2 \times 10^8$ m s^{-1}	2

Q26.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A		1

Q27.

Question Number	Acceptable answers		Additional guidance	Mark
	• Two rays correctly drawn including extrapolation	(1)	Acceptable rays: • from arrowhead on object through the optical centre of the lens • from arrowhead on object parallel to the axis up to the lens and then through the principal focus on the other side • from the principal focus on the same side and through the arrowhead on the object to the lens and then parallel to the axis <u>Example of calculation</u> M = image size / object size (accept use of distances) = 8.0 cm / 2.0 cm = 4.0  	4
	• Completes diagram with image at 10.6 cm (range 9.0 cm to 12.0 cm)	(1)		
	• Magnification = 3.8 (3.5 to 4.0)	(1)		
	• Conclusion consistent with values for distance and M	(1)		

Q28.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q29.

Question Number	Answer	Mark
	B – TIR as angle of incidence is greater than the critical angle	**1**
	Incorrect Answers: A – light is reflecting at an incorrect angle C – light is not refracted D – light is not refracted	

Q30.

Question Number	Acceptable answers	Additional guidance	Mark
	• Light strikes the edges of the long crystals at angles greater than the critical angle **(1)** • It is repeatedly totally internally reflected along the crystal **(1)**		**2**

Q31.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ with $u = 100$ and $v = (-)300$ **(1)** • $f = 150$ (mm) **(1)** • converging lens with focal length 150 mm **(1)**	**(MP3 dependent on MP2)** Example of calculation $\frac{1}{f} = \frac{1}{100\text{ mm}} - \frac{1}{300\text{ mm}}$ $\frac{1}{f} = \frac{3-1}{300\text{ mm}}$ $f = 150\text{ mm}$ MP3 accept if annotated in question Accept convex for converging	**3**

Q32.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• use of $1/v + 1/u = 1/f$ **and** $P = 1/f$ to determine power required	(1)	Example of calculation $1/f = 1/0.02$ cm + $1/0.275$ cm $f = 0.0186$ cm $P = 1/f = 53.6$ D For person, $P = 1/0.0193$ $= 51.81$	
	• use of $P = 1/f$ to determine power of person's lens	(1)	Spectacle power = 53.63 – 51.81 = 1.82 D Choose +2.0 D	
	• use of $P = P_1 + P_2$ to determine additional power required	(1)		
	• $P = 1.82$ (D)	(1)		**(4)**

Q33.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• use of $1/f = 1/u + 1/v$ • $u = 4.8$ cm	(1) (1)	Example of calculation 1/1.6 cm = $1/u$ + 1/ 2.4 cm $u = 4.8$ cm	2

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• use of $n = c / v$ • use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **Or** $n = \sin i / \sin r$ with correct angles • $\theta = 11°$	(1) (1) (1)	Accept use of $v_2 \sin\theta_1 = v_1 \sin\theta_2$ for MP1 and MP2 but $v_1 \sin\theta_1 = v_2 \sin\theta_2$ scores neither Example of calculation $n = 3 \times 10^8$ m s^{-1} / 2.18×10^8 m s^{-1} $= 1.376$ $1 \times \sin 15° = 1.376 \times \sin\theta$ $\theta = 10.8°$	3

Q34.

Question Number	Acceptable answers		Additional guidance	Mark
	• use of $P = 1/f$ • use of $P = P_1 + P_2$ etc • total power = 63.8 (D) • Comparative statement consistent with their values	(1) (1) (1) (1)	**MP4** An attempt at a % must be made and a clear comparison with the 80% must be made e.g % for cornea from 44.8 / 63.8 is 71% which is not 80% so no Example of calculation P_{cornea} = 1/ 0.0223 m = 44.84 D P_{lens} = 1/ 0.0527 m = 18.98 D Total power = 63.82 D	4

Q35.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• Appropriate line of best fit (1)		1
(ii)	• Calculates a gradient using at least half the drawn line (1) • η=1.37 to 1.47 (1) • leading to a conclusion that glass is silica (1) **Or** conclusion consistent with their value for η	Example of calculation $\frac{0.9-0.05}{0.58} = 1.47$ silica	3

Q36.

Question Number	Answer	Mark
	C - 1.5	**1**
	Incorrect Answers: all select incorrect data from question Correct method: image distance ÷ object distance A – uses focal length ÷ object distance B – uses object distance ÷ image distance D – uses object distance ÷ focal length	

Q37.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of lens equation $1/f = 1/v + 1/u$ (1) • Use of magnification = v/u (1) • Magnification = 15 (1)	Example of calculation 1/17.9 mm = 1/v + 1/16.7 mm v = (-)249 mm magnification = 249 mm / 16.7 mm = 14.9	3

Q38.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (to calculate m) (1) • Use of $m = \frac{\text{image height}}{\text{object height}}$ to calculate distance between dots on screen (1) • Uses tan/sin **or** small angle approximation to calculate the angle (1) • Answer consistent with their calculation (1) • Comparison with 0.0003 radians **or** 0.017° and conclusion consistent with their value for θ (1)	Example of calculation $m = \frac{0.75\text{ m}}{0.09\text{ m}} = 8.3$ Image height = 8.3 x 0.005 m = 0.042 (m) $\tan(\frac{\theta}{2}) = \frac{0.042/_2\text{ m}}{4.5\text{ m}}$ $\theta = 0.5° = \frac{0.5\pi}{180}$ rads = 0.0092radians 0.009 radians > 0.0003 radians so student can distinguish between the dots	5

Q39.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q40.

Question Number	Answers	Additional Guidance	Mark
	D	sin 61° / sin 42°	**(1)**

Q41.

Question Number	Answer	Additional guidance	Mark
	B	$(\frac{v_2}{f})$	**(1)**

Q42.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Light is refracted as it passes into medium 2	(1)	MP2 see use of the equation	6
	• Angle of refraction may be calculated using $n_1\sin\theta_1 = n_2\sin\theta_2$	(1)		
	• Angle of refraction = 89.81°	(1)		
	• Angle of <u>incidence</u> at layer 2-3 is greater than the critical angle	(1)	MP5 accept totally internally reflected and TIR	
	• So <u>total internal reflection</u> occurs (at layer 2-3 interface)	(1)	MP6 is not just for saying there is a mirage.	
	• So light/ rays appear to come from surface of road (so that observer sees mirage)	(1)	<u>Example of Calculation</u> $\sin^{-1}\left(\frac{1.00032 \times \sin 89.59°}{1.00030}\right) = 89.81°$	

Q43.

Question Number	Acceptable Answers		Additional Guidance	Mark
(i)	• use of $n_1 \sin i_1 = n_2 \sin i_2$ • with angle of incidence in plastic = 28° • angle of deviation = angle of refraction – angle of incidence • angle of deviation = 16°	(1) (1) (1) (1)	Example of calculation $n_1 \sin i_1 = n_2 \sin i_2$ $1.47 \sin (90° - 62°) = 1.00 \sin i_2$ $i_2 = 43.6°$ angle of deviation = 44° − 28° = 16°	4
(ii)	• Going from the centre of the lens towards the edge the angle of incidence in the plastic increases • The angle of deviation increases • (So) all rays cross (the axis) at the principal focus	(1) (1) (1)	Accept focal point for principal focus	3

Q44.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Use of $m = \frac{image\ height}{object\ height}$ • Use of $m = \frac{v}{u}$ • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ • Use of $P = \frac{1}{f}$ • 21 D	(1) (1) (1) (1)	Example of Calculation $m = \frac{3.5 \times 10^{-3}\ \text{m}}{2.0 \times 10^{-4}\ \text{m}} = 17.5$ $v = 17.5 \times 5.0 \times 10^{-2}\text{m} = 0.875$ (m) $\frac{1}{f} = \frac{1}{5.0 \times 10^{-2}\ \text{m}} + \frac{1}{0.875\ \text{m}}$ $f = 0.047$ m $P = \frac{1}{0.047\ \text{m}} = 21.1$ D	5

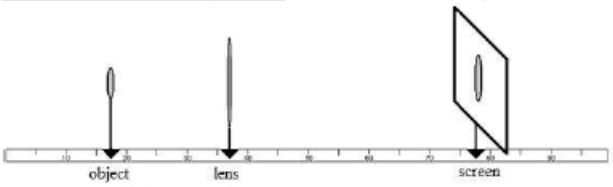
Q45.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B because the power of a diverging lens is negative, so the total power = 9.4 D – 4.2 D = 5.2 D A is not correct because the total power should be obtained from (9.4 D – 4.2 D), but this is (9.4 D + 4.2 D) C is not correct because this is (4.2 D – 9.4 D) using negative power for a converging lens and positive for a diverging lens where it should be the opposite so that (9.4 D – 4.2 D) is used D is not correct because – 13.6 D = – 9.4 D – 4.2 D, as if both lenses are diverging, which is not the case		1

Q46.

Question Number	Answers	Mark
	The only correct answer is D ***A** is incorrect because the angle of incidence must be greater than the critical angle* ***B** is incorrect because the angle of incidence must be greater than the critical angle **and** $n_1 < n_2$* ***C** is incorrect because the light must be incident upon the boundary in the medium with the larger refractive index*	1

Q47.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• diagram with illuminated object, lens, screen and metre rule (1) • lens position adjusted until clear image located on screen (1) • object, image distances calculated from metre rule readings (1) • procedure repeated for at least 4 other positions of the lens (1)	Example of Diagram:  Example of calculation: $\frac{1}{u} = -\frac{1}{v} + \frac{1}{f}$ $y = mx + c$	**(4)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• 1/*v* plotted against 1/*u* and intercept(s) of line read off (1) • lens equation compared with equation of a straight line (1) • f = 1/intercept (1)	Question 5 to be marked holistically	**(3)**

Q48.

Question Number	Answer	Mark
	B $v_1 < v_2$ $n_1 > n_2$	1
	Incorrect Answers: A – incorrect equality for speed C – incorrect equality for speed and refractive index D – incorrect equality for refractive index	

Q49.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of trigonometry to determine angle of ray to normal in liquid **(1)** • Use of n sin θ = constant **(1)** • $n = 1.42$ **(1)**	Example of calculation $(10.2 - 4.0) \div 2 = 3.1$ cm $\tan \theta = 3.1$ cm / 35 cm $\theta = 5.06°$ $n = \sin 7.2° / \sin 5.06°$ $n = 1.42$	3

Q50.

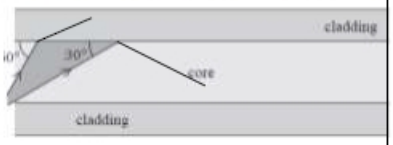
Question Number	Answers	Mark
	The only correct answer is C ***A** is incorrect because the focal length of the lens increases* ***B** is incorrect because the focal length of the lens increases* ***D** is incorrect because lens power is the reciprocal of the focal length*	1

Q51.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$, re-arranged to make $\frac{1}{v}$ the subject	(1)	$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ $y=mx+c$	5
	• Comparison with $y=mx+c$	(1)		
	• So intercept equals $1/f$	(1)		
	• Use the y intercept to calculate a value for f	(1)		
	• Comment on the agreement with the initial determination including an appropriate justification	(1)		
	OR			
	• Since $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$, when $\frac{1}{u}=0, f=v$	(1)		
	• When $\frac{1}{v}=0, f=v$	(1)		
	• Use the y intercept to calculate a value for f	(1)		
	• Use the x intercept to calculate a value for f	(1)		
	• Comment on the agreement with the initial determination including an appropriate justification	(1)		
	OR			
	• Read a pair of corresponding values from the graph	(1)		
	• Use of $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ to calculate a value for f	(1)		
	• Read a second pair of corresponding values from the graph	(1)		
	• Use of $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ to calculate a second value for f	(1)		
	• Comment on the agreement with the initial determination including an appropriate justification	(1)		

Q52.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ • Angle in cladding $\theta = 90(°)$ • Critical angle = 50.3(°)	(1) (1) (1)	Accept alternative method using $\sin c = \frac{1}{n}$ **and** $n = \frac{c}{v}$ to give $n = \frac{v_{cladding}}{v_{core}}$ **Or** $n = \frac{n_{core}}{n_{cladding}}$ Use of $\sin c = \frac{1}{n}$ with n=1.2 or 1.56 gains 1 mark Example of calculation e.g. $1.56 \sin \theta_1 = 1.20 \sin \theta_2$ $1.56 \sin c = 1.20 (\sin 90°)$ $\sin c = \frac{1.20}{1.56}$ $c = 50.3(°)$	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Left hand side of beam refracts away from normal • Right hand side of beam totally internally reflected • State Student C is correct	(1) (1) (1)	Ignore any line continued beyond cladding Ignore any reflection Reflection correct by eye Do not award if any line shown in cladding **(MP3 dependent on MP1 and MP2)**  Arrows on rays not needed	3

Q53.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B because at angles less than or equal to the critical angle not all of the light is reflected internally such that angle of incidence is equal to the angle of reflection A is not correct because total internal reflection occurs at angles greater than the critical angle but at the critical angle the angle of refraction is 90 degrees, so the reflection is not total C is not correct because internal reflection is not total at angles less than the critical angle D is not correct because internal reflection is not total at angles less than the critical angle		1