Name: _____

Topic 5: Waves and Particle Nature of Light Part 4

Date:

Time:

Total marks available:

Total marks achieved: _____

Questions

Q1.

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

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

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

The diagram is not expected to be to scale.

(4)

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

(3)

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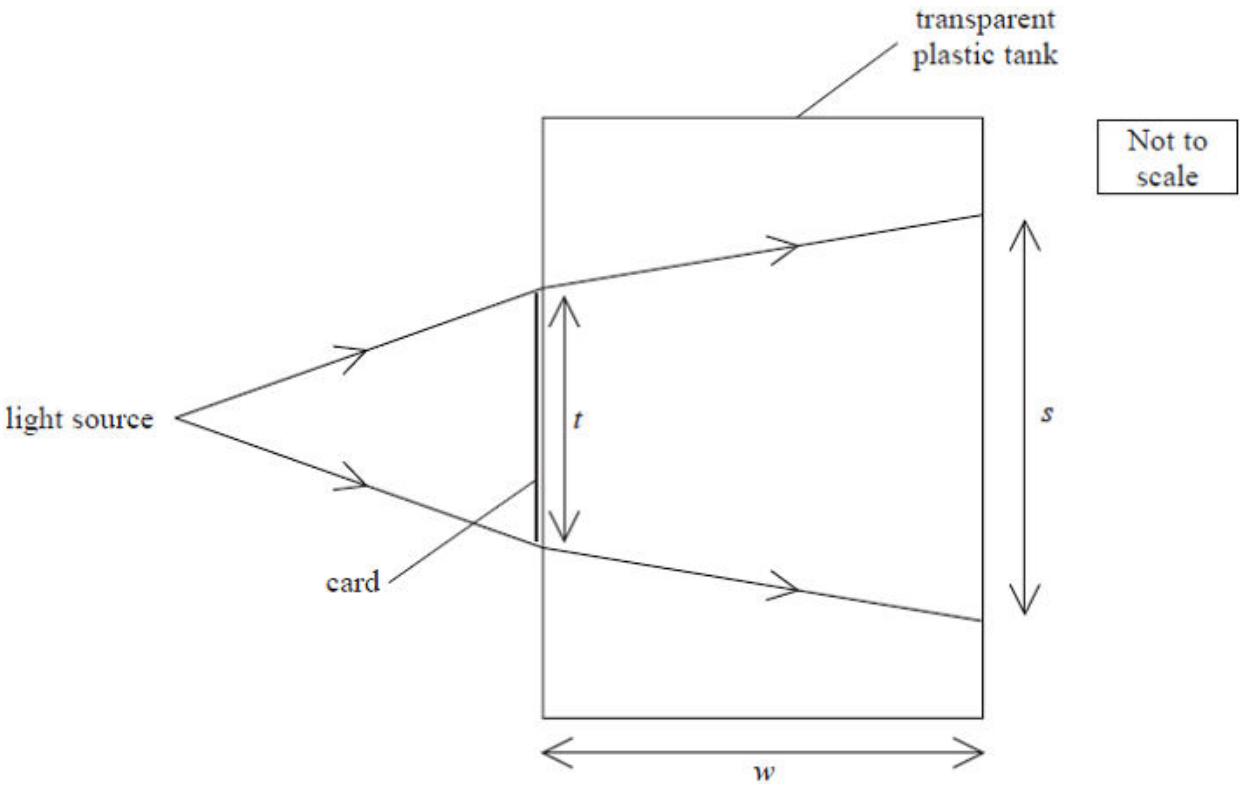
Power = ...

(Total for question = 7 marks)

Q2.

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

$w = 35.0\,\text{cm}$
$t = 4.0\,\text{cm}$
$s = 10.2\,\text{cm}$

(3)

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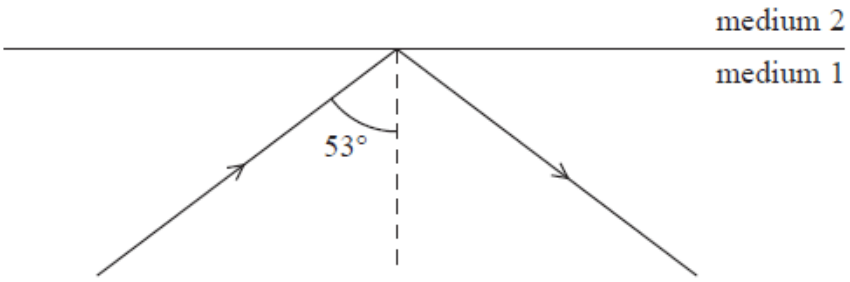
(Total for question = 3 marks)

Q3.

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



Which of the following can be deduced?

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

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

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

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

(Total for question = 1 mark)

Q4.

The photograph shows a 'quiet boil' electric kettle. The makers of the kettle claim that it boils water with much less noise than a standard kettle.

A laboratory technician takes some measurements to compare a 'quiet boil' electric kettle with a standard electric kettle.

The table shows the results recorded by the technician.

	Quiet boil kettle	Standard kettle
Mass of water / kg	1.20	1.20
Initial temperature of water / °C	10	10
Final temperature of water / °C	100	100
Potential difference / V	243	247
Current / A	11.9	11.8
Time taken to heat water to boiling point / s	168	172
Average sound intensity / mW m^{-2}	3.72	10.5

A student uses the values in the table to calculate the efficiency of each kettle at heating the water to boiling point. He calculates the efficiency of the 'quiet boil' kettle to be 0.93

Calculate the efficiency of the standard kettle.

specific heat capacity of water = 4180 J kg^{-1} K^{-1}

(4)

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Efficiency = ...

(b) The intensity of the sound produced by each kettle was measured with a sound meter which was 30.0 cm from the centre of the kettle.

Calculate the energy transferred by sound while the water in the standard kettle is brought to the boil. You may treat the kettle as a point source.

(4)

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Energy transferred = ...

(c) The label on the original packaging of the quiet boil electric kettle states, 'This kettle is much more efficient than a standard kettle because it produces less sound.'

Explain the extent to which this statement is supported by your calculations.

(2)

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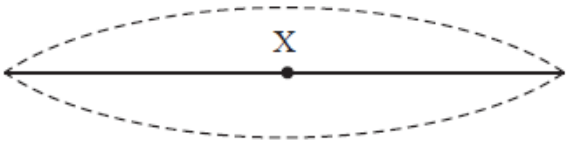
(Total for question = 10 marks)

Q5.

Guitar strings can oscillate with simple harmonic motion.

Shortly after the string is plucked, a standing wave exists on the string. The simplified diagram below shows a string in three positions of the standing wave.



(a) State what is meant by simple harmonic motion.

(2)

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(b) (i) Describe the acceleration of point X on the string as it moves between the extreme positions of its motion.

(2)

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(ii) Comment on the energy changes in the string as it moves between the extreme positions of its motion.

(3)

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(c) The oscillating string has a length of 0.53 m. Calculate the frequency of the sound emitted when the string oscillates as shown previously.

speed of the wave on the string = 270 m s^{-1}

(3)

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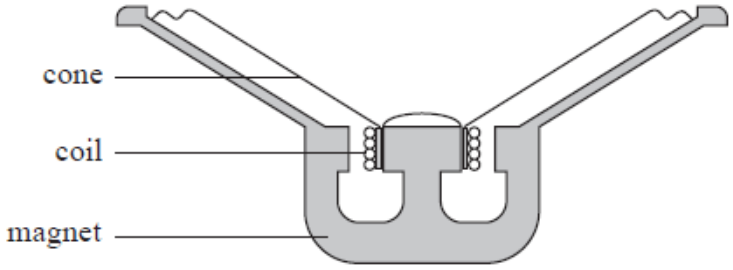
Frequency = ...

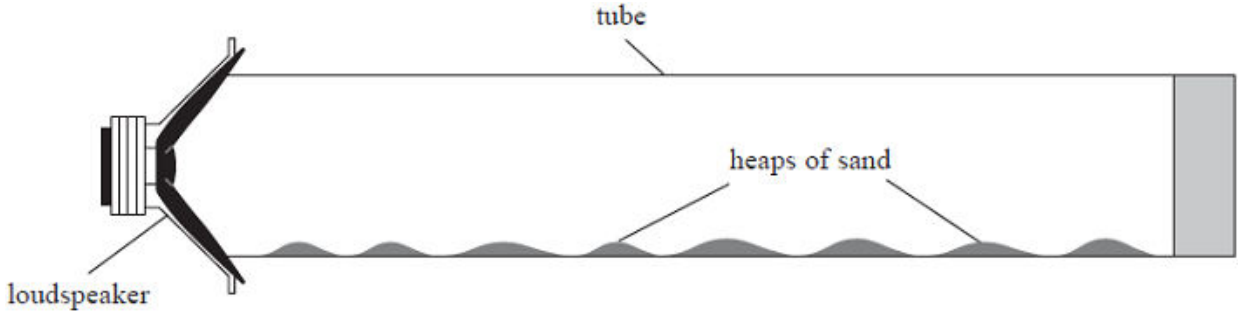
(Total for question = 10 marks)

Q6.

A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate. The loudspeaker is mounted in a wooden box. A cross-section through the loudspeaker is shown.



The student connected a signal generator to the loudspeaker, and placed the loudspeaker near to one end of a long tube containing sand. The student adjusted the signal generator until the sand collected in small heaps as shown.



(i) Explain why the sand collects in heaps.

(4)

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(ii) The student determined the distance *d* between the centres of adjacent heaps.

Describe the procedure she should follow to determine an accurate value for *d*.

(3)

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(iii) Assess whether the experimental data is consistent with a value for the speed of sound of $340\,\text{m}\,\text{s}^{-1}$.

signal generator frequency = 3.25 kHz.

d = 5.1 cm

(3)

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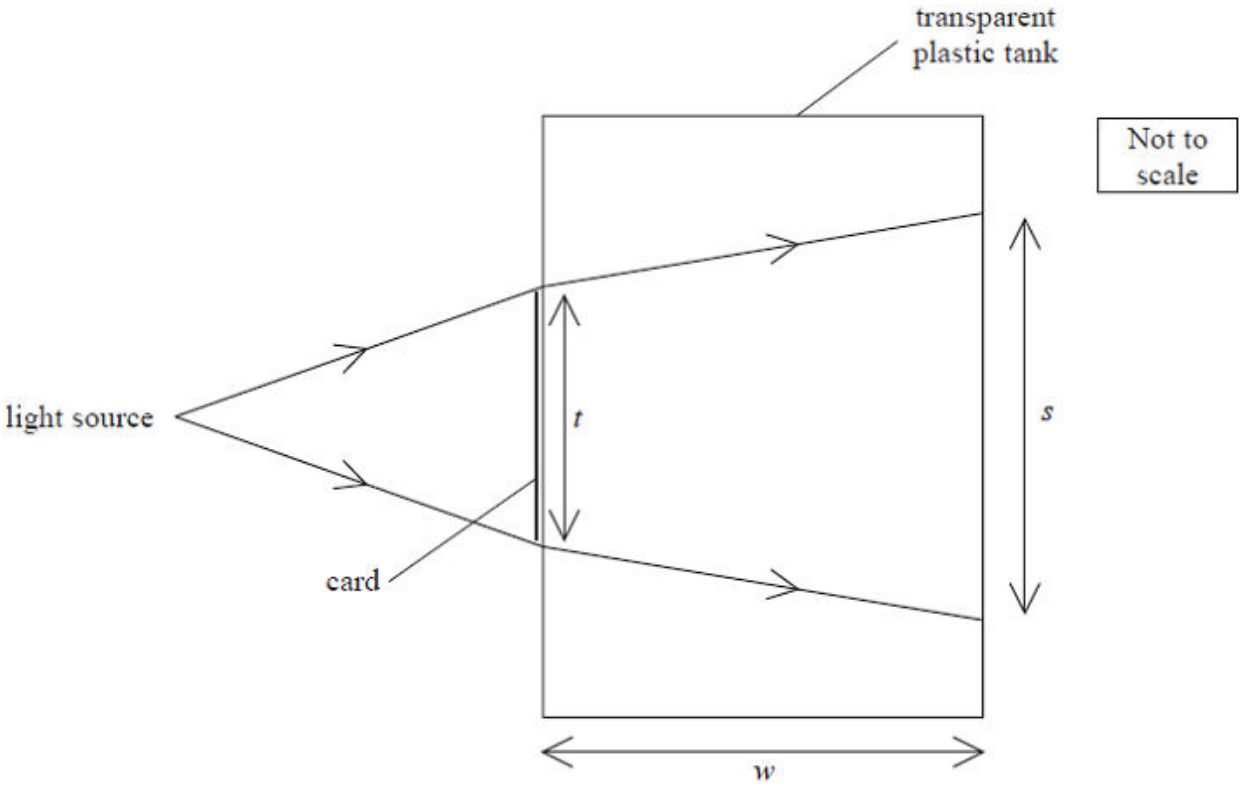
(Total for question = 10 marks)

Q7.

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



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

Determine the speed of light in the liquid.

(2)

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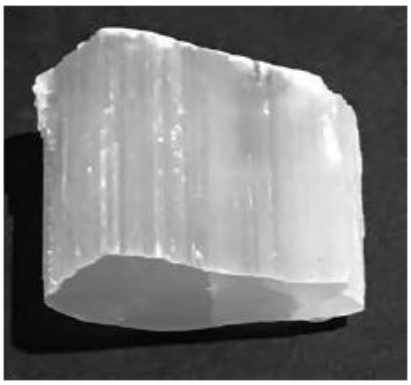
Speed of light = ...

(Total for question = 2 marks)

Q8.

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



Selenite has a refractive index of 1.52

Calculate the speed of light in selenite.

(2)

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Speed of light in selenite = ...

(Total for question = 2 marks)

Q9.

The photograph shows a guitar.

When a guitar string is plucked, a standing wave is created.

Explain how a standing wave is created on the string.

(3)

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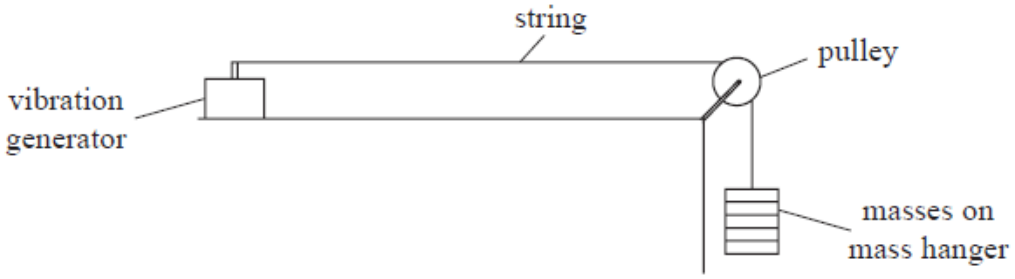
(Total for question = 3 marks)

Q10.

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

The diagram represents an arrangement used to generate standing waves on a string.



A standing wave pattern with two nodes is obtained as shown.

Which of the following single changes could produce a standing wave pattern with three nodes?

☒ **A** decreasing the distance between the vibration generator and pulley

☒ **B** decreasing the frequency of the vibration generator

☒ **C** decreasing the mass on the mass hanger

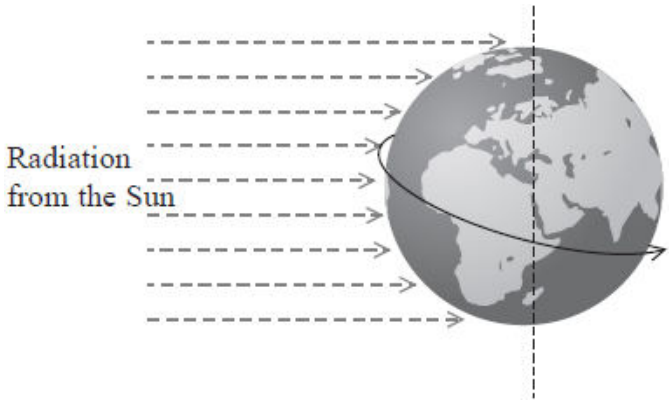
☒ **D** decreasing the mass per unit length of the string

(Total for question = 1 mark)

Q11.

Solar panels consisting of combinations of photovoltaic cells use energy in the radiation received from the Sun to generate electricity.

The average intensity of radiation from the Sun incident at the Earth's surface over a 24-hour period has been determined to be 164 $W\,m^{-2}$.



(i) The average intensity of radiation from the Sun at the Earth's surface is much less than the intensity incident at the top of the Earth's atmosphere.

Explain why.

(4)

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(ii) It is claimed that the area of solar panels needed to generate 100 GW of power is about 0.5% of the surface area of the Earth.

Assess the validity of this claim.

radius of Earth = 6.4×10^6 m

typical efficiency of solar panels = 25%

(4)

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(Total for question = 8 marks)

Q12.

The photograph shows an ultrasonic mouse repeller used in a house.

The mouse repeller produces ultrasound that repels mice but cannot be heard by humans.
The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

speed of sound = 340 m s^{-1}

State what is meant by superposition of waves.

(2)

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(Total for question = 2 marks)

Q13.

Some sunglasses have lenses made from polarising filters.

You are given two pairs of identical sunglasses.

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

(2)

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(Total for question = 2 marks)

Q14.

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

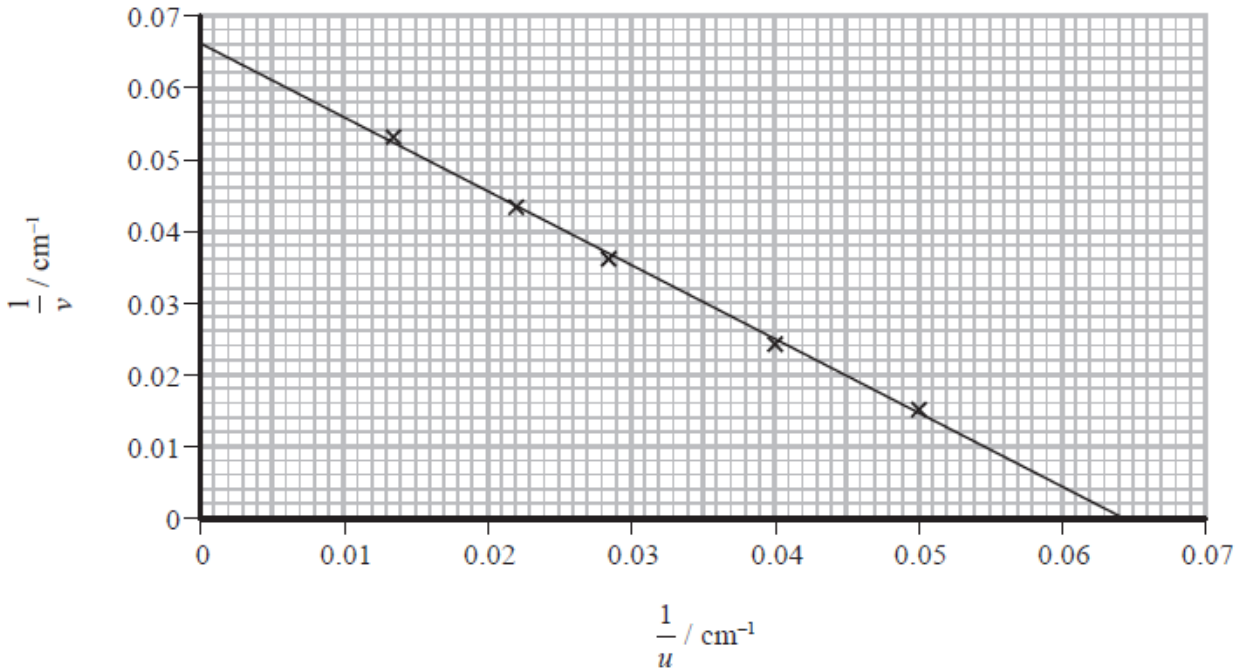
He placed the lens a distance *u* from an illuminated object. He placed a screen on the other side of the lens and moved the screen until a sharp image of the object was produced. He measured the corresponding image distance *v*.

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.

(5)

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(Total for question = 5 marks)

Q15.

The idea of energy quantisation was used to explain the photoelectric effect, first observed by Heinrich Hertz.
When ultraviolet radiation is shone onto a metal surface, electrons may be released.
A cadmium surface is illuminated with light of wavelength 2.54×10^{-7} m.

Calculate the maximum kinetic energy of the photoelectrons released from the surface.

Work function of cadmium = 4.07 eV

(4)

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Maximum kinetic energy = ... J

(Total for question = 4 marks)

Q16.

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

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

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

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

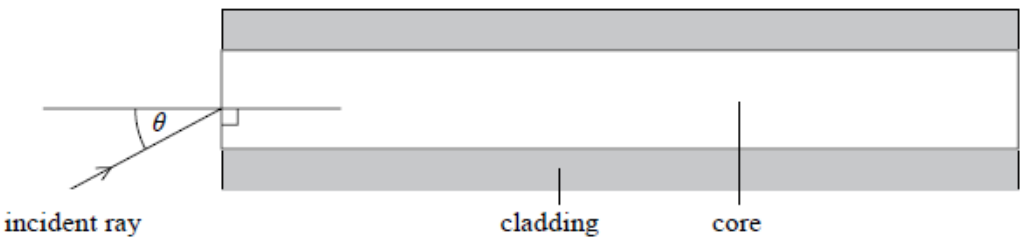
☒ **C** less than or equal to the critical angle.

☒ **D** less than the critical angle.

(Total for question = 1 mark)

Q17.

One type of optical fibre is made from a glass core surrounded by a glass cladding of lower refractive index. The light ray passes along the fibre by total internal reflection. The diagram shows a light ray incident on one end of the fibre.



A light ray enters the core with an angle of incidence θ and the angle of refraction is 20°.

Show that the light ray will be totally internally reflected when it meets the boundary between the core and the cladding.

$n_{core} = 1.56$

$n_{cladding} = 1.44$

(4)

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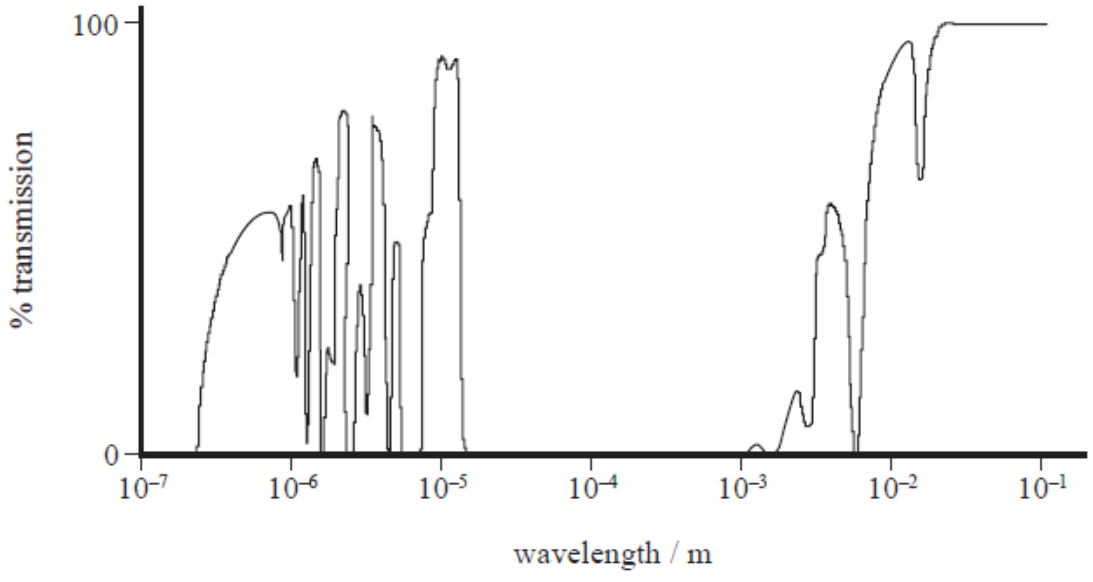
(Total for question = 4 marks)

Q18.

In 1990, the Hubble Space Telescope (HST) was launched into a low Earth orbit above the Earth's atmosphere.

The transmission of electromagnetic radiation through the atmosphere is shown on the graph.



State one advantage shown by this graph of positioning a telescope above the atmosphere.

(1)

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(Total for question = 1 mark)

Q19.

An electron gun uses a potential difference V to accelerate electrons of mass m and charge e from rest to a speed v.
The potential difference V can be expressed as

☐ **A** $\frac{mv^2}{2e}$

☐ **B** $\frac{2ev^2}{m}$

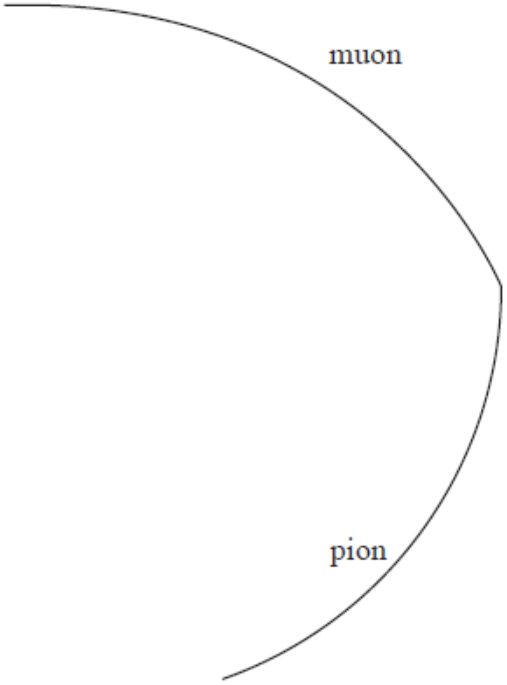
☐ **C** $\sqrt{\frac{2ev}{m}}$

☐ **D** $\sqrt{\frac{mv}{2e}}$

(Total for question = 1 mark)

Q20.

A negatively charged pion decays into a muon and an antineutrino. The diagram shows tracks in a particle detector formed in such an event.



Use a vector diagram to determine the momentum of the antineutrino.

The initial momentum of the muon is 1.59×10^{-19} N s.

(5)

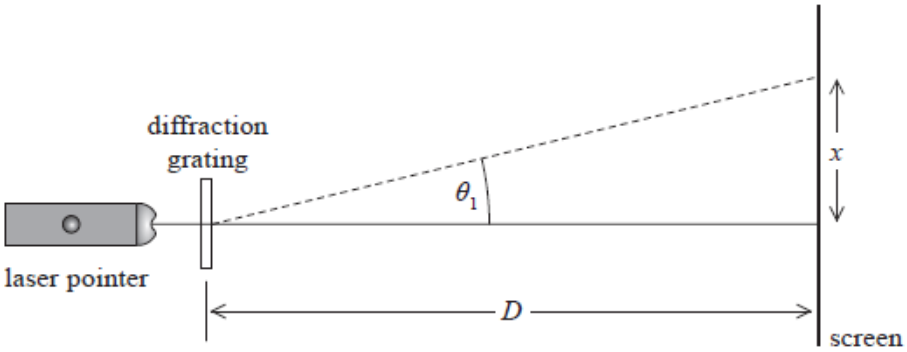
Momentum of antineutrino = ...

Direction of antineutrino = ...

(Total for question = 5 marks)

Q21.

Light from a laser pointer was passed through a diffraction grating. The light was perpendicular to the diffraction grating as shown. A diffraction pattern was produced on a screen.



The distance between the first order maximum and the central maximum of the diffraction pattern was x. The distance between the diffraction grating and the screen was D.

Distance x was measured to be 0.500 m with a metre rule. The wavelength of light λ_1 from the laser pointer was 650 nm.

The laser pointer was replaced with one that produced light of a different wavelength. The new distance x was measured to be 0.400 m.

D = 1.45 m

Explain one modification to this method that would decrease the uncertainty in the calculated value of λ_2.

(2)

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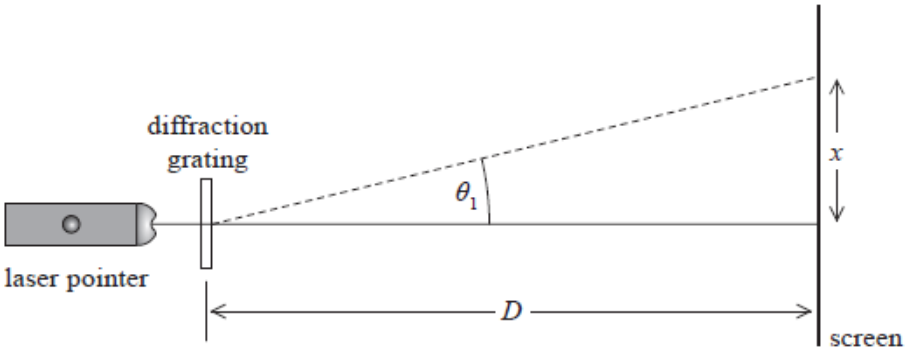
(Total for question = 2 marks)

Q22.

Light from a laser pointer was passed through a diffraction grating. The light was perpendicular to the diffraction grating as shown. A diffraction pattern was produced on a screen.



The distance between the first order maximum and the central maximum of the diffraction pattern was x. The distance between the diffraction grating and the screen was D.

In another experiment, the light from the laser pointer was not quite perpendicular to the screen.

Explain how this would change the diffraction pattern produced on the screen.

(3)

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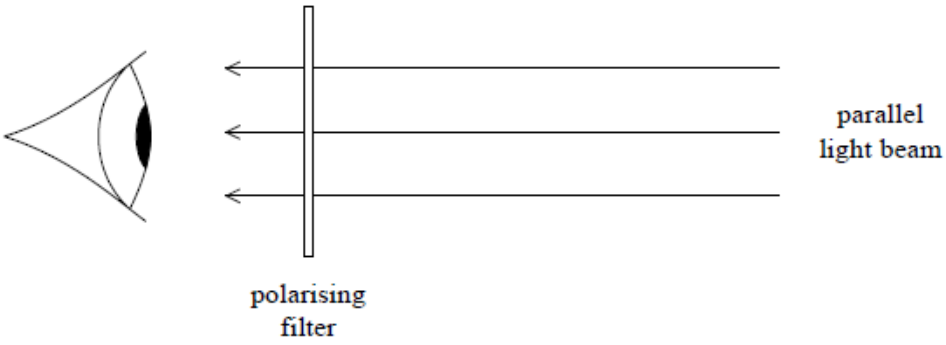
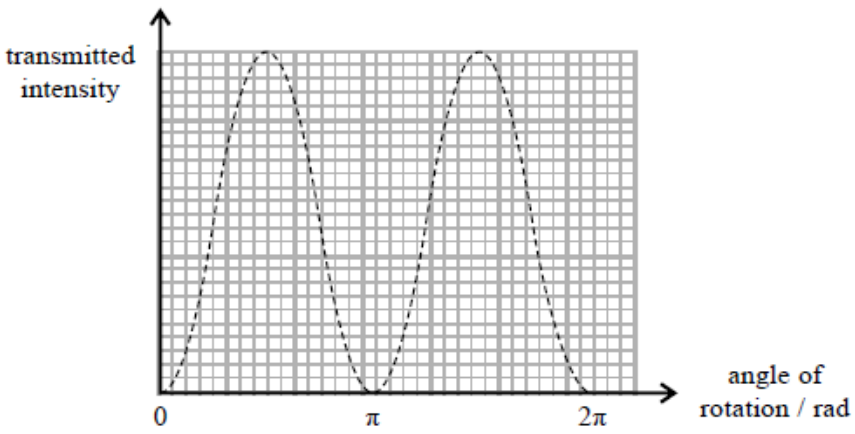
(Total for question = 3 marks)

Q23.

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



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



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

(6)

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(Total for question = 6 marks)

Q24.

In a model of a hydrogen atom, it is assumed that the electron behaves like a wave with a de Broglie wavelength λ. The wave associated with the electron forms a standing wave whose wavelength is equal to the circumference of the circular path.

Calculate the velocity of the electron based on this model.

(3)

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Velocity = ...

(Total for question = 3 marks)

Q25.

Which of the following wave properties is **not** exhibited by sound waves?

(1)

☒ **A** diffraction

☒ **B** interference

☒ **C** polarisation

☒ **D** refraction

(Total for question = 1 mark)

Q26.

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

Ultrasound can be used to investigate the structure of organs of the human body using the pulse-echo technique.
The level of detail obtained depends on the wavelength and the length of the pulses.

Which line of the table shows a change to wavelength and a change to pulse length that would each improve the level of detail?

		Wavelength	Pulse length
☒	**A**	decrease	decrease
☒	**B**	increase	decrease
☒	**C**	decrease	increase
☒	**D**	increase	increase

(Total for question = 1 mark)

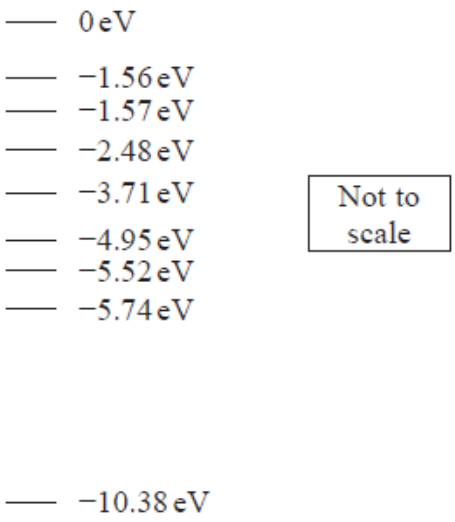
Q27.

In 1905 Einstein published his equation for the photoelectric effect.

In 1916 Millikan demonstrated that the maximum kinetic energy of photoelectrons is consistent with Einstein's equation.

Millikan's experiments involved using different frequencies of light. These were obtained using a mercury vapour lamp which produced an emission spectrum with a specific number of known frequencies.

The diagram shows some energy levels for a mercury atom.



Determine which transition from the −3.71 eV energy level would produce light of wavelength 6.1×10^{-7} m.

(4)

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Transition from −3.71 eV to .....

(Total for question = 4 marks)

Q28.

The photograph shows an ultrasonic mouse repeller used in a house.

The mouse repeller produces ultrasound that repels mice but cannot be heard by humans.
The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

speed of sound = 340 m s^{-1}

Calculate the wavelength of the ultrasound produced.

(2)

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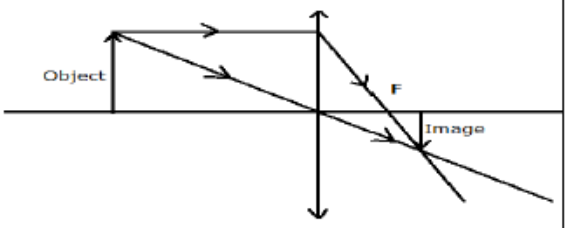
Wavelength = ...

(Total for question = 2 marks)

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of a correct ray (1) • use of second correct ray (1) • indicates image formed where rays cross (1) • image drawn is real, inverted and diminished (1)	Correct rays are: Ray through the principal focus and parallel to the principal axis Ray parallel to principal axis then through the principal focus Ray through the optical centre of the lens Example of diagram:  	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• use of $1/f = 1/v + 1/u$ for u estimate 4 – 10 mm (1) • use of $P = 1/f$ (1) • P = (120 D to 230 D) (1)	Example of calculation: Assuming the thickness of 8 mm: $1/f = 1/0.008 + 1/0.045$ $P = 1/f$ P = 147 D Full credit for any thicknesses in range 4 – 10 mm	**(3)**

Q2.

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) ÷ 2 = 3.1 cm tan θ = 3.1 cm / 35 cm θ = 5.06° n = sin 7.2° / sin 5.06° n = 1.42	3

Q3.

Question Number	Answer	Mark
	B	1

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $W = VIt$ (1) • use of $\Delta E = mc\Delta\theta$ (1) • use of efficiency = useful power output / total power input (1) • efficiency = 0.90 Or 90% (1)	Example of calculation: W = 247 V × 11.8 A × 172 s = 501 000 J ΔE = 1.20 kg × 4180 J kg^{-1} K^{-1} × (101 - 11) K = 451 000 J Efficiency = 451 000 / 501 000 = 0.90	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• calculates area of sphere of radius 30 cm = 1.13 m^2 (1) • use of $I = P/A$ (1) • use of $W = Pt$ (1) • W = 2.0 J (1)	Example of calculation: Area = 4π × (0.3 m)^2 = 1.13 m^2 P = 10.5 × 10^{-3} W m^{-2} × 1.13 m^2 = 1.19 × 10^{-2} W W = 1.19 × 10^{-2} W × 172 s = 2.0 J	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	An explanation that makes reference to the following: • the quiet boil electric kettle is more efficient, but only by 3% which isn't 'much' (1) • the energy transferred by sound is very small, so it is not the reason for the difference (1)	Allow 1 mark if the student gives a comment that the uncertainties are too high to draw a valid conclusion without reference to the data in the question, the candidate's calculations may be awarded one mark	**(2)**

Q5.

Question Number	Answer	Mark
(a)	Force (or acceleration): • proportional to displacement from equilibrium/undisplaced/rest position (1) • always acting towards the equilibrium/undisplaced/rest position **Or** always in the opposite direction to the displacement (1)	2
(b)(i)	Acceleration is a maximum at an extreme position (towards X) (1) Acceleration decreases to zero at X (1)	2
(b)(ii)	**Max 3** Total energy remains constant (1) (Elastic) potential energy is transferred to kinetic energy as string moves towards X (1) Kinetic energy is zero at an extreme position and a maximum at X (1) (Elastic) potential energy is a maximum at an extreme position and a minimum at X (1)	3
(c)	Use of $\lambda = 2l$ (1) Use of $v = f\lambda$ (1) $f = 250$ Hz (1) <u>Example of calculation:</u> $\lambda = 2 \times 0.53\ m = 1.06\ m$ $f = v/\lambda = 270\ m\ s^{-1}/1.06\ m = 254.7\ Hz$	3
	Total for question	10

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark

(i)	• A standing wave is set up in the tube **Or** interference (of sound waves) takes place in the tube (1) • Where constructive interference occurs the amplitude is a maximum **Or** at antinodes the amplitude is a maximum (1) • Where destructive interference occurs the amplitude is a minimum **Or** at nodes the amplitude is zero/minimum (1) • Sand is displaced from points of max amplitude to points of min amplitude **Or** sand is displaced from antinodes to nodes (1)		4
(ii)	• Measure over at least 3 heaps (1) • Divide by the number of gaps between the heaps (1) • Repeat measurement and calculate average (1)	i.e at least 2 gaps	3

(iii)	• Use of $d = \frac{\lambda}{2}$ (1) • Use of $v = f\lambda$ (1) • v = 330 (m s^{-1}) and a comment on consistency with 340 m s^{-1} (1)	Example of calculation: $\lambda = 2d = 2 \times 5.1 \times 10^{-2}$ m = 0.102 m $v = 3.25 \times 10^{3}$ Hz × 0.102 m = 332 m s^{-1}	3

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $n = c / v$ (1) • $v = 2.1 \times 10^{8}$ m s^{-1} (allow ecf from (a)) (1)	Example of calculation $v = c/n$ $= 3.00 \times 10^{8}$ m s^{-1} / 1.42 $= 2.11 \times 10^{8}$ m s^{-1}	2

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $n = c / v$ (1) • $v = 2.0 \times 10^8$ m s^{-1} (1)	Example of calculation $1.52 = 3.00 \times 10^8$ m s^{-1} / v 1.97×10^8 m s^{-1}	2

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Waves are reflected at ends of strings (1) • The reflected waves meet and superpose/interfere (1) • Where they meet in phase constructive interference takes place producing points of maximum amplitude **Or** Where they meet in phase constructive interference takes place producing antinodes **Or** Where they meet in antiphase destructive interference takes place producing points of zero/minimum amplitude **Or** Where they meet in antiphase destructive interference takes place producing nodes (1)		3

Q10.

Question Number	Answer	Mark
	The only correct answer is C because decreasing the mass on the hanger decreases the tension in the string and, since $v = \sqrt{\frac{T}{\mu}}$, decreases the speed of waves on the string. $\lambda = v/f$ so the wavelength is shorter and a whole wavelength could fit in the original length A the wavelength at the original frequency is unchanged, so decreasing the length will not allow a whole wavelength B decreasing the frequency will increase the wavelength, since wave speed is unchanged, so this will not allow a whole wavelength D since $v = \sqrt{\frac{T}{\mu}}$, decreasing the mass per unit length will increase the wave speed, increasing the wavelength at the original frequency, so this will not allow a whole wavelength	1

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Radiation is absorbed/scattered passing through the atmosphere. (1) • Radiation is reflected from the top of the atmosphere (1) • Only half of the Earth's surface has radiation from the Sun incident on it at any one instant. (1) • The intensity of radiation (normal to the surface) is greater at the equator than at the poles. (1)		4

(ii)	• Use of $A=4\pi r^2$ (1) • Use of efficiency= $\frac{\text{useful power output}}{\text{total power input}}$ (1) • Use of $I=\frac{P}{A}$ (1) • % of surface needed is 0.0005%, so claim is not valid (1) [Accept reverse calculation to show power generated by cells over 0.5% of the Earth would generate 1.06×10^5 GW]	Example of calculation: $A=\frac{P}{I}$ $=\frac{100\times10^9\ \text{W}}{0.25\times164\ \text{W m}^{-2}}=2.44\times10^9\text{m}^2$ $A=4\pi\times(6.4\times10^6\ \text{m})^2$ $=5.15\times10^{14}\text{m}^2$ % needed = $\frac{2.44\times10^9\text{m}^2}{5.15\times10^{14}\ \text{m}^2}\times100\%=0.00047\ \%$	4

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• Two or more waves meet (1) • The (resultant) displacement (at a point) is the sum of the individual displacements from the individual waves (1)	Do not accept sum of amplitudes	2

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	• Pass light through one lens of the glasses and view the light through the lens of the second pair of glasses. Rotate one pair of glasses through 90° **(1)** • If the light intensity varies then the glasses use polarising filters **(1)**	Allow full credit for a suitably annotated diagram.	2

Q14.

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)	$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ $y=mx+c$	
	• 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)		5
	• 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)		

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $c=f\lambda$ and $E=hf$ **(1)** • Converts eV to J **(1)** • Use of $E = W + KE_{max}$ **(1)** • $KE_{max} = 1.3 \times 10^{-19}$ J **(1)**	Example of calculation: $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\text{Js}\times3\times10^{8}\text{m s}^{-1}}{2.54\times10^{-7}\text{m}} = 7.831\times10^{-19}\text{J}$ Work function = 6.51×10^{-19} J $E = W + KE_{\max}$ $KE_{\max} = 7.83\times10^{-19}\text{J} - 6.51\times10\text{ -}19\text{J} = 1.32\times10^{-19}\text{J}$	**4**

Q16.

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

Q17.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **(1)** • $c = 67^\circ$ **(1)** • Determines the angle of incidence is 70° **(1)** • so i > c so the ray does totally internally reflect **(1)**	Example of calculation: $1.56\times\sin c = 1.44\times\sin90^\circ$ $c = 67.4^\circ$	**4**

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Stars emitting infra-red radiation can be detected above the atmosphere **Or** Some visible wavelengths emitted by stars reduced to **50% intensity or less by the** atmosphere (1)	Accept identified wavelength range	1

Q19.

Question Number	Answer	Mark
	A	1

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	• Draws one labelled scaled vector (either pion or muon) (1) • start of muon line should begin at start of pion line **Or** end of muon line should coincide with end of pion line (1) • angle between them should be approx 30° (1) • p of antineutrino = 9.5×10^{-20} N s ± 0.5×10^{-20} N s (1) • angle of antineutrino with muon = 150° ± 5° **Or** angle of antineutrino with pion = 120° ± 5° (1)	Label can be "pion" or momentum value. The line should be straight and have an arrow. 	5

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Measure the distance between the two 1st/2nd order maxima (1) **Or** measure the distance from the 2nd order to the central maximum (1) **Or** increase the distance from the grating to the screen • This increases the distance measured on the screen (and reduce the % uncertainty) MP2 dependent upon MP1		**2**

Q22.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Maxima on one side move closer to the central maximum (1) • Maxima on the other side move further away from the central maximum (1) • Intensity of maxima would be different on each side of central maximum (1)	Allow 1 mark for spacing of maxima on screen will change	**3**

Q23.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>
Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).
</td><td>6</td></tr>
</table>

<table>
<tr><td>* (continued)</td><td>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td><td></td></tr>
</table>

Question Number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single plane • including the direction of propagation of the light • the light incident on the filter must be plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of π/2 rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		

Question Number	Acceptable answers	Additional guidance	Mark
* (continued)	**Alternative answer** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single direction • perpendicular to the direction of propagation of the light • the light incident on the filter is plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of π/2 rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		

Q24.

Question number	Acceptable answers	Additional guidance	Mark
	• Calculates wavelength λ (circumference) **(1)** • Use of $p = h/\lambda$ **(1)** • $v = 2.2 \times 10^6$ m s^{-1} **(1)**	Example of calculation: $\lambda = 2\pi r = 2\pi \times 5.3 \times 10^{-11}$m $= 3.33 \times 10^{-10}$ m $\lambda = h/mv$ so $v = h/m$. $v = 6.63\times10^{-34}$ J s/(9.1×10^{-31} kg$\times3.33\times10^{-10}$ m) $v = 2.188 \times 10^6$ m s^{-1}	**3**

Q25.

Question Number	Answer	Mark
	C - polarisation	**1**
	Incorrect Answers: A – diffraction is exhibited by sound waves B – interference is exhibited by sound waves D – refraction is exhibited by sound waves	

Q26.

Question Number	Answer	Mark
	The only correct answer is A because detail is improved by both decreasing pulse length and decreasing wavelength B increasing wavelength decrease detail C increasing pulse length decrease detail D increasing pulse length and increasing wavelength both decrease detail	**1**

Q27.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $E=hf$ (1) • Use of $c = f\lambda$ (1) • Apply conversion factor of 1.6×10^{-19} for photon energy from J to eV (1) • Level = -5.74 (eV) (1)	Example of calculation $f = 3.00 \times 10^{8}$ m s^{-1} / 6.1×10^{-7} m $= 4.91 \times 10^{14}$ Hz $E = 6.63 \times 10^{-34}$ J s $\times$ 4.91×10^{14} Hz $= 3.26 \times 10^{-19}$ J 3.26×10^{-19} J / 1.6×10^{-19} C = 2.04 eV Level = -3.71 eV - 2.04 eV = -5.75 eV	4

Q28.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $v = f\lambda$ (1) • $\lambda = 0.013$ m (1)	Example of calculation 340 m s^{-1} = 26.0 kHz $\times$ λ $\lambda = 0.013$ m	2