Question 1

(*b*) What is reflection?

**light rebounding (off surfaces)** **(3)**

Spherical mirrors can be either convex or concave.

Draw a ray diagram to show the formation of an image in a convex mirror.

**object, correct mirror** **(3)**
**two correct reflected rays** **(3)**
**correct image** **(3)**

A person looks at her image in a shiny spherical decoration when her face is 30 cm from the surface of the decoration. The diameter of the decoration is 20 cm. Find the position of the image.

**f = r/2 = 5 cm** *(–1 if f = 10 cm used)* **(3)**
**1/u + 1/v = 1/f** **(3)**
**substitution** **(3)**
**v = 30/7 = 4.3 cm (behind the mirror)** **(3)**
*(–1 for omission of or incorrect units)*

Concave mirrors, rather than convex mirrors, are used by dentists to examine teeth. Explain why.

**to give a magnified image** **(4)**

Question 2

(*e*) **Draw a ray diagram to show the formation of an image in a convex mirror.**

two correct reflected rays 4
image behind the mirror 3

Question 3

**3.** **The following is part of a student's report on an experiment to measure the focal length of a concave mirror.**

**"I started with the object 6 cm from the mirror but couldn't get an image to form on the screen. I moved the object back a few centimetres and tried again, but I couldn't get an image to form on the screen until the object was 24 cm from the mirror. From then on I moved the object back 8 cm each time and measured the corresponding image distances. I wrote my results in the table."**

| $u$/cm | 24.0 | 32.0 | 40.0 | 48.0 |
|---|---|---|---|---|
| $v$/cm | 72.5 | 40.3 | 33.0 | 27.9 |

**Draw a labelled diagram of the apparatus used.**

apparatus: e.g. bulb, mirror, screen 3

*(components appropriately consistent and each labelled)*

correct arrangement 3

correct shape of mirror 3

**Give two precautions that should be taken when measuring the image distance.**

measure from the back of the mirror / measure from the centre (pole) of the mirror / avoid parallax error / ensure image is sharp / have both screen and mirror vertical, *etc.* *(any two)* 2 × 3

**Explain why the student was unable to form an image on the screen when the object was close to the mirror.**

object inside the focal length / virtual image formed 6

**Use all of the data in the table to calculate a value for the focal length of the mirror.**

$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ 3

calculation of $f$ *(3 marks for each correct value for f to a maximum of 3 × 3)* 3 × 3

average of $f$ values *($f \approx 17.9$ cm)* 3

***OR***

label axes correctly 3

plot four points correctly *(–1 for each incorrectly plotted point)* 3

straight line with good distribution 3

read intercept points *(–1 if only one intercept point used)* 3

calculation of $f$ value *($f \approx 17.9$ cm)* 3

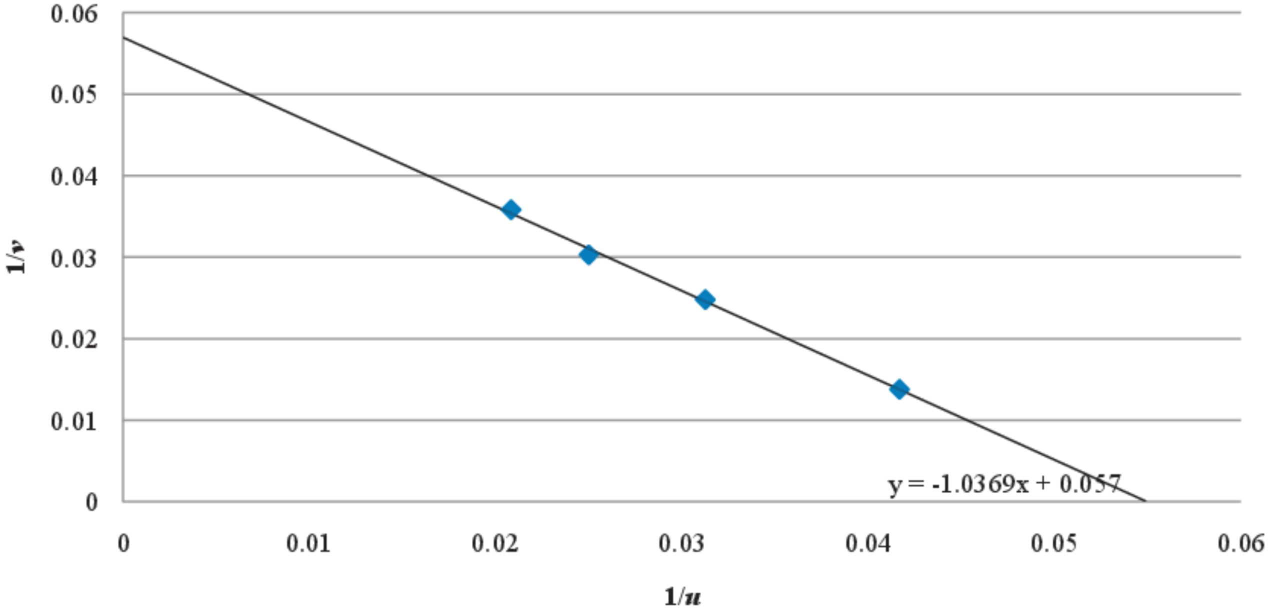
*(–1 for inappropriate scale)*

| $u$/cm | 24.0 | 32.0 | 40.0 | 48.0 |
|---|---|---|---|---|
| $1/u$ | 0.042 | 0.031 | 0.025 | 0.021 |
| $v$/cm | 72.5 | 40.3 | 33.0 | 27.9 |
| $1/v$ | 0.014 | 0.025 | 0.030 | 0.036 |

**Describe how the student could have found an approximate value for the focal length of the mirror before starting the experiment.**

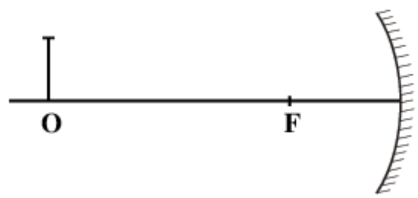
measure image distance for distant object 4

# Question 3: 1/*u* vs 1/*v*




Question 4

**(d) An object O is placed 30 cm in front of a concave mirror of focal length 10 cm. How far from the mirror is the image formed? (7)**




$1/u + 1/v = 1/f$ / $1/30 + 1/v = 1/10$ 4

$v = 15$ (cm) = 0.15 (m) 3

Question 5

**Question 3**

In an experiment to measure the focal length of a concave mirror, an approximate value for the focal length was found. The image distance $v$ was then found for a range of values of the object distance $u$. The following data was recorded.

| $u$/cm | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 |
|---|---|---|---|---|---|---|
| $v$/cm | 60.5 | 30.0 | 23.0 | 20.5 | 18.0 | 16.5 |

**How was an approximate value for the focal length found?**

image of / light from a distant object (e.g. window) focused on a screen 6
measure distance from screen to mirror 2

**What was the advantage of finding the approximate value for the focal length?**

to avoid placing object inside (or near) $f$ (during experiment) / to make it easier to find the image (later)
to confirm (or to indicate magnitude of) final answer 2

**Describe, with the aid of a labelled diagram, how the position of the image was found.**

apparatus: object, concave mirror, screen 6
arrangement: correct arrangement with object and screen on same side of mirror and with image on screen 6

**( -1 if no diagram; -1 if no reference to image)**

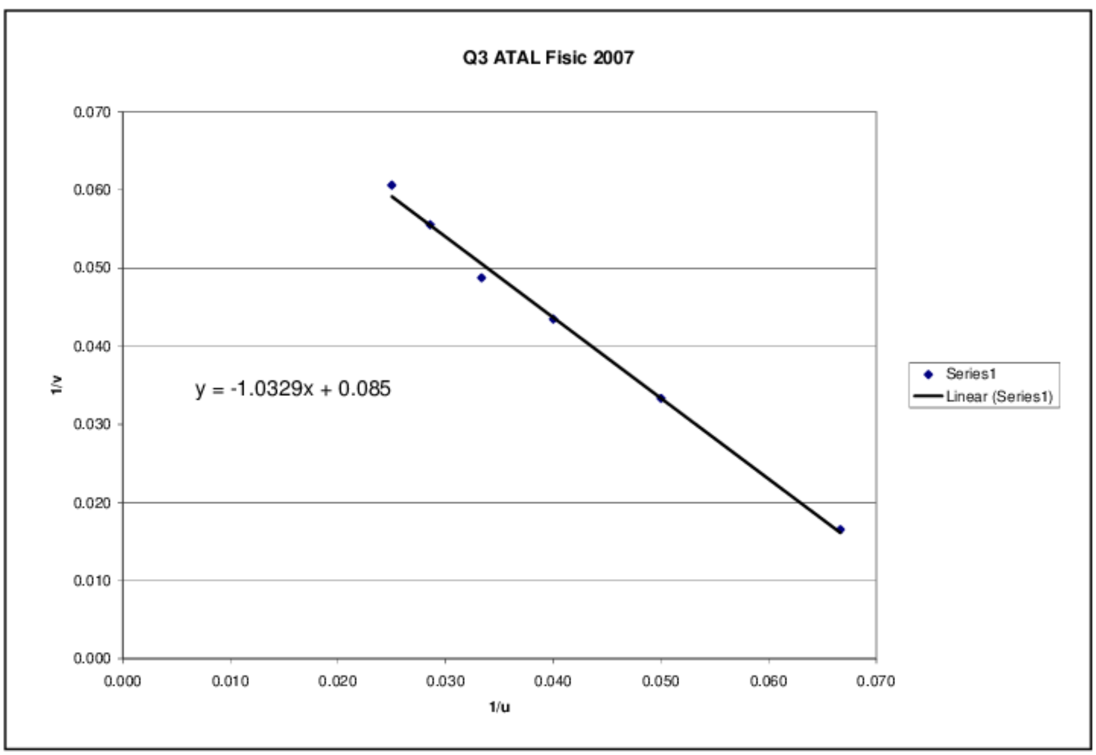
**Calculate the focal length of the concave mirror by drawing a suitable graph based on the recorded data.**

| | | |
|---|---|---|
| calculate $^1/u$ and $^1/v$ values | label axes $u$ and $v$ | 3 |
| label axes | plot at least five points | 3 |
| plot at least five points | draw smooth curve | 3 |
| straight line | locate point where $u = v$ | 3 |
| extrapolate to cut axis (or axes) / read axis (or axes) value = (0.085 ± 0.003) | read coordinate(s) | 3 |
| focal length = 12.0 ± 1.0 (cm) | focal length = 12.0 ± 0.3 (cm) | 3 |

**(no unit required)**

**For use of data table rather than graphical work:** formula: $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ (3)

correct substitution (3)
one correct $f$ value (3)
$f$ *average* (2 x 3)



Question 6

One of the recorded angles of refraction is inconsistent with the others. Which one?

**23 °** **(4)**

Describe, with the aid of a labelled diagram, how the student found the angle of refraction.

**rectangular block**

**pins / ray box / laser** *(–1 if no label)*

**correct incident, normal and refracted rays drawn**

**angle of refraction indicated**

**protractor / trigonometry** *(any four)* **(4 × 3)**

Calculate a value for the refractive index of the substance by drawing a suitable graph based on the recorded data.

| ***Sin i*** | **0.34** | **0.50** | **0.64** | **0.77** | **0.87** | **0.94** | **0.98** |
|---|---|---|---|---|---|---|---|
| ***Sin r*** | **0.23** | **0.34** | **0.45** | **0.39** | **0.59** | **0.64** | **0.68** |

**sin *i* and sin *r* calculated** *(–1 for each incorrect value)* **(3)**
**axes labelled** **(3)**
**6 points plotted** *(–1 for each incorrect point)* **(3)**
**straight line with good fit** **(3)**
**method for finding slope** **(3)**
**slope = n ≈ 1.44** **(3)**
*(–1 for inappropriate scale)*

Using a graph to calculate a value for the refractive index is a more accurate method than calculating the refractive index for each pair of angles and then finding the mean.
Give two reasons for this.

**outliers can be identified / slope gives weighted mean / reference to origin**

**/ reference to Tan θ** *(any two)* **(4 + 2)**

## Question 7

**Describe, with the aid of a labelled diagram, how the student obtained the data.**

| | | |
|---|---|---|
| apparatus: e.g. ray box, convex lens, screen | | 3 |
| correct arrangement of apparatus | **(–1 if screen is not labelled)** | 3 |
| adjust to get image in sharp focus | | 3 |
| measure $u$ and $v$ | | 3 |
| repeat for different positions of object | | 3 |

**Why is it difficult to measure the image distance accurately?**

difficult to locate sharp image / centre of lens — 4

**Using all the data in the table, find the value for the focal length of the lens.**

| | |
|---|---|
| formula | 3 |
| derivation of $f$ (3 marks per each correct value for $f$ – max mark 3×3) | 3×3 |
| average $f$ ( = 10.0 ± 0.2) cm | 3 |

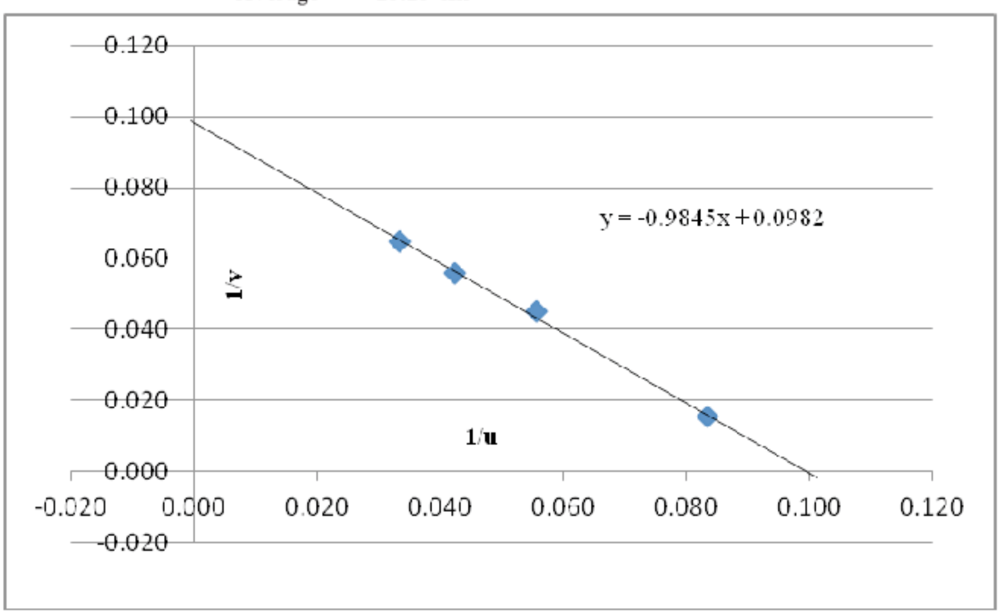
**Why is it difficult to measure the image distance when the object distance is less than 10 cm?**

image is virtual / image on same side as object / no image formed on screen — 6

Graphical method:

| | |
|---|---|
| inverse values for $u$ and $v$ | 3 |
| plot points on graph | 3 |
| straight line | 3 |
| read intercept | 3 |
| correct value for $f$ ( = 10.0 ± 0.2) cm | 3 |

| **1/u** | **1/v** | **1/u+1/v** | ***f*** |
|---|---|---|---|
| 0.083 | 0.016 | 0.099 | 10.12 |
| 0.056 | 0.045 | 0.101 | 9.92 |
| 0.042 | 0.056 | 0.098 | 10.18 |
| 0.033 | 0.065 | 0.098 | 10.18 |
| | | Average | **10.10 cm** |




## Question 8

**(*e*)** **If a diamond has a refractive index of 2.42, what is the speed of light in the diamond?**

$n = \frac{c_1}{c_2}$ — 4

$c_2 = \frac{3\times10^8}{2.42} = 1.24 \times 10^8 \text{ m s}^{-1}$ *(–1 for omission of or incorrect units)* — 3

Question 9

**(i) If the refractive index of the glass is 1.5, calculate the value of $\theta$.**

$n_g = \frac{\sin i}{\sin r}$ 3

correct value for $i$ $(= 60°)$ 3

correct value for $r$ $(= 35.26°)$ 3

answer: $\theta = 54.7(4)°$ 3

**(ii) What would be the value of the angle $\theta$ so that the ray of light emerges parallel to the side of the glass block?**

reference to critical angle, $i_c$ / $n_g = \frac{1}{\sin i_c}$ 3

$i_c = 41.81°$ 3

$\theta = 48.2°$ 3

**(iii) Calculate the speed of light as it passes through the glass.**

$n_g = \frac{c_a}{c_g}$ 4

$c_g = \frac{2.9979 \times 10^8}{1.5}$ / $2 \times 10^8$ m s$^{-1}$ **( –1 for omission of or incorrect units)** 3

**Question 3**
In an experiment to verify Snell's law, a student recorded the following data.

| $i$ / ° | 30 | 40 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|
| $r$ / ° | 19 | 26 | 30 | 33 | 36 | 38 | 40 |

| sin $i$ | 0.500 | 0.643 | 0.766 | 0.819 | 0.866 | 0.906 | 0.939 |
|---|---|---|---|---|---|---|---|
| sin $r$ | 0.325 | 0.438 | 0.500 | 0.544 | 0.588 | 0.615 | 0.643 |

**Draw a labelled diagram of the apparatus used. On your diagram, indicate an angle *i* and its corresponding angle *r*.**

diagram to show:

a target medium e.g. glass block 3
incident ray (from ray box) 3
perpendicular / normal and refracted ray 3
label angles $i$ and $r$ 3

**12**

**Using the recorded data, draw a suitable graph and explain how your graph verifies Snell's law.**

correct sin $i$ and sin $r$ values for six points **(–1 per each incorrect/omitted point)** 4
label axes correctly on graph paper 3
plot six points correctly **(–1 per each incorrect/omitted point)** 3
straight line showing good distribution 3
correct statement / correct equation / $\sin i \propto \sin r$ 3

**Using your graph, find the refractive index**

correct slope method 3
($n$ = ) 1.41 [range: 1.38 – 1.52] 3

**22**

**The student did not record any values of *i* below 30°, give two reasons why?**

to reduce the (percentage) error 3
elaboration e.g. difficult to measure /read angles, $r < i$ , etc. 3

**6**

Question 11

## Question 2

**A student was asked to measure the focal length of a converging lens. The student measured the image distance *v* for each of three different object distances *u*.**
**The student recorded the following data.**

| $u$/ cm | 20.0 | 30.0 | 40.0 |
|---|---|---|---|
| $v$/ cm | 65.2 | 33.3 | 25.1 |

**Describe how the image distance was measured.**

object, (converging) lens, screen /search pin **(for any two items, 3 marks)** 2×3
<u>sharp</u> image (state/imply) // no parallax (between image and search pin) 3
measure (distance) from <u>image</u>/<u>screen</u> to (centre of) lens 3

**12**

**Give two precautions that should be taken when measuring the image distance.**

measure from the centre of the lens (to the screen) / measure perpendicular distance / avoid parallax error / check zero error in metre rule **(any two precautions)** 2×3

**6**

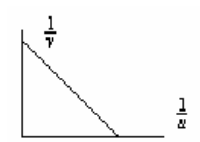
**Use all of the data to calculate the focal length of the converging lens.**

$^1/_u + {}^1/_v = {}^1/_f$ 3
correct substitution (once) 3
$f$ = 15.3 cm, 15.8 cm, 15.4 cm 3+2+1
$f_{ave}$ = (15.5 ± 0.4) cm **(–1 for omission of or incorrect unit)**

**15**

**Alternative (graphical method):**

| | | | |
|---|---|---|---|
| $1/u$ | 0.050 | 0.033 | 0.025 |
| $1/v$ | 0.0153 | 0.0300 | 0.0398 |




inverse values for u and for v 2× 3
plot points 3
read intercept(s) 3
$f$ = (15.87 ± 0.40) cm 3 (–1 for omission of or incorrect unit)

**What difficulty would arise if the student placed the object 10 cm from the lens?**

object inside focal <u>point</u>/<u>length</u> / virtual image / image cannot be formed on a screen / difficult to locate image (by no parallax method) (any *one*) 7

**7**

**Question 12 (c)**

**Information is transmitted over long distances using optical fib res in which a ray of light is guided along a fibre. Each fibre consists of a core of high quality glass with a refractive index of 1.55 and is coated with glass of a lower refractive index.**

**Explain, with the aid of a labelled diagram, how a ray of lig ht is guided along a fibre.**

Diagram:

| | |
|---|---|
| showing light ray in glass fibre | 3 |
| showing ray being reflected at least once | 3 |
| **(–1 if no label)** | |
| reference to critical angle/ total internal reflection | 3 |
| | **9** |

**Why is each fibre coated with glass of lower refractive index?**

| | |
|---|---|
| ray travelling from denser to rarer medium // so that total internal reflection oc curs | 3 |
| total internal reflection occurs / $i > i_c$ // no light escapes | 3 |
| | **6** |

**What is the speed of the light as it passes through the fibre?**

| | |
|---|---|
| $n = \frac{c_{air}}{c_{glass}}$ // $c_{glass} = \frac{3.0\times10^8}{1.55}$ | 4 |
| $c_{glass} = 1.94\times10^8\ \text{m s}^{-1}$ **(no penalty for units)** | 3 |
| | **7** |

**Light passing through optical fibres must travel through an enormous length of glass. Impurities in the glass reduce the power transmitted by half every 2 km. The initial power being transmitted by the light is 10 W. What is the power being transmitted by the light after it has travelled 8 km through the fibre?**

| | |
|---|---|
| $(\frac{1}{2})^4$ // $\frac{1}{16}$ // $(10 \div 16)$ | 3 |
| $(P =)\ 0.625\ (\text{W})$ $[= \frac{5}{8}(\text{W})]$ | 3 |
| | **6** |

## Question 9

**What is meant by refraction of light?**

bending of light 3

going from one medium to another (of different refractive index) 3

(appropriate diagram showing light ray passing through two different media .. 2 × 3)

**State Snell's law of refraction.**

the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant 6

$\sin i \propto \sin r$ / $\frac{\sin i}{\sin r} = \text{constant}(n)$ (3)

notation (3)

**An eye contains a lens system and a retina, which is 2.0 cm from the lens system. The lens system consists of the cornea, which acts as a fixed lens of power 38 $m^{-1}$, and a variable internal lens just behind the cornea. The maximum power of the eye is 64 $m^{-1}$. Calculate:**

**(i) how near an object can be placed in front of the eye and still be in focus;**

**(ii) the maximum power of the internal lens.**

(i) $P_{max:} = (64\ m^{-1} =)\ \frac{1}{f}$ 3

$f = 0.0156$ m $= 1.56$ cm 3

(For lens system:) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ / $\frac{1}{u} + \frac{1}{2} = \frac{1}{1.56}$ 3

(Object distance:) $u = 7.14$ cm 3

(–1 for omission of or incorrect units)

(ii) $P_{max} = P_1 + P_2$ / $64 = 38 + P_2$ / $P_2 = 26\ (m^{-1})$ 3

**Light is refracted as it enters the cornea from air as shown in the diagram. Calculate the refractive index of the cornea.**

$n = \frac{\sin i}{\sin r}$ / $\frac{\sin 37}{\sin 27}$ 3

$n = 1.3256$ / $1.33$ 3

**Draw a diagram to show the path of a ray of light as it passes from water of refractive index 1.33 into the cornea.**

line representing interface between two media 3

straight line (accept a *slight* refraction) representing the light ray through the two media 3

**A swimmer cannot see properly when she opens her eyes underwater. When underwater:**

**(i) why does the cornea not act as a lens?**

light not refracted at cornea (state/imply) 3

water and cornea have the same $n$ value 3

**(ii) what is the maximum power of the eye?**

26 ($m^{-1}$) / maximum power of the internal lens 3

**(iii) why do objects appear blurred?**

internal lens not powerful enough to focus light on retina / eye is long-sighted

/ light not brought to a focus (on the retina) 3

**(iv) explain how wearing goggles allows objects to be seen clearly.**

light refracted on passing from air to cornea 3

cornea (now) acts as a lens ( state/imply) 2

Question 14

**Question 7**
**What is meant by the refraction of light? (6)**

| | |
|---|---|
| the bending (of light) | 3 |
| on passing from one medium to another | 3 |

(correctly labelled diagram … 2 x 3 )

**A converging lens is used as a magnifying glass.**
**Draw a ray diagram to show how an erect image is formed by a magnifying glass. (12)**

| | |
|---|---|
| object inside focal point | 3 |
| two (appropriate) rays from object to lens | 3 |
| two rays emerge correctly from lens | 3 |
| rays produced back to form upright virtual image (on same side as object) | 3 |

**[ max. of 3 marks if mirror used.**
**-1 if object or image not labelled.]**

**A diverging lens cannot be used as a magnifying glass. Explain why. (5)**

| | |
|---|---|
| diminished image | 3 |
| <u>always</u> formed | 2 |

**The converging lens has a focal length of 8 cm. Determine the two positions that an object can be placed to produce an image that is four times the size of the object? (15)**

| | |
|---|---|
| $1/u + 1/v = 1/f$ | 3 |
| ( magnification = ) $v/u$ or $I/O$ stated or implied | 3 |
| for real image: $1/u + 1/4u = 1/8$ | 3 |
| => $u = 10$ cm | 3 |
| for virtual image: : $1/u - 1/4u = 1/8$ / $u = 6$ cm | 3 |

**(-1 for omission of or incorrect unit ….penalise once only)**

**The power of an eye when looking at a distant object should be 60 m$^{-1}$. A person with defective vision has a minimum power of 64 m$^{-1}$.**

**Calculate the focal length of the lens required to correct this defect. (12)**

| | |
|---|---|
| $P = P_1 + P_2$ | 3 |
| $60 = 64 + P_2$ / $P_2 = -4$ (m$^{-1}$) | 3 |
| $P = 1/f$ / $f = 1/P$ / $1/f = (-)4$ | 3 |
| $f = (-)¼$ m / (-)25 cm **[-1 for omission of or incorrect unit]** | 3 |

**What type of lens is used? Name the defect. (6)**

| | |
|---|---|
| diverging / concave (lens) | 3 |
| short sight / short sightedness / myopia | 3 |

## Question 15

**Describe, with the aid of a diagram, how the student obtained the angle of refraction. (9)**

pins / ray box (to obtain incident and refracted rays) 3

diagram to show: outline of block, incident and refracted ray, normal 3

measure angle between refracted ray and normal (using a protractor / trig.) 3

| | | | | | | |
|---|---|---|---|---|---|---|
| sin *i* | 0.34 | 0.50 | 0.64 | 0.77 | 0.87 | 0.94 |
| sin *r* | 0.24 | 0.33 | 0.44 | 0.50 | 0.59 | 0.64 |

**Draw a suitable graph on graph paper and explain how your graph verifies Snell's law. (18)**

sin *i* and sin *r* correct values ( -1 for each incorrect value) 3

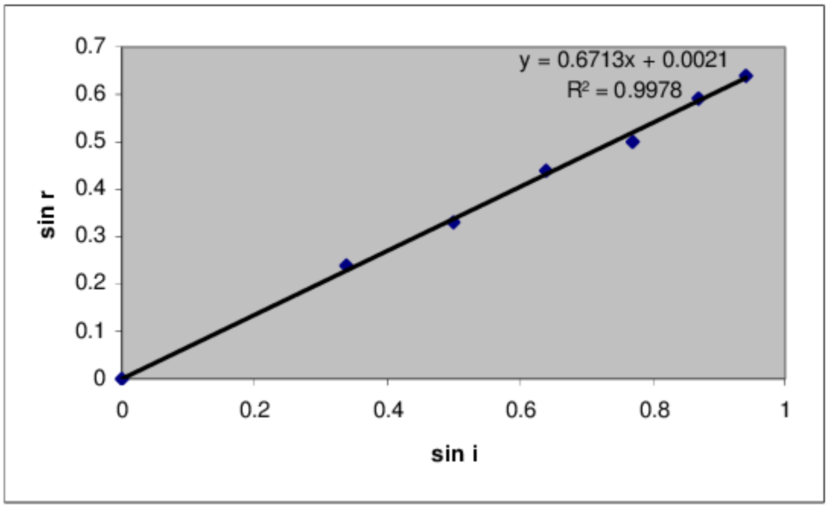
labelled axes 3

at least 5 points plotted correctly 3

straight line drawn 3

good distribution 3

conclusion e.g. sin *i* proportional to sin *r* / straight line through the origin 3




**From your graph, calculate the refractive index of the substance. (9)**

correct method for slope e.g. $(m =)\ y_2 - y_1 / x_2 - x_1$ 3

substitute coordinates of two points on the graph 3

$n = 1.49$ (accept range: 1.44 – 1.50 ) 3

**The smallest angle of incidence chosen was 20°. Why would smaller values lead to a less accurate result? (4)**

greater percentage error (in these readings) 4

## Question 16

*(e)* **The refractive index of a liquid is 1.35, what is the critical angle of the liquid?**

$n_g = {}^1/\sin i_c$ ….. (4 marks)

$i_c = 47.8°$ (-1 penalty for answer 53.1° …. gradian mode used) 7

## Question 17

**any one primary colour** **(2)**

**any one secondary colour** **(2)**

**correct pair: red and cyan / green and magenta / blue and yellow** **(3)**

Question 18

**E = hf** **(3)**

**c = fλ** **(3)**

**E = 2.8 × $10^{-19}$ J** *(–1 for omission of or incorrect units)* **(3)**

Sensors in the eye can respond to single photons. Where in the eye are these sensors located?

**retina** **(3)**

State two differences between the electromagnetic radiation emitted from a laser and the electromagnetic radiation emitted from a vapour lamp.

**laser has one frequency/wavelength only / laser light is more powerful / laser light is coherent / laser light is collimated** *(any two)* **(4 + 2)**

Derive, with the aid of a labelled diagram, the diffraction grating formula.

**diffraction grating, two rays on diagram** **(3)**

**θ and d indicated on diagram** **(3)**

**nλ indicated on diagram** *(if n =1 award zero marks)* **(3)**

**nλ linked to constructive interference** **(3)**

**Sinθ = nλ/d from diagram** **(3)**

Calculate the number of lines per millimetre on the grating used in the experiment.

**nλ = dSinθ** **(3)**

**d = 0.000002497 m** **(3)**

**i.e. 400 (lines per mm)** **(3)**

What would be observed on the screen if the laser was replaced by a source of white light?

**spectra / dispersion / colours** **(5)**

Question 19

**(*b*)** **A narrow beam of light undergoes dispersion when it passes through either a prism or a diffraction grating.**

**What is meant by dispersion?**

separation of light 3

into its different colours / frequencies / wavelengths 3

**Give two differences between what is observed when a narrow beam of light undergoes dispersion as it passes through a prism, and what is observed when a narrow beam of light undergoes dispersion as it passes through a diffraction grating.**

red light deviated least in a prism and deviated the most in a grating (or equivalent) 3

many spectra observable with a grating, only one with a prism 3

**Give another example of light undergoing dispersion.**

rainbow, *etc.* 4

**Yellow light of wavelength 589 nm is produced in a low-pressure sodium vapour lamp. What causes the sodium atoms to emit this light?**

electrons changing energy levels 3

**Calculate the highest order image that could be produced when a beam of light of this wavelength is incident perpendicularly on a diffraction grating that has 300 lines per mm.**

$n\lambda = d\sin\theta$ 3

$n \leq \frac{d}{\lambda}$ $(= 5.65)$ / $\sin\theta = 1$ *(stated or implied)* 3

$n = 5$ 3

Question 20

**The diagram shows a simplified version of the electromagnetic spectrum. Name the sections A and B in the diagram.**

A: infra red /I.R 3

B: ultra violet / U.V 3

**Describe how to detect each of these radiations.**

A: thermometer (with blackened bulb) / temperature sensor /photographic plate / mobile phone camera/ etc 3

effect e.g. rise in temperature 2

B: (shine on) Vaseline/detergents / phosphor 2

effect e.g. fluorescence / glows 2

**An electromagnetic radiation has a wavelength of 4 m. Name the section of the electromagnetic spectrum in which this radiation is located.**

$c = f\lambda$ 3

$f = 7.5 \times 10^7$ Hz ($\approx$ 75 MHz) 3

short wave radio / TV FM radio 3

**Distinguish between interference and diffraction.**

interference:

when waves from different sources overlap // when waves superimpose 3

a new wave is formed // to form a resultant wave (of greater or lower amplitude) 3

**(suitable diagram could merit {3 + 3})**

diffraction:

the spreading of a wave // the bending of waves // the spreading of waves 3

into the (geometrical) shadow of an obstacle // around obstacles // by passing them through an aperture 3

**(suitable diagram could merit {3 + 3})**

**Can a diffraction grating which diffracts light also diffract X-rays?**

no 3

**Justify your answer.**

line spacing must be similar to the wavelength of the radiation (for diffraction to occur) /

the spacing between lines in (such) a grating is too large (for diffraction to occur) /

for x-ray diffraction, gratings in which lines are separated by infinitesimal distances are required 6

**(award 3 marks for: '$\lambda_{light} > \lambda_{x\text{-}ray}$')**

**Light travels as a transverse wave. Name another type of wave motion.**

longitudinal 3

**Give two differences between these two types of wave motion.**

transverse can be polarized – longitudinal cannot // (medium) vibrates perpendicular to direction wave travels – (medium) vibrates parallel to direction (longitudinal) wave travels

any *two* 4+4

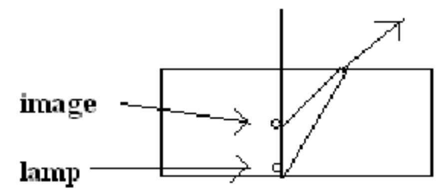
Question 21

**(*b*)** **State the laws of refraction of light.**

incident ray, refracted ray and normal in same plane 3

$\frac{\sin \hat{i}}{\sin \hat{r}}$ =constant 3

**A lamp is located centrally at the bottom of a large swimming pool, 1.8 m deep. Draw a ray diagram to show where the lamp appears to be, as seen by an observer standing at the edge of the pool.**




correct emergent ray 4

image position correctly indicated 3

**At night, when the lamp is switched on, a disc of light is seen at the surface of the swimming pool. Explain why the area of water surrounding the disc of light appears dark.**

(no light emerges from pool due to) total internal reflection / appropriate diagram 3

**Calculate the area of the illuminated disc of water.**

$n = \frac{1}{\sin i_C}$ (=1.33) 3

$i_C = 48.76°$ 3

(radius of disc =) $r = 1.8 \tan 48.76$ / 2.053 (m) 3

$area = \pi r^2$ / 13.24 $m^2$ 3

## Question 7

**When light shines on a compact disc it acts as a diffraction grating causing diffraction and dispersion of the light. Explain the underlined terms.**

| | |
|---|---|
| spreading (out) of a wave | 3 |
| when it passes through a gap / by an obstacle | 3 |
| splitting (up of white) light | 3 |
| into (its constituent / different) colours | 3 |
| | **12** |

**Derive the diffraction grating formula.**

| | |
|---|---|
| diagram showing grating, two rays, angle θ indicated | 3 |
| (for constructive interference) path difference = $n\lambda$ | 3 |
| path difference = $d \sin\theta$ | 3 |
| $n\lambda = d\sin\theta$ | 3 |
| | **12** |

**An interference pattern is formed on a screen when green light from a laser passes normally through a diffraction grating. The grating has 80 lines per mm and the distance from the grating to the screen is 90 cm. The distance between the third order images is 23.8 cm.**

**Calculate**

(i) **the wavelength of the green light;**

| | |
|---|---|
| $d = \frac{1}{80000}(m)$ // $d = 1.25\times10^{-5}(m)$ | 3 |
| ($\sin\theta$ // $\tan\theta$ // θ in radian = ) $\frac{23.8}{90}$ // $\frac{11.9}{90}$ // 0.264 // 0.132 | 3 |
| correct substitution into formula | 3 |
| $\lambda = (551 \pm 5)$ nm **(–1 for omission of or incorrect unit)** | 3 |

(ii) **the maximum number of images that are formed on the screen.**

| | |
|---|---|
| (For maximum number:) $\theta \to 90^\circ$ // $n\lambda = d$ | 3 |
| $n = 22.7$ | 3 |
| (number of images = 22 + 22 + 1 = 45): accept: 22 // 44 // 45 | 3 |
| | **21** |

**The laser is replaced with a source of white light and a series of spectra are formed on the screen.**

**Explain**

(i) **how the diffraction grating produces a spectrum;**

| | |
|---|---|
| different colours | 3 |
| (have) different wavelengths/frequencies | 3 |
| constructive interference occurs / bright images formed at different θ | 3 |

(ii) **why a spectrum is not formed at the central (zero order) image.**

| | |
|---|---|
| at central image θ = 0 // constructive interference occurs for all $f$ / $\lambda$ / colours // path difference zero // 'all colours meet', (state/imply) | 2 |
| | **11** |

Question 23

## Question 3

In an experiment to measure the wavelength of monochromatic light, a diffraction pattern was produced using a diffraction grating with 500 lines per mm. The angle between the first order images was measured. This was repeated for the second and the third order images.

The table shows the recorded data.

| Angle between first order images | Angle between second order images | Angle between third order images |
|---|---|---|
| 34.2° | 71.6° | 121.6° |

**Draw a labelled diagram of the apparatus used in the experiment.**

spectrometer // screen / metre stick 3
(monochromatic) light source // laser 3
(diffraction) grating labelled 3
correct arrangement 3

**Explain how the first order images were identified.**

nearest on either side to <u>brightest</u>/<u>central</u>/<u>straight through</u>/ <u>zero order</u> image (state/imply) 3

**Describe how the angle between the first order images was measured.**

procedure l.h.s. (e.g. <u>crosshair</u> / <u>focus</u> on 1st order image left of central image and note reading) 3
repeat for 1st order image on r.h.s. 3
subtract 3

Laser method:
- measure $x$ between 1st order images (3)
- measure $D$ from screen to grating (3)
- reference to tan / radian / correct protractor method (3)

**Use the data to calculate the wavelength of the monochromatic light.**

$n\lambda = d \sin\theta$ / $n\lambda = \frac{dx}{D}$ 3

(n=1) $\lambda = \frac{\sin(17.1)}{5\times10^5(1)} = 5.8808\times10^{-7} \approx 5.88\times10^{-7}$ m 3

(n=2) $\lambda = \frac{\sin(35.8)}{5\times10^5(2)} = 5.8496\times10^{-7} \approx 5.85\times10^{-7}$ m 3

(n=3) $\lambda = \frac{\sin(60.8)}{5\times10^5(3)} = 5.8195\times10^{-7} \approx 5.82\times10^{-7}$ m 3

$\lambda_{average} = 5.85\times10^{-7}$ m / 585 nm [range: (585 ± 2) nm] 4

**(–1 for omission of or incorrect units)**

{For any one of the following errors in the calculation for λ:

value of $2\theta$ used / average of given angles used / incorrect $d$

➔ award a maximum of (3 +3 +4)

## Question 24

(*d*) **Why does diffraction not occur when light passes through a window?**

| | | |
|---|---|---|
| width of window / gap | | 4 |
| is too large | | 3 |
| ["window is too wide (relative to wavelength of light)", 7 marks] | state/imply | |

## Question 25

(*e*) **Why is a fluorescent tube an efficient source of light?**

| | | |
|---|---|---|
| (a relatively) high percentage/most of the (electrical) energy is converted to | | 4 |
| light (energy) | state/imply | 3 |

Question 26

**Question 2**

In an experiment to measure the wavelength of monochromatic light, a narrow beam of the light fell normally on a diffraction grating. The grating had 300 lines per millimetre. A diffraction pattern was produced. The angle between the second order image to the left and the second order image to the right of the central bright image in the pattern was measured. The angle measured was 40.6°.

**Describe, with the aid of a labelled diagram, how the data was obtained. (9)**

diagram to show: spectrometer, grating labelled, light source // laser, grating labelled, screen 3
**( -1 for no label)**
focus on / line up /rotate T to obtain image on r.h.s. and note reading; repeat for image on l.h.s // measure $x$ between 2nd order images on screen and $D$ from screen to grating 3
**(-1 if 2nd order image on only one side of n=0 used)**
subtract readings (to obtain angle) // use trigonometry /tan / sin / protractor to obtain angle 3
**( a valid protractor method ... 3 X 3 )**

**How was a narrow beam of light produced? (6)**

adjust width of slit (in the collimator/spectrometer ) // use a laser 6

**Use the data to calculate the wavelength of the monochromatic light. (15)**

$n\lambda = d \sin\theta$ 3

$n = 2$ 3

$d = 1/(3.00 \times 10^5)$ m $= 3.33 \times 10^{-6}$ m $= 3.33 \times 10^{-3}$ cm $= 1/300$ mm 3

$\theta = 20.3^0$ 3

$\lambda = 5.78 \times 10^{-7}$ m ($= 578 \approx 580$ nm ) **( -1 for omission of or incorrect unit)** 3

[ If n = 2 used with 40.6°, ( answer $\lambda = 1083$ nm), apply –1.
If n = 4 used with 40.6°, ( answer $\lambda = 542$ nm), apply -1.
If n = 4 used with 20.3°, ( answer $\lambda = 289$ nm), apply -1.]

**Explain how using a diffraction grating of 500 lines /mm leads to a more accurate result. (6)**

greater angle/distance between images 3
smaller % error (in the measurement of $\theta$) 3

**Give another way of improving the accuracy of this experiment. (4)**

repeat and get average $\lambda$ // repeat for different /higher order(s) 4
[specific adjustments to spectrometer // increase $D$ or $\lambda$ (for laser method) ... are acceptable]

Question 27

**Question 7**
**A student used a laser, as shown, to demonstrate that light is a wave motion.**

**(i) Name the two phenomena that occur when light passes through the pair of narrow slits. (6)**

diffraction 3
interference 3

**(ii) A pattern is formed on the screen. Explain how the pattern is formed. (12)**

slits act as coherent sources 3

waves overlap / meet / path difference between waves (or shown on diagram ) 3

constructive interference gives brightness / bright lines / bright fringes 3

destructive interference gives darkness / dark lines / dark fringes 3

**(iii) What is the effect on the pattern when**

**(a) the wavelength of the light is increased. ( 4)**

distance between fringes / lines / spots increases // pattern more spread out 4

**(b) the distance between the slits is increased. ( 4)**

distance between fringes / lines / spots decreases // pattern less spread out 4

**Describe an experiment to demonstrate that sound is also a wave motion. (12)**

two loudspeakers connected to signal generator // rotate vibrating (tuning) fork 3

walk in front of and parallel to speakers // near ear 3

observation: (e.g. sound loud and low / waxes and wanes) 3

conclusion: interference occurs showing that sound is a wave motion 3

**Sound travels as longitudinal waves while light travels as transverse waves. Explain the difference between longitudinal and transverse waves. (9)**

**longitudinal waves**: the direction of the vibrations (of medium) 3

is parallel to the direction of (propagation) of the wave 3

**transverse wave**: the direction (of the vibrations) is perpendicular to the (direction of the) wave 3

**Describe an experiment to demonstrate that light waves are transverse waves. (9)**

light source and two pieces of polaroid 3

rotate one polaroid relative to the other and light (intensity)decreases (to zero) 3

polarization indicates transverse waves 3