PEARSON EDEXCEL IAL PHYSICS · YPH11

PHYSICS



EXAM QUESTION PACK

UNIT 2: WAVES AND PARTICLE NATURE OF LIGHT

SCORE	PERCENTAGE
/189	%

STEMUP

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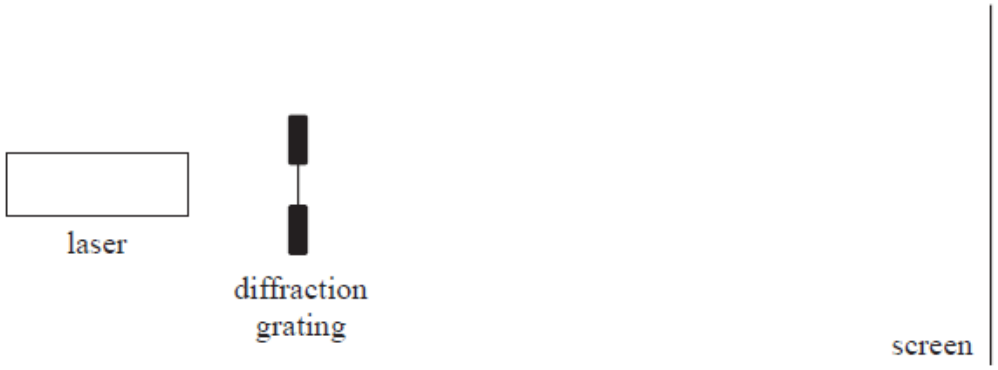
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Q1.

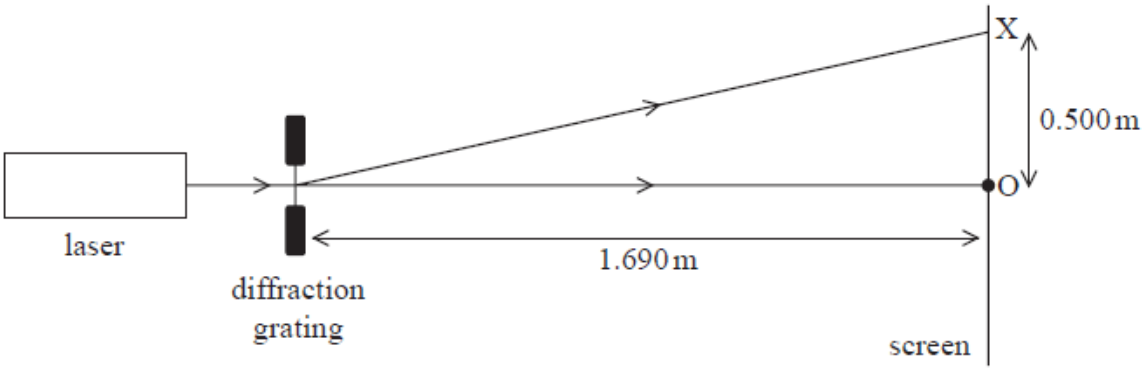
A laser, a diffraction grating and a screen are set up as shown. The laser emits monochromatic light.



When the laser is switched on, a series of bright dots is seen on the screen.

(a) The diagram below shows the position of the central dot at O. The next bright dot appears at position X.

The diffraction grating has 450 lines per mm.



Determine the wavelength of the light from the laser.

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Wavelength = ...

(b) Explain why a series of bright dots is seen on the screen.

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(c) The laser is replaced by a source producing a parallel beam of bright white light.

Suggest what would now be observed on the screen.

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(Total for question = 9 marks)

Q2.

Astronomers often use the unit megaparsec (Mpc) for astronomical distances. In a textbook a value for the Hubble constant is given as 72 km s^{-1} Mpc^{-1}.

(a)(i) Show that 72 km s^{-1} Mpc^{-1} is equivalent to a Hubble constant of about 2.3×10^{-18} s^{-1}.

1 Mpc = 3.09×10^{22} m

(2)

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(ii) Determine a value for the age of the universe in years.

1 year = 3.16×10^7 s

(2)

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Age of universe = ... years

(b) In the 1950s, astronomers realised that they had made an error in their determination of distances to galaxies. Galaxies are twice as far away as astronomers had previously thought.

Explain how this changed the age of the universe as calculated by astronomers.

(2)

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(Total for question = 6 marks)

Q3.

In the 17th century, Kepler proposed his 'law of harmonies' for planetary motion. This law suggested that the ratio of the square of the orbital period T to the cube of the mean radius R has the same value for all the planets that orbit the Sun.

Mathematically his 'law of harmonies' can be written

$$T^2 = KR^3$$

where K is a constant.

(a) The table shows data for Earth and Mars.

Planet	T / s	R / m
Earth	3.16×10^{7}	1.50×10^{11}
Mars	5.93×10^{7}	2.28×10^{11}

Show that, for Earth and for Mars, K has a value of about $3.0 \times\times 10^{-19}$ s^2 m^{-3}.

(3)

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(b) Kepler's law of harmonies was derived later by Newton. Newton applied his law of gravitation to a planet moving in an approximately circular orbit around the Sun.

Determine a value for K by applying Newton's law of gravitation to a planet of mass m moving in a circular orbit about the Sun.

mass of Sun = 1.99×10^{30} kg

(3)

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K = ... s^2 m^{-3}

(c) Jupiter is the most massive planet in the solar system and has many moons. Kepler's law of harmonies applies to the orbiting moons. However, the value of K for the moons is not the same as the value that applies to planets orbiting the Sun.

Ganymede is Jupiter's largest moon. Ganymede has an orbital radius of 1.07×10^{9} m and an orbital period of 172 hours.

Another moon, Io, has an orbital radius of 4.22×10^{8} m.

Calculate the orbital period T_I of Io about Jupiter.

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T_I = ...

(Total for question = 8 marks)

Q4.

The astronomer Hertzsprung used parallax to determine the distances to some of the variable stars known as Cepheids.

(a) Using parallax measurements, astronomers can determine distances to all stars with a parallax angle
larger than 2.4×10^{-7} rad.

The variable star Alpha Cephei is 4.6×10^{17} m from the Earth.

Deduce whether the distance to Alpha Cephei could be determined from parallax measurements.

distance from Earth to Sun = 1.5×10^{11} m

(3)

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(b) Cepheids are a type of standard candle.

Describe how standard candles can be used to determine distances to stars.

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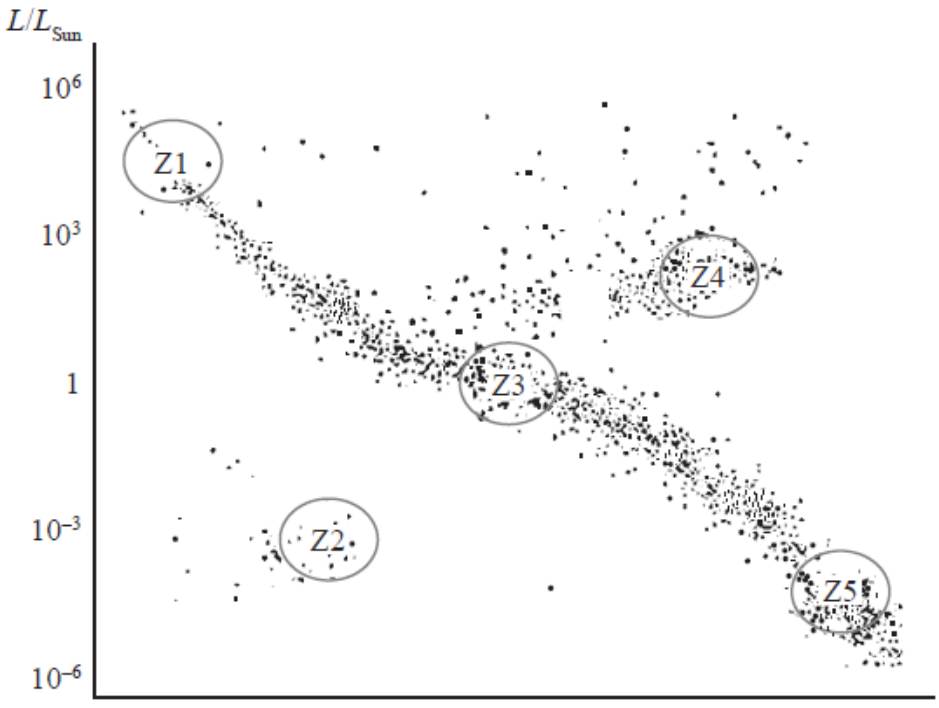
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(c) The Sun is a yellow star with a surface temperature of about 6000 K. In the 20th century, astronomers discovered a large variety of stars in our galaxy. Hertzsprung and Russell developed the Hertzsprung-Russell (HR) diagram as a way of classifying stars.

An HR diagram is shown below.



(i) Label the x-axis of the HR diagram. You should include approximate values.

(3)

(ii) There are five zones, Z1, Z2, Z3, Z4 and Z5, identified on the HR diagram.

Complete the following table. You should match one zone with each description.

(3)

Description	Zone
High mass hot stars	
Low mass cool stars	
Low mass hot stars	

*(iii) The position of a star on the HR diagram changes as the star evolves.

Explain how a star like the Sun evolves as it progresses from zone Z3 to its final position on the HR diagram.

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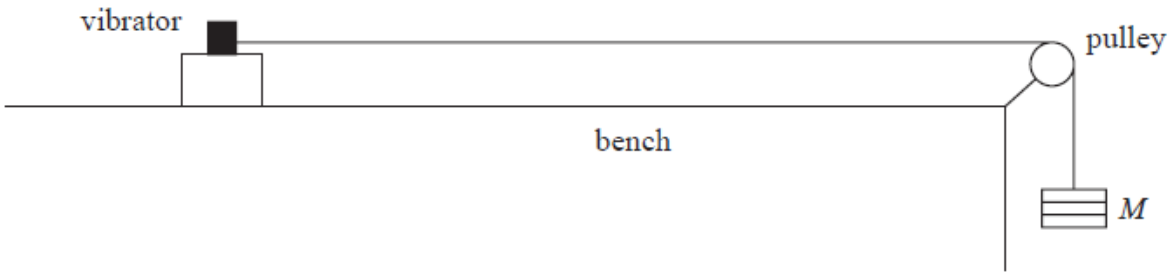
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(Total for question = 18 marks)

Q5.

A student investigated stationary waves on a stretched string. The string was attached to a vibrator and a mass M, as shown.



(a) Explain how a stationary wave forms on the string.

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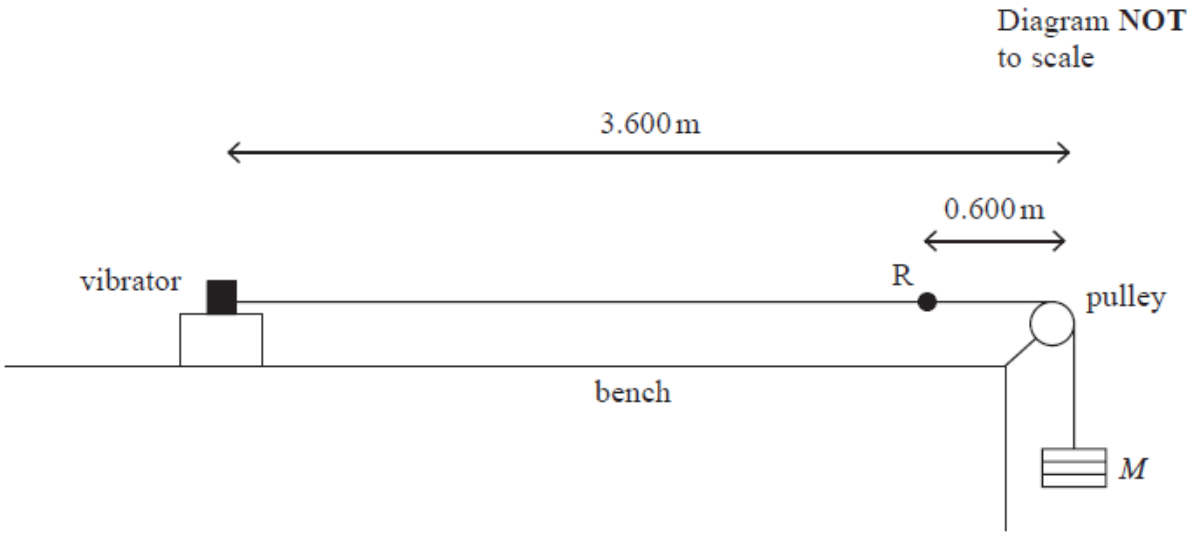
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(b) The frequency of the stationary wave was 30.0 Hz. The distance between the vibrator and the pulley was 3.600 m. Point R is 0.600 m from the pulley, as shown.



Determine whether there was a node at point R.

M = 0.300 kg

mass per unit length of string = 2.27×10^{-3} kg m^{-1}

(5)

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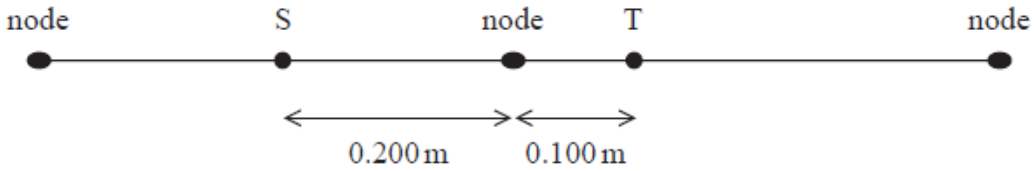
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(c) The mass *M* was changed and the frequency of the vibrator was adjusted, so that a different stationary wave formed on the string. Adjacent nodes were separated by 0.400 m. The diagram shows two points, S and T, on the string at an instant when the string was straight.



(i) Explain the phase relationship between points S and T.

(2)

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(ii) Explain how the amplitude of vibration of the string at point S compares with the amplitude of vibration of the string at point T.

(2)

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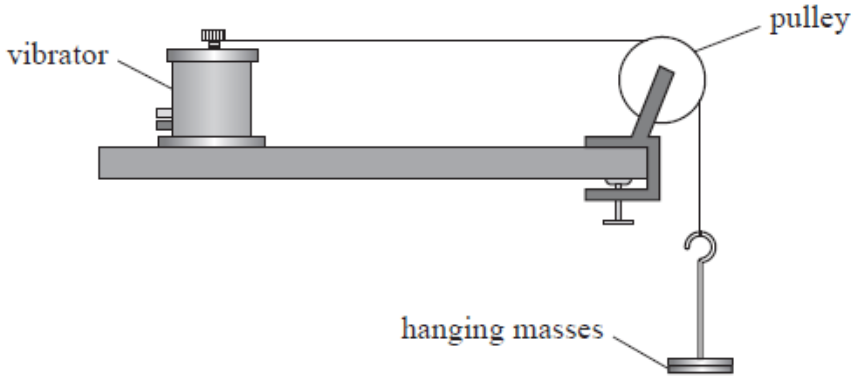
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(Total for question = 12 marks)

Q6.

A student investigated stationary waves on a string, using the apparatus shown.



The frequency *f* of the vibrator was adjusted until a stationary wave was formed with a node at each end. This was repeated for various stationary waves on the string. A metre rule was used to measure the distance *d* between adjacent nodes on the string.

(a) The resolution of the metre rule was 1 mm, but the measurements were recorded to the nearest 0.5 cm.

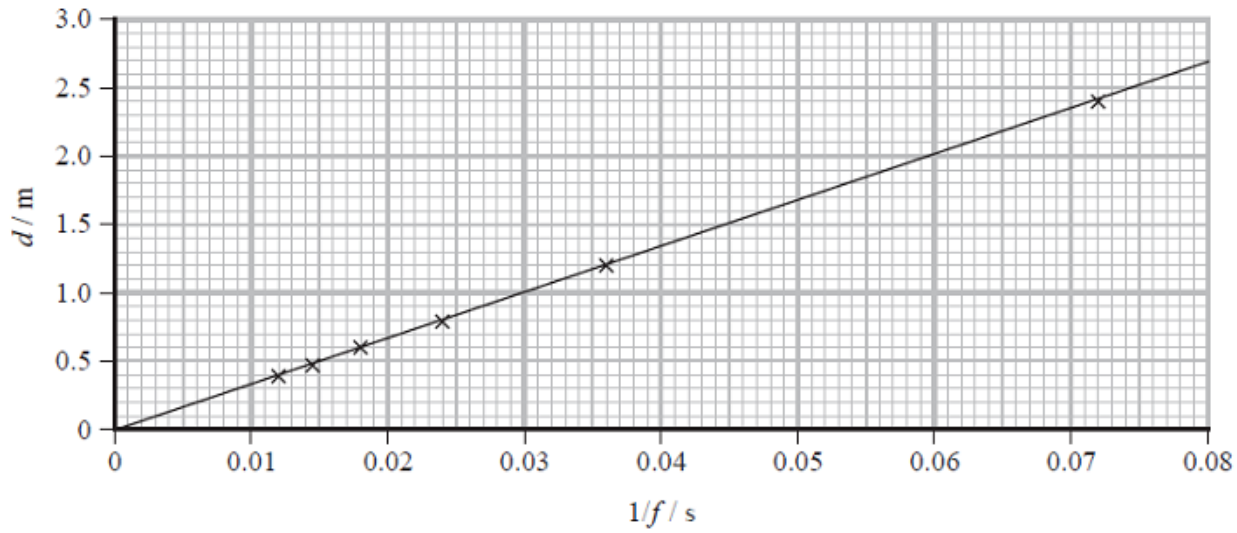
Suggest why.

(1)

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(b) The student plotted a graph of *d* against 1/*f* as shown.



(i) Determine the total mass of the hanging masses used in the investigation.

mass per unit length of string = 4.5×10^{-4} kg m^{-1}

(5)

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Total mass of hanging masses = ...

(ii) The string was replaced with one that had twice the mass per unit length.

The length of the string and the mass of the hanging masses did not change.

Add a line to the graph to show how *d* varied with 1/*f* for the new string.

(2)

(Total for question = 8 marks)

Q7.

The spectrum of light emitted by the star Chi Lupi provides evidence of mercury atoms in the outer layers of the star. The light emitted from the star is compared with light emitted from a mercury lamp on Earth.

(a) The lamp contains 1.65×10^{19} mercury atoms in a volume of 1.50×10^{-5} m^3. The pressure of the mercury vapour is 4.25×10^4 Pa.

Calculate the mean kinetic energy of the mercury atoms.

(3)

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Mean kinetic energy of mercury atoms = ...

(b) One line in the spectrum of light from Chi Lupi has a wavelength of 576.933 nm.

The equivalent line in a mercury spectrum produced on Earth is 576.959 nm.

A student concluded from this data that Chi Lupi is moving towards the Earth, and that the relative velocity of Chi Lupi is about 1400 m s^{-1}.

Deduce whether the student's conclusions are correct.

(4)

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(c) The surface temperature of Chi Lupi is twice the surface temperature of the Sun.

The radius of Chi Lupi is three times the radius of the Sun.

State where Chi Lupi would be located on the Hertzsprung-Russell diagram.

(1)

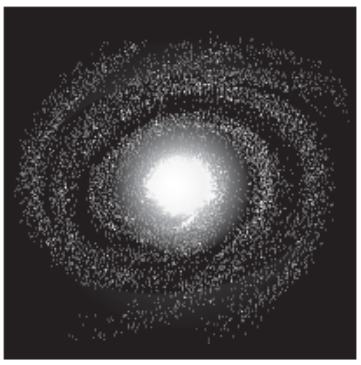
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(Total for question = 8 marks)

Q8.

The image shown is a representation of our galaxy, the Milky Way.



(Source: © daulon/Shutterstock)

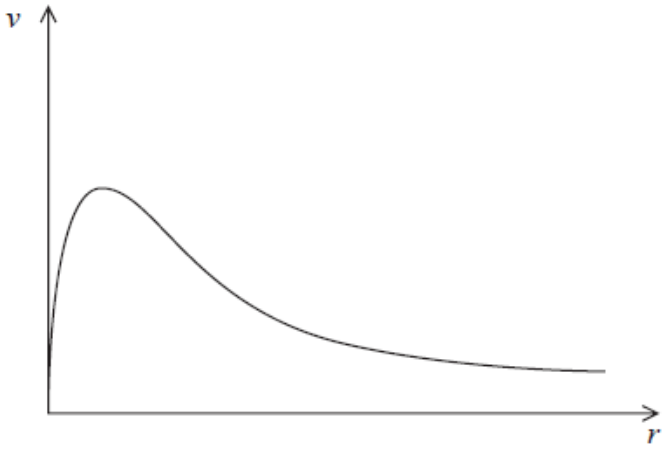
(a) Astronomers think that there is a very large concentration of stars in the central region of the galaxy. Outside this central region the concentration of stars is very much less. All stars in the galaxy are rotating about its centre.

It can be shown that the velocity v of a star a distance r from the centre of the galaxy is given by the expression

$$v = \sqrt{\frac{GM}{r}}$$

where M is the mass of the galaxy contained in a sphere of radius r.

(i) The graph shows how astronomers expect v to vary with r.



Explain how the expression gives the variation of v with r shown in the graph.

(3)

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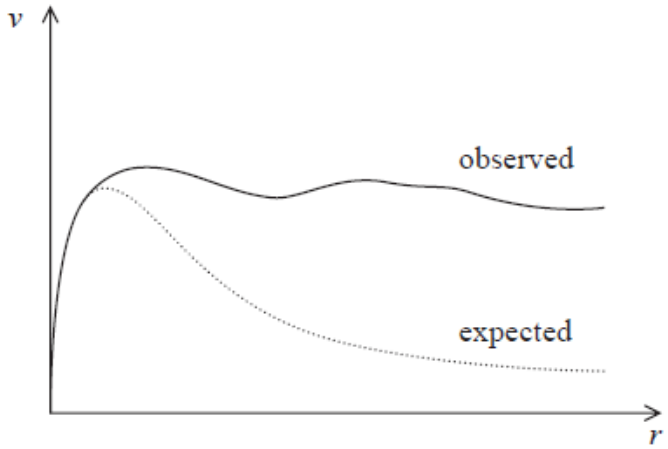
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(ii) The observed variation of v with r has been added to produce the graph below.



Suggest why the 'observed' velocity varies as shown.

(2)

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(b) The ultimate fate of the universe may be a closed universe, but astronomers cannot be sure what their current models predict.

Explain why astronomers cannot be sure that the universe is closed.

(2)

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(Total for question = 7 marks)

Q9.

The planets orbit the Sun in approximately circular orbits. The orbital time T of a planet is related to the average distance r of the planet from the Sun.

(a)(i) Show that T is related to r by the expression:

$$T^2 \propto r^3$$

(3)

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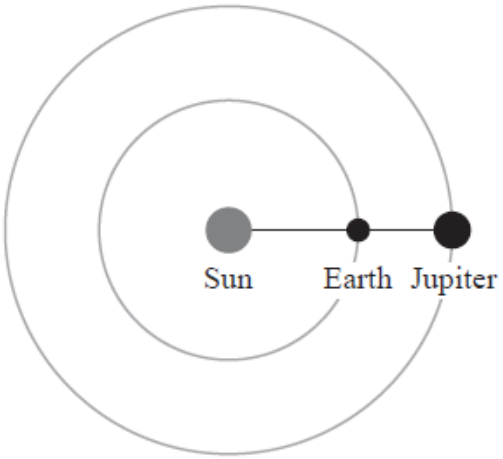
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(ii) When planets align as they orbit the Sun they are said to be 'in opposition'.

The diagram shows the Earth and Jupiter in opposition.



NOT TO SCALE

A website states that the Earth and Jupiter are in opposition every 13 months.

Deduce whether this statement is correct.

mean distance from Earth to Sun = 1.5×10^{11} m
mean distance from Jupiter to Sun = 7.8×10^{11} m
T_{Earth} = 12 months

(5)

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(b) The distance of Jupiter from the Sun varies from 7.4×10^{11} m to 8.2×10^{11} m.

Calculate the change in gravitational potential energy of Jupiter as it moves from its closest distance to its furthest distance from the Sun.

mass of Sun = 2.0×10^{30} kg
mass of Jupiter = 1.9×10^{27} kg

(3)

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Change in gravitational potential energy = ...

(Total for question = 11 marks)

Q10.

When an earthquake occurs, two types of wave travel through the Earth. The two types of wave are P-waves (longitudinal) and S-waves (transverse).

(a) The velocities of P-waves and S-waves as they travel through the Earth are related to the density ρ of the material they are travelling through.

The velocity v_p of P-waves and the velocity v_s of S-waves are given by the following equations:

$$v_p = \sqrt{\frac{K + \frac{4}{3}G}{\rho}} \qquad v_s = \sqrt{\frac{G}{\rho}}$$

where K and G are constants for a particular material below the Earth's surface.

(i) The density of one material is 2700 kg m^{-3}.

Calculate v_p and v_s in this material.

K = 7.55×10^{10} Pa

G = 2.61×10^{10} Pa

(4)

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v_p = ...

v_s = ...

(ii) The Earth contains layers of liquid. The value of G for liquids is 0.

Explain whether S-waves can travel through liquids.

(2)

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(b) During a single earthquake, S-waves can be produced by more than one source. If two coherent S-waves meet, interference can take place.

(i) Explain what is meant by coherent.

(2)

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(ii) A scientist created a model to predict the effect of two coherent S-waves at different distances from the source. The model predicted the amplitude of the S-waves at positions A and B shown on the diagram.



The amplitude of the waves at position A was zero. The amplitude of the waves at position B was greater than zero.

Explain why the amplitude of the waves at position A was zero.

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(Total for question = 11 marks)

Q11.

Ultraviolet light is incident on a zinc plate. If the photon energy is greater than the work function of the zinc, electrons are released.

(a) State what is meant by work function.

(1)

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(b) The ultraviolet (UV) section of the electromagnetic spectrum can be split into three parts, known as UVA, UVB and UVC. The range of wavelengths of these parts is given in the table.

	UVC	UVB	UVA
Range of wavelength / nm	200–280	280–320	320–400

The minimum de Broglie wavelength of the released electrons is 1.50×10^{-9} m.

Deduce whether the ultraviolet light incident upon the zinc plate is UVA, UVB or UVC.

work function of zinc = 4.30 eV

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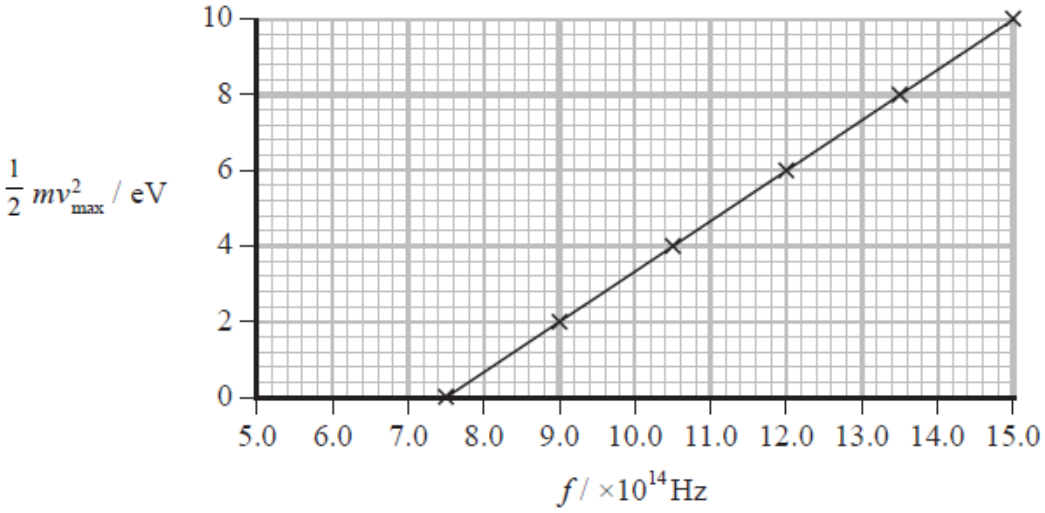
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(c) A student used a zinc plate and UV light of different frequencies in an experiment. The student's graph of maximum kinetic energy of the released electrons against the frequency of the incident UV light is shown.



Einstein's photoelectric equation applies to this situation.

$$hf = \phi + \frac{1}{2}mv^2_{max}$$

Describe **two** ways that the graph is not consistent with the values known for a zinc plate. Your answer should include calculations.

work function of zinc = 4.30 eV

(4)

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(Total for question = 11 marks)

Q12.

Wolf 359 is a red dwarf star. The distance of the star from Earth was first determined from parallax measurements made by the astronomer Max Wolf.

(a)(i) The parallax angle was 2.01×10^{-6} rad.

Calculate the distance, in metres, of Wolf 359 from Earth.

mean distance from Earth to Sun = 1.50×10^{11} m

(2)

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Distance of Wolf 359 from Earth = ... m

(ii) Explain why parallax measurements can only be used to determine the distances to a relatively small number of stars.

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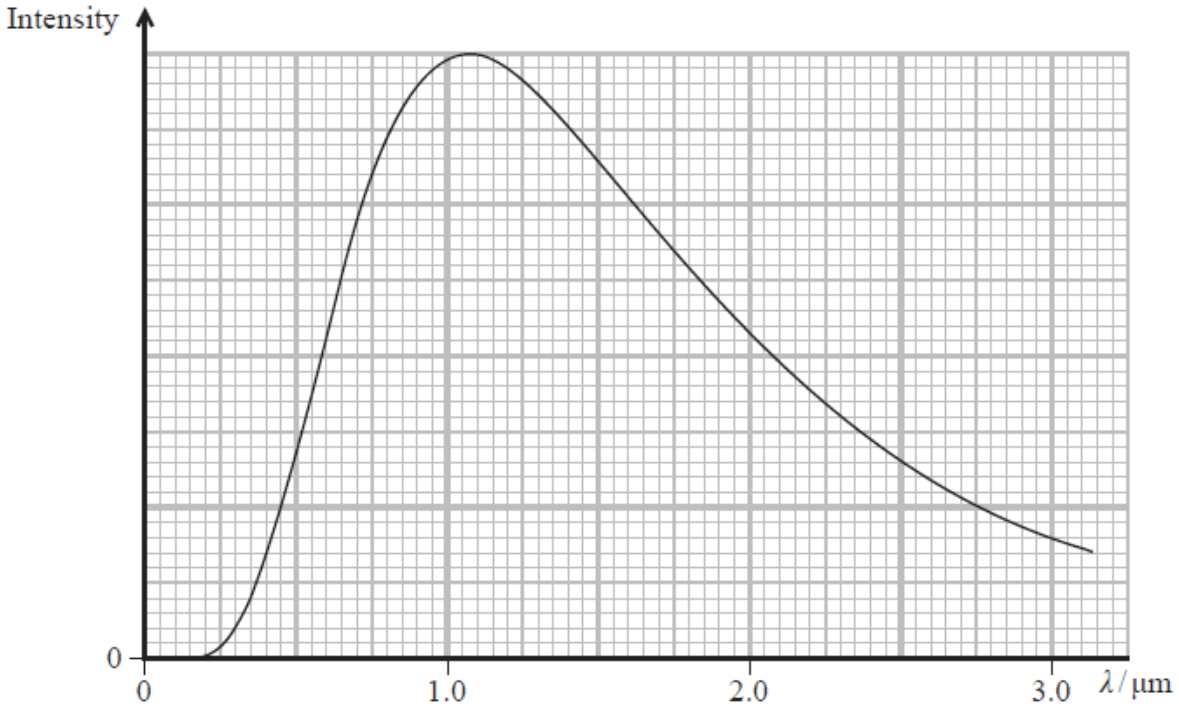
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(b) The graph shows how the intensity of radiation from the star Wolf 359 varies with wavelength.



(i) Show that the surface temperature of Wolf 359 is about 2700 K.

(3)

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(ii) The radius of the Sun is R_{Sun}. The radius of Wolf 359 is 0.16 R_{Sun}.

It is claimed that the luminosity of Wolf 359 is less than 0.1% of the luminosity of the Sun, L_{Sun}.

Deduce whether this claim is correct.

$R_{Sun} = 6.96 \times 10^8$ m
$L_{Sun} = 3.83 \times 10^{26}$ W
$T = 2700$ K

(3)

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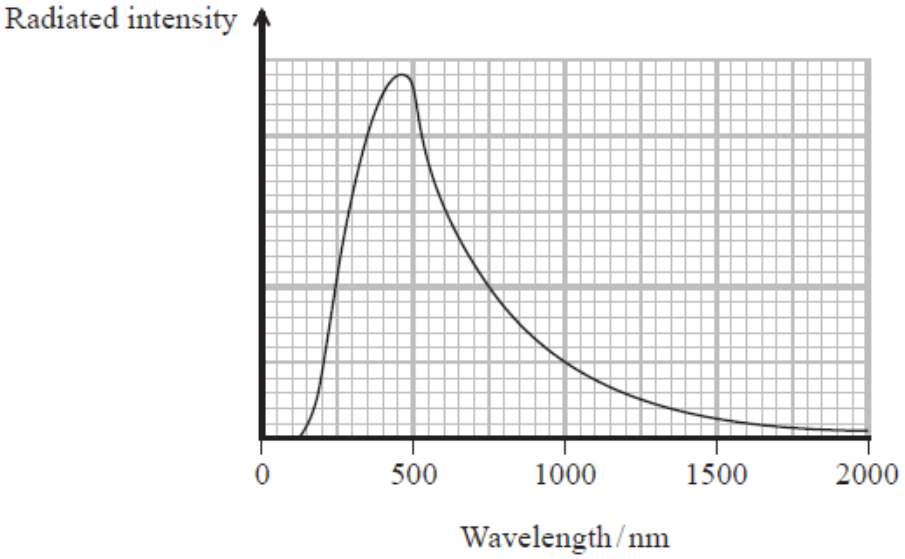
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(Total for question = 10 marks)

Q13.

Procyon is the brightest star in the constellation Canis Minor. The graph shows how the radiated intensity from Procyon varies with wavelength.



A website states that Procyon has twice the diameter of the Sun.

Assess the accuracy of this statement.

luminosity of Procyon = 2.65×10^{27} W
diameter of Sun = 6.96×10^{8} m

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(Total for question = 5 marks)

Q14.

A standard candle in the galaxy M81 has a luminosity 14 800 times the luminosity of the Sun. The intensity of radiation received from the standard candle, measured at the top of the Earth's atmosphere, is 3.64×10^{-17} W m^{-2}.

$L_{Sun} = 3.83 \times 10^{26}$W

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Distance of M81 from Earth = ...

(Total for question = 3 marks)

Q15.

Light is a transverse wave.

(a) Describe the difference between transverse waves and longitudinal waves.

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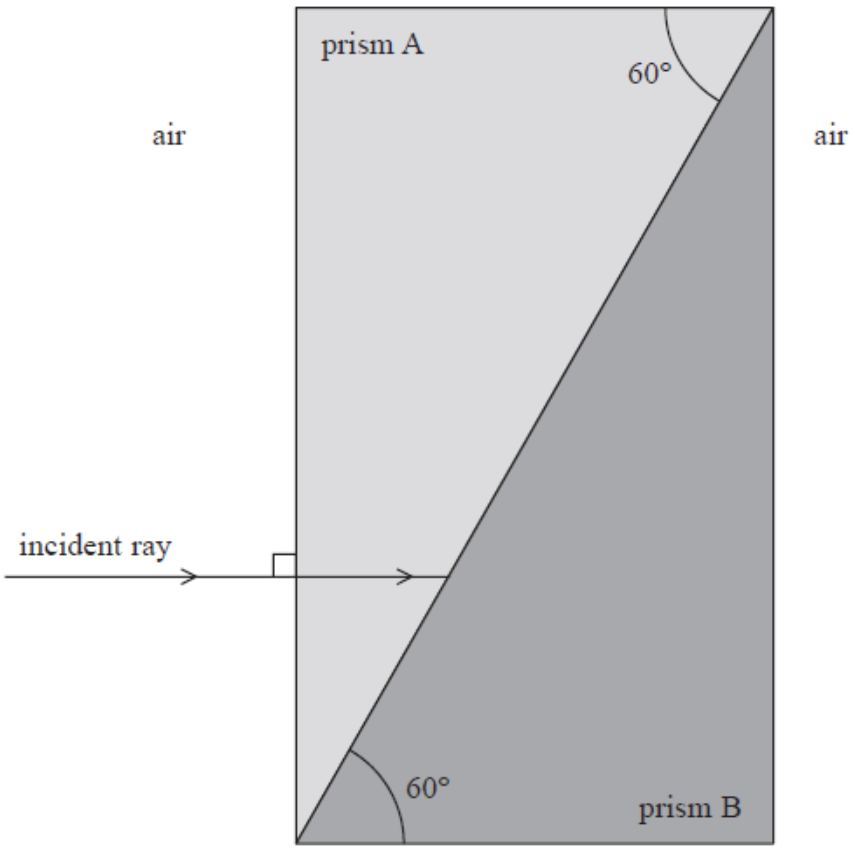
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(b) Two prisms, A and B, made from different types of glass are placed in contact as shown. An

incident ray of light enters prism A.



(i) State why the incident ray of light does not change direction as it enters prism A.

(1)

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(ii) The refractive index of the glass in prism B is greater than the refractive index of the glass in prism A. When the ray of light reaches the boundary between the prisms, some light is reflected and some is refracted.

Complete the diagram to show the two paths taken by the reflected and refracted light until they have returned to the air.

(4)

(iii) Calculate the angle of refraction as this ray of light travels across the boundary between prism A and prism B.

refractive index of glass in prism A = 1.40
refractive index of glass in prism B = 1.55

(3)

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Angle of refraction = ...

(c) The light emerging from prism B is observed through a polarising filter. The polarising filter is rotated gradually, and the light transmitted by the filter varies in intensity.

Explain how this observation demonstrates that light waves are transverse.

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(Total for question = 12 marks)

Q16.

* In the early 20th century, observations of the photoelectric effect demonstrated that light behaves as a particle.

Explain how observations from the photoelectric effect demonstrate the particle nature of light.

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(Total for question = 6 marks)

Q17.

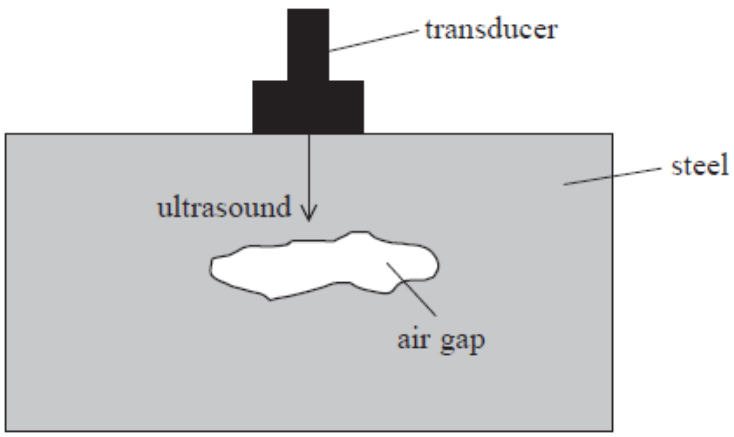
Rolled steel joists (RSJs) are used in the construction of buildings, as shown.



(Source: © Jon Kempner / Shutterstock)

The strength of an RSJ is greatly reduced if there are air gaps within the steel.
Ultrasound is used to detect any air gaps in the RSJ.

Pulses of ultrasound are sent by a transducer into an RSJ as shown. Any returning ultrasound is detected by the transducer.



(a) Explain how this arrangement can be used to show whether the RSJ contains an air gap.

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(b) Ultrasound is a sound wave with a frequency greater than 20 kHz. The frequency of ultrasound used by the transducer in this method is 5 MHz.

Explain why a much higher frequency than 20 kHz is needed in this method.

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(Total for question = 7 marks)

Q18.

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

In 1927, G P Thomson first demonstrated that electrons passing through a nickel crystal produce a diffraction pattern.

Which of the following can be concluded from this observation?

☒ **A** Electrons behave as particles.

☒ **B** Electrons behave as waves.

☒ **C** Electrons behave as both particles and waves.

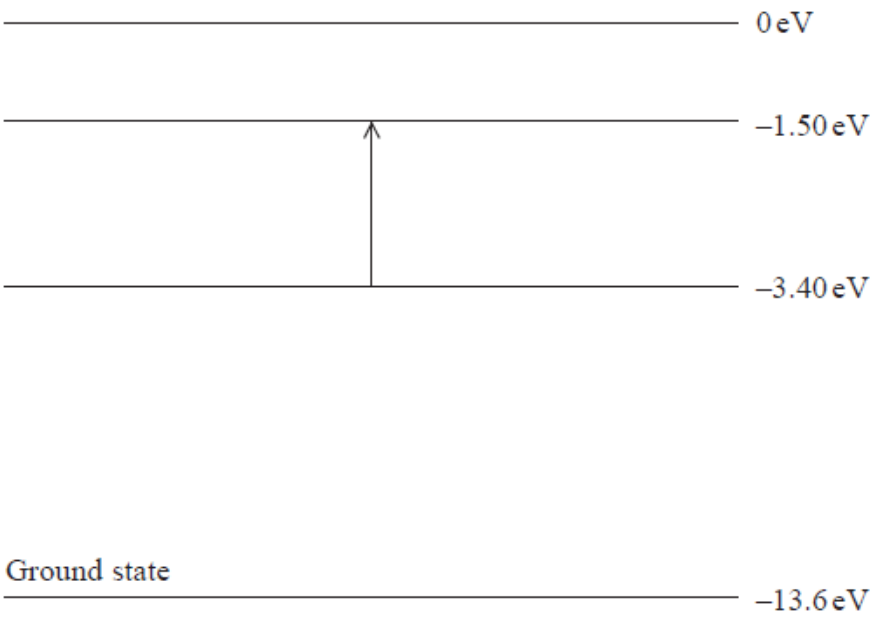
☒ **D** Electrons behave as neither particles nor waves.

(Total for question = 1 mark)

Q19.

Sirius A is the brightest star in the night sky and is mostly composed of hydrogen.

(a) When light from Sirius A passes through the hydrogen in the outer layers of the star, some light is absorbed. This causes electrons in the hydrogen to be excited. The diagram shows an electron being excited from the –3.40 eV level to the –1.50 eV level.



The wavelengths of the different colours of visible light are shown in the table below.

violet	blue	green	yellow	orange	red
380–450 nm	450–495 nm	495–570 nm	570–590 nm	590–620 nm	620–750 nm

Deduce the colour of the visible light that caused the electron transition shown in the diagram.

(4)

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(b) A light year is the distance travelled by light in one year.

Sirius A is 8.60 light years from Earth. The intensity of radiation from Sirius A received on Earth is 1.17×10^{-7} Wm^{-2}.

Calculate the power of Sirius A.

(4)

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Power of Sirius A = ...

(c) When hydrogen gas is excited in the laboratory, only certain wavelengths of light are emitted.

Explain why.

(2)

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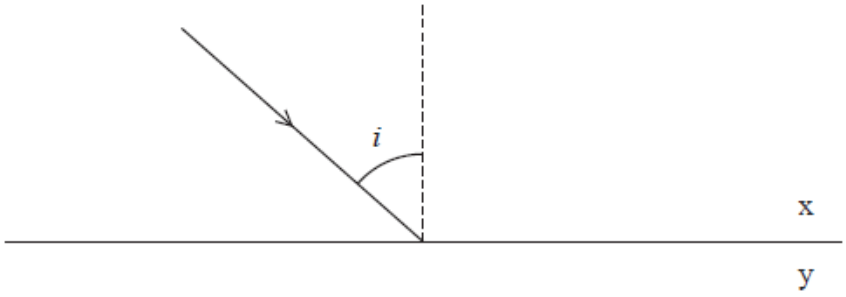
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(Total for question = 10 marks)

Q20.

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

A ray of light is incident on the boundary between two materials, x and y, as shown. The refractive index value for material x is n_x and for material y is n_y.



Which row of the table gives the conditions required for total internal reflection to take place at this boundary?

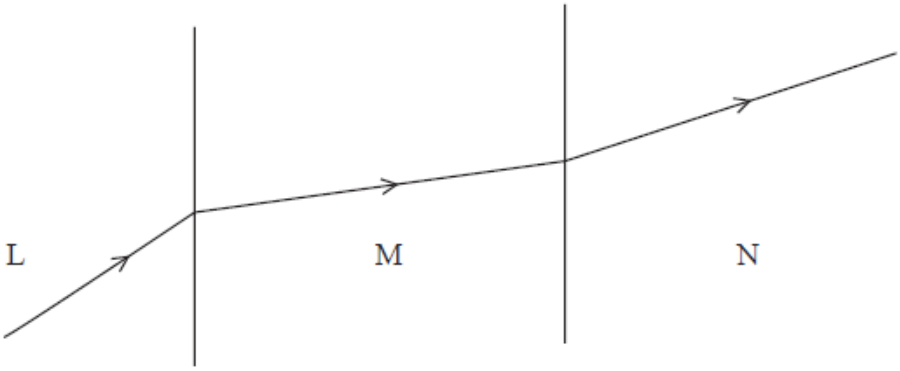
		Condition 1	Condition 2
☒	**A**	$i >$ critical angle	$n_x > n_y$
☒	**B**	$i >$ critical angle	$n_x < n_y$
☒	**C**	$i <$ critical angle	$n_x > n_y$
☒	**D**	$i <$ critical angle	$n_x < n_y$

(Total for question = 1 mark)

Q21.

Select one answer from A to D and put a cross in the box ☒. 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 shows refraction of a ray of light as it passes through three transparent substances, L, M and N. The speeds of light in the three substances are v_L, v_M and v_N, respectively.



Which of the following shows the relationship between v_L, v_M and v_N?

☒ **A** $v_L > v_M > v_N$

☒ **B** $v_L > v_N > v_M$

☒ **C** $v_N > v_M > v_L$

☒ **D** $v_M > v_N > v_L$

(Total for question = 1 mark)

Q22.

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

When the distance between the Sun and the planet Mercury is 4.60×10^{10} m, the intensity of solar radiation at the surface of Mercury is 1.45×10^{4} W m^{-2}.

Which of the following expressions gives the power of the Sun?

☒ **A** $(1.45 \times 10^4)\ (\pi)\ (4.60 \times 10^{10})^2$

☒ **B** $(1.45 \times 10^4)\ (4\pi)\ (4.60 \times 10^{10})^2$

☒ **C** $\dfrac{(1.45 \times 10^4)}{(\pi)(4.60 \times 10^{10})^2}$

☒ **D** $\dfrac{(1.45 \times 10^4)}{(4\pi)(4.60 \times 10^{10})^2}$

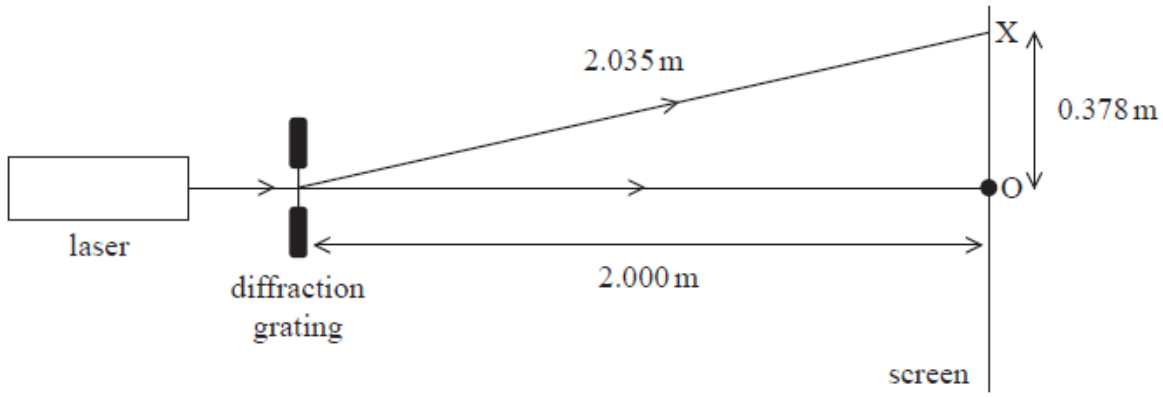
(Total for question = 1 mark)

Q23.

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

A laser, diffraction grating and screen are set up as shown. The position of the central maximum is O and the position of the first order maximum is X.

The diffraction grating has 300 lines per mm.



Which of the following expressions gives the wavelength of the laser light?

☒ **A** $(300\,000) \times \left(\frac{0.378}{2.000}\right)$

☒ **B** $(300\,000) \times \left(\frac{0.378}{2.035}\right)$

☒ **C** $\left(\frac{1}{300\,000}\right) \times \left(\frac{0.378}{2.000}\right)$

☒ **D** $\left(\frac{1}{300\,000}\right) \times \left(\frac{0.378}{2.035}\right)$

(Total for question = 1 mark)

Q24.

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 gravitational field strength at the surface of the Earth is g.

Another planet has the same density as the Earth, but twice the radius of the Earth.

What is the gravitational field strength at the surface of this planet?

☒ **A** $4g$

☒ **B** $2g$

☒ **C** $\frac{g}{2}$

☒ **D** $\frac{g}{4}$

(Total for question = 1 mark)

Q25.

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

A communications satellite has a mass of 935 kg. The satellite has an orbital radius four times the radius of the Earth.

☒ **A** 0 N

☒ **B** 570 N

☒ **C** 2300 N

☒ **D** 9200 N

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer		Mark
a	Calculates θ (using tan)	(1)	
	Calculates d using $\frac{1}{\text{number of lines per m}}$	(1)	
	Use of $n\lambda = d\sin\theta$	(1)	
	$\lambda = 6.3 \times 10^{-7}$ m	(1)	**4**
	Example of calculation $\tan\theta = \frac{0.500\text{ m}}{1.690\text{ m}}$, therefore $\theta = 16.5°$ $d = \frac{1}{450{,}000} = 2.22 \times 10^{-6}$ m. $\lambda = \frac{d\sin\theta}{n} = \frac{(2.22 \times 10^{-6}\text{m})(\sin 16.5°)}{(1)} = 6.31 \times 10^{-7}$ m		
b	(Waves from the different slits meet and) superposition/interference takes place	(1)	
	(Bright dots are where) waves are in phase	(1)	
	(Superposition/interference) is constructive	(1)	**3**
c	White dot at O	(1)	
	Spectra seen (either side of O)	(1)	**2**
	Total for question		**9**

Q2.

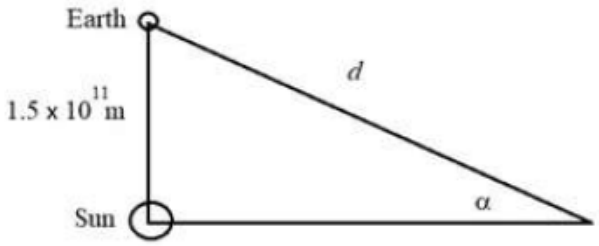
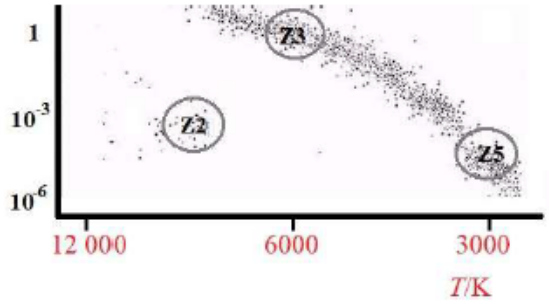
Question Number	Answer		Mark
(a)(i)	Use of $v = H_0 d$	(1)	
	$H_0 = 2.33 \times 10^{-1}$ (s^{-1})	(1)	2
	Example of calculation $H_0 = \frac{72 \times 10^3 \text{ m s}^{-1}}{3.09 \times 10^{22} \text{ m}} = 2.33 \times 10^{-18} \text{ s}^{-1}$		
(a)(ii)	Use of $t = \frac{1}{H_0}$	(1)	
	$t = 1.36 \times 10^{10}$ (years) ecf from (i)	(1)	2
	Example of calculation $t = \frac{1}{2.33 \times 10^{-1} \text{ s}^{-1}} = 4.29 \times 10^{17} \text{ s}$ $t = \frac{4.29 \times 10^{17} \text{ s}}{3.16 \times 10^7 \text{ s year}^{-1}} = 1.36 \times 10^{10} \text{ years}$		
(b)	H_0 is halved (for the same recessional velocity)	(1)	
	So the (calculated) age of the universe doubles (dependent upon MP1)	(1)	
	OR		
	The universe would have taken twice as long to expand to its current size (assuming it expanded at the same rate)	(1)	
	So the age of the universe is double what was previously thought (dependent upon MP1)	(1)	2
	Allow 1 mark max for H_0 is lower so universe is older than previously thought **Or** universe would have taken longer to expand to current size so it is older than previously thought.		
	Total for question		6

Q3.

Question Number	Answer		Mark
(a)	Use of $T^2 = KR^3$	(1)	
	K for Earth = 2.96×10^{-19} ($s^2\ m^{-3}$)	(1)	
	K for Mars = 2.97×10^{-1} ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation		
	$K = \frac{T^2}{R^3} = \frac{(3.16 \times 10^7 s)^2}{(1.50 \times 10^{11} m)^3} = 2.959 \times 10^{-19}\ s^2\ m^{-3}$		
	$K = \frac{T^2}{R^3} = \frac{(5.93 \times 10^7 s)^2}{(2.28 \times 10^{11} m)^3} = 2.967 \times 10^{-19}\ s^2\ m^{-3}$		
(b)	**Either**		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Re-arrangement with $v = \frac{2\pi r}{T}$ to identify K as $\frac{(2\pi)^2}{GM}$	(1)	
	$K = 2.97 \times 10^{-19}$ ($s^2\ m^{-3}$)	(1)	
	Or		
	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Re-arrangement with $\omega = \frac{2\pi}{T}$ to identify K as $\frac{(2\pi)^2}{GM}$	(1)	
	$K = 2.97 \times 10^{-19}$ ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation		
	$\frac{GMm}{r^2} = m\omega^2 r$		
	$\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$		
	$T^2 = \frac{(2\pi)^2}{GM} r^3$		
	$K = \left(\frac{4\pi^2}{6.67 \times 10^{-11}\ N\ m^2\ kg^{-2} \times 1.99 \times 10^{30}\ kg}\right) = 2.97 \times 10^{-1}\ s^2 m^{-3}$		

(c)	Use of $T^2 = KR^3$	(1)	
	T = 43 hours	(1)	**2**
	Example of calculation		
	$\left(\frac{T_I}{T_G}\right)^2 = \left(\frac{R_I}{R_G}\right)^3$		
	$T = \sqrt{\left(\frac{4.22 \times 10^8\ m}{1.07 \times 10^9\ m}\right)^3 \times (172\ hour)^2} = 42.6$ hours		
	Total for question		**8**

Q4.

Question Number	Answer		Mark
(a)	Use of trigonometry to calculate the parallax angle **Or** Use of trigonometry to calculate distance	(1)	
	(Smallest) parallax angle = 3.3×10^{-7} (rad) **Or** max distance = 6.25×10^{17} (m)	(1)	
	Comparison of calculated value with corresponding value in question with valid conclusion	(1)	3
	Example of calculation $\sin\alpha = \dfrac{1.5 \times 10^{11}\ \text{m}}{d}$ $\alpha = \sin^{-1}\left(\dfrac{1.5 \times 10^{11}\ \text{m}}{4.6 \times 10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad **Or** $\alpha = \left(\dfrac{1.5\times10^{11}\ \text{m}}{4.6\times10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad (small angle approximation)		
			
(b)	The intensity (of radiation from the candle) is measured	(1)	
	The luminosity of the standard candle is known	(1)	
	The inverse square law is used to determine the distance [Accept reference to $I=L/4\pi d^2$ with symbols defined]	(1)	3
(c)(i)	Axis labelled with T / K	(1)	
	Reverse logarithmic scale	(1)	
	6000 K in correct position on scale	(1)	3
	Example of graph labelling 		
(c)(ii)			

Description	Zone		
High mass hot stars	Z1	(1)	
Low mass cool stars	Z5	(1)	
Low mass hot stars	Z2	(1)	3

(c)(iii)

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 structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content

IC1 The star is fusing hydrogen in its core

IC2 When fusion ceases (the core of the star cools and) the core collapses/contracts (under gravitational forces)

IC3 The star (moves to Z4 as it expands and) becomes a red giant star

IC4 Temperature (in the core) is high enough for helium fusion to begin

IC5 Helium begins to run out and then fusion ceases

IC6 The star becomes a white dwarf (in Z2)

6

Total for question **18**

Q5.

Question Number	Answer		Mark
a	Wave reflected at the pulley Superposition/interference (takes place)	(1) (1) (1)	3
b	Use of $W = mg$ Use of $v = \sqrt{(T/\mu)}$ Use of $v = f\lambda$ to find λ $\lambda = 1.2$ (m) node to node distance = $\lambda/2$, so there is a node at R **Or** See $\lambda/2 = 0.6$m, so there is a node at R (MP4 requires evidence of calculation) Example of calculation Tension in string = $W = mg = (0.300\text{ kg})\ (9.81\text{ N kg}^{-1}) = 2.94$N $v = \sqrt{(T/\mu)} = \sqrt{\frac{2.94\text{ N}}{2.27 \times 10^{-3}\text{ kg m}^{-1}}} = 36.0\text{ m s}^{-1}$ $\lambda = \frac{v}{f} = \frac{(36.0\text{ m s}^{-1})}{(30\text{ Hz})} = 1.20\text{ m}$ node to node distance = $\lambda/2$, so node to node distance = 0.60 m.	(1) (1) (1) (1) (1)	5
ci	S and T are in antiphase **Or** 180° out of phase **Or** π radians out of phase S and T are in adjacent node-to-node regions **Or** S and T are in adjacent loops	(1) (1)	2
cii	S has a greater amplitude than T S is at an antinode **and** T is between a node and antinode **Or** S is at an antinode **and** T is not **Or** T is closer to a node than S (MP2 dependent on MP1)	(1) (1)	2
	Total for question		**12**

Q6.

Question Number	Answer		Mark
a	Difficult to judge/measure the exact position of node **Or** Ruler is not close to the string (so there might be parallax error)	(1)	1
bi	Calculates gradient by best fit or plotted points from graph	(1)	
	Recognises distance between adjacent nodes = $\lambda/2$ **Or** Recognises that speed of waves on the string = 2 × gradient	(1)	
	Use of $v = \sqrt{\frac{T}{\mu}}$ to find T	(1)	
	Use of $T = mg$ with $g = 9.81$ Nkg^{-1} (accept $W = mg$)	(1)	
	m = 0.21 kg	(1)	5
	Example of calculation Gradient = $\frac{2.7\ m}{0.080\ s} = 33.75$ ms^{-1} Speed = 2 × gradient = 67.5 ms^{-1} v = $\sqrt{T/\mu}$, 67.5 m s^{-1} = $\sqrt{\frac{T}{4.5 \times 10^{-4}\ \text{kg m}^{-1}}}$ $T = 2.05$ N m = $\frac{W}{g} = \frac{T}{g} = \frac{2.05\text{N}}{9.81\ \text{Nkg}^{-1}} = 0.209$ kg		
bii	Straight line with shallower gradient drawn, starting from origin	(1)	
	Line has a gradient of around 0.7 × line drawn	(1)	2
	(Graph line if continued to the last value for $1/f$ should be between 1.8 and 2.0m for d).		
	Total for question		8

Q7.

Question Number	Answer		Mark
(a)	Use of $pV = NkT$	(1)	3
	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	(1)	
	$\frac{1}{2}m\langle c^2\rangle = 5.8 \times 10^{-20}$ J	(1)	
	Example of calculation $T = \frac{pV}{Nk} = \frac{4.25\times10^{4}\text{ Pa}\times1.50\times10^{-5}\text{ m}^3}{1.65\times10^{19}\times1.38\times10^{-23}\text{ J K}^{-1}} = 2800$ K $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}\times 1.38\times10^{-23}\text{ J K}^{-1}\times 2800\text{ K} = 5.80\times10^{-20}$ J		
(b)	Use of $\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ with wavelength measured on Earth in denominator	(1)	4
	v = 13500 m s^{-1}	(1)	
	The student is correct to say that the star is moving towards the Earth, as the measured wavelength is less than that from the lamp spectrum.	(1)	
	Comparison of calculated velocity with 1400 m s^{-1} and appropriate conclusion.	(1)	
	Example of calculation $v = \frac{\Delta\lambda}{\lambda}c = \frac{(576.933\text{-}576.959)\times10^{-9}\text{m}}{576.959\times10^{-9}\text{ m}}\times3.00\times10^{8}\text{ m s}^{-1} = (-)1.35\times10^{4}\text{ m s}^{-1}$ So the star's velocity is much larger than 1400 m s^{-1}		
(c)	On the main sequence, above the position of the Sun **Or** above and to the left of the position of the Sun	(1)	1
	Total for question		8

Q8.

Question Number	Answer		Mark
(a)(i)	$v \propto \sqrt{\frac{M}{r}}$	(1)	
	Within the central region M changes a lot (so v increases) **Or** Outside the central region M is approximately constant (so v decreases)		
	As r increases v reaches a peak value as shown on the graph	(1)	
	[A bald description of the graph having a peak value can score MP3]	(1)	**3**
(a)(ii)	There must be more mass (than we can observe)	(1)	
	[Accept statement that there must be a greater gravitational force]		
	There is dark matter present (in the galaxy)	(1)	**2**
(b)	(For a closed universe) the density of the universe must be greater than the critical density	(1)	
	And the (average) density of the universe is uncertain **Or** the amount of dark matter is uncertain	(1)	**2**
	Total for question		7

Q9.

Question Number	Answer		Mark
(a)(i)	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Re-arrangement with $\omega = \frac{2\pi}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$	(1)	
	Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2)	(1)	
	OR		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Re-arrangement with $v = \frac{2\pi r}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$	(1)	
	Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2)	(1)	3
	Example of calculation		
	$\frac{GMm}{r^2} = m\omega^2 r$		
	$\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$		
	$T^2 = \frac{(2\pi)^2}{GM} r^3$		
	$\therefore T^2 \propto r^3$		

(a)(ii)	Use of $T^2 \propto r^3$	(1)	
	T_J = 142 months (11.9 years)	(1)	
	Use of $\omega = \frac{\theta}{t}$ and $\omega = \frac{2\pi}{T}$	(1)	
	Calculation of time elapsed for planets to be in opposition	(1)	
	Time between opposition is 13.1 months, with an appropriate conclusion (dependent upon MP4)	(1)	5
	Example of calculation		
	$\left(\frac{T_J}{T_E}\right)^2 = \left(\frac{r_J}{r_E}\right)^3$		
	$\left(\frac{T_J}{1\text{ year}}\right)^2 = \left(\frac{7.8 \times 10^{11}\text{ m}}{1.5 \times 10^{11}\text{ m}}\right)^3$		
	$T_J = 12\text{ months} \times \sqrt{\left(\frac{7.8 \times 10^{11}\text{ m}}{1.5 \times 10^{11}\text{ m}}\right)^3} = 142\text{ months}$		
	At the next opposition Earth will have done one more orbit than Jupiter plus whatever fraction of an orbit Jupiter has completed.		
	If t is the time to next opposition, both planets will have the same angular displacement, so equating $\theta = 2\pi\, t/T$ for both planets where for Earth the time is $(t - 12)$.		
	$\frac{2\pi\text{ rad }(t-12)\text{ month}}{12\text{ month}} = \frac{2\pi\text{ rad }t}{142\text{ month}} \therefore t = 13.1\text{ month}$		

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(b)	Use of $V = (-)\frac{GM}{r}$	(1)	
	Use of $\Delta V \times m$	(1)	
	$\Delta E_{grav} = 3.3 \times 10^{34}$ J	(1)	**3**
	<u>Example of calculation</u> $\Delta V = -GM\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$ $\Delta V = -6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 2.0 \times 10^{30}\text{kg} \times \left(\frac{1}{8.2 \times 10^{11}\ \text{m}} - \frac{1}{7.4 \times 10^{11}\ \text{m}}\right)$ $\Delta V = 1.76 \times 10^{7}\ \text{J kg}^{-1}$ $\therefore \Delta E_{grav} = 1.76 \times 10^{7}\ \text{J kg}^{-1} \times 1.9 \times 10^{27}\ \text{kg} = 3.34 \times 10^{34}$ J		
	Total for question		**11**

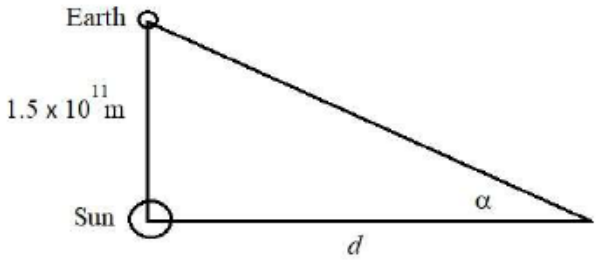
Q10.

Question Number	Answer		Mark
ai	Use of $v_p = \sqrt{\frac{K+\frac{4}{3}G}{\rho}}$	(1)	
	Use of $v_s = \sqrt{\frac{G}{\rho}}$	(1)	
	$v_p = 6400\ \text{m s}^{-1}$	(1)	
	$v_s = 3100\ \text{m s}^{-1}$ (Only one unit error applied across both answers)	(1)	**4**
	Example of calculation $v_p = \sqrt{\frac{K+\frac{4}{3}G}{\rho}} = \sqrt{\frac{(7.55\times10^{10}\text{Pa})+\frac{4}{3}(2.61\times10^{10}\text{Pa})}{(2700\ \text{kgm}^{-3})}} = 6392\ \text{m s}^{-1}$ $v_s = \sqrt{\frac{G}{\rho}} = \sqrt{\frac{(2.61\times10^{10}\text{Pa})}{(2700\ \text{kgm}^{-3})}} = 3109\ \text{m s}^{-1}$		
aii	(When $G = 0$), $v_s = 0\ (\text{m s}^{-1})$	(1)	
	S-waves cannot travel through liquids	(1)	**2**
	(MP2 dependent on MP1 being awarded)		
bi	Same frequency	(1)	
	Constant phase difference/relationship	(1)	**2**
bii	There is a path difference (for waves travelling from the two sources to A)	(1)	
	This causes a phase difference of π radians / 180° (at A) **Or** waves are in antiphase (at A)	(1)	
	Destructive interference/superposition (at A)	(1)	**3**
	Total for question		**11**

Q11.

Question Number	Answer		Mark
a	Minimum energy (required to release electrons from the surface of a metal)	(1)	1
b	Use of $\lambda = h/p$ with $\lambda = 1.50 \times 10^{-9}$ m	(1)	
	Use of $p = mv$ with $m = 9.11 \times 10^{-31}$ kg	(1)	
	Converts work function from eV into J	(1)	
	Use of $hf = \Phi + \frac{1}{2}mv^2_{max}$ to find hf	(1)	
	Use of $E = hf$ **and** $v = f\lambda$ to find λ	(1)	
	$\lambda = 250$ nm, so UVC	(1)	6
	Example of calculation $\lambda = h/p$ so $p = h/\lambda = \frac{(6.63 \times 10^{-34}\ \text{Js})}{(1.50 \times 10^{-9}\ \text{m})} = 4.42 \times 10^{-25}\ \text{kg m s}^{-1}$ so $v = \frac{p}{m} = \frac{(4.42 \times 10^{-25}\ \text{kg m s}^{-1})}{(9.11 \times 10^{-31}\ \text{kg})} = 4.85 \times 10^{5}\ \text{ms}^{-1}$ KE $= \frac{1}{2}mv^2 = \frac{1}{2}(9.11 \times 10^{-31}\ \text{kg})(4.85 \times 10^{5}\ \text{ms}^{-1})^2 = 1.07 \times 10^{-19}$ J $\Phi = (4.30\ \text{eV})(1.60 \times 10^{-19}\ \text{J eV}^{-1}) = 6.88 \times 10^{-19}$ J $E = hf = \Phi + \frac{1}{2}mv^2_{max} = 6.88 \times 10^{-19}\ \text{J} + 1.07 \times 10^{-19}\ \text{J} = 7.95 \times 10^{-19}$ J $f = \frac{E}{h} = \frac{(7.95 \times 10^{-19}\ \text{J})}{(6.63 \times 10^{-34}\ \text{Js})} = 1.20 \times 10^{15}$ Hz $\lambda = \frac{v}{f} = \frac{(3.00 \times 10^{8}\ \text{ms}^{-1})}{(1.20 \times 10^{15}\ \text{Hz})} = 2.50 \times 10^{-7}$ m (250nm) UVC		
c	**MAX 2 for work function** y-intercept of graph should be (negative) work function y-intercept is approximately (-) 10.0 eV (so cannot be zinc) **Or MAX 2 for threshold frequency** Threshold frequency is the x-intercept / 7.5×10^{14} Hz threshold frequency should be 1.0×10^{15} Hz, (so cannot be zinc) **Or MAX 2 for Planck constant** Gradient of graph should be the Planck constant (allow "gradient = h") Calculates that gradient of the graph is approx. 2.1×10^{-33} (Js) (so not correct) (Alternative for work function pair of marks: hf_0 should be the work function **Or** calculate work function from hf_0(1) hf_0 from graph = 3.1eV (so cannot be zinc) (1))	(1) (1) (1) (1) (1) (1)	4
	Total for question		11

Q12.

Question Number	Answer		Mark
(a)(i)	Use of trigonometry to calculate distance **Or** use of small angle approximation to calculate distance	(1)	
	Distance to Wolf 359 = 7.5×10^{16} (m)	(1)	**2**
	Example of calculation  $\tan(2.01 \times 10^{-6}) = \frac{1.50 \times 10^{11}\ \text{m}}{d}$ $\therefore d = \frac{1.50 \times 10^{11}\ \text{m}}{2.01 \times 10^{-6}} = 7.46 \times 10^{16}\ \text{m}$		
(a)(ii)	Parallax angle decreases as distance from the Earth increases **Or** parallax is only suitable for (relatively) close stars	(1)	
	As parallax angle is too small to measure for distant stars	(1)	**2**
(b)(i)	λ_{max} read from graph	(1)	
	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	(1)	
	$T = 2680$ (K) [accept 2635 K → 2760 K]	(1)	**3**
	Example of calculation $T = \frac{2.898 \times 10^{-3}\ \text{m K}}{1.08 \times 10^{-6}\ \text{m}} = 2683\ \text{K}$		
(b)(ii)	Use of $L = \sigma AT^4$	(1)	
	$L = 4.70 \times 10^{23}$ W (allow ecf from (b)(i))	(1)	
	Comparison of calculated value of L with L_{Sun} and appropriate conclusion **Or** comparison of calculated L/L_{Sun} percentage with 0.1% and appropriate conclusion	(1)	**3**
	Example of calculation $L = 4\pi\,(0.16 \times 6.96 \times 10^8\ \text{m})^2 \times 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}\ (2700\ \text{K})^4$ $L = 4.70 \times 10^{23}\ W$ $\frac{L}{L_{Sun}} \times 100\% = \frac{4.70 \times 10^{23}\ W}{3.83 \times 10^{26}\ W} \times 100\% = 0.12\%$		
	Total for question		**10**

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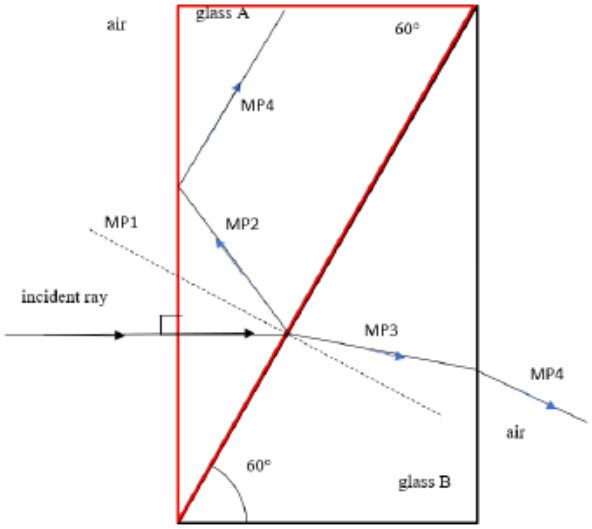
Q13.

Question Number	Answer		Mark
	λ_{max} read from graph [450 nm → 500 nm]	(1)	
	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	(1)	
	Use of $L = \sigma A T^4$	(1)	
	Use of $A = 4\pi r^2$	(1)	
	$D_P = 4.6 \times D_{Sun}$ so statement is incorrect Or $D_P = 3.2 \times 10^9$ m, which is more than twice Sun's diameter, so statement is incorrect	(1)	5
	Example of calculation $T = \frac{2.898 \times 10^{-3}\ \text{m K}}{470 \times 10^{-9}\ \text{nm}} = 6170\ \text{K}$ $A = \frac{2.65 \times 10^{27}\ \text{W}}{5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^4 \times (6170\ \text{K})^4} = 3.22 \times 10^{19}\ \text{m}^2$ $r = \sqrt{\frac{3.22 \times 10^{19}\ \text{m}^2}{4\pi}} = 1.60 \times 10^9\ \text{m}$ $\frac{D_P}{D_{Sun}} = \frac{2 \times 1.60 \times 10^9\ \text{m}}{6.96 \times 10^8\ \text{m}} = 4.6$		
	Total for question		**5**

Q14.

Question Number	Answer		Mark
	Use of $L = 14800\ L_{Sun}$	(1)	
	Use of $I = \frac{L}{4\pi d^2}$	(1)	
	$d = 1.1 \times 10^{23}$ m	(1)	3
	Example of calculation $L_{candle} = 14\,800 \times 3.83 \times 10^{26}\ \text{W} = 5.67 \times 10^{30}\ \text{W}$ $d = \sqrt{\frac{L}{4\pi I}} = \sqrt{\frac{5.67 \times 10^{30}\text{W}}{4\pi \times 3.64 \times 10^{-17}\text{W m}^{-2}}} = 1.11 \times 10^{23}\ \text{m}$		
	Total for question		**3**

Q15.

Question Number	Answer	Mark
a	Transverse: vibrations/oscillations are perpendicular to the direction of (wave) travel (1) Longitudinal: vibrations/oscillations are parallel to the direction of (wave) travel (1)	2
bi	The light is (incident on the boundary) along the normal **Or** The angle of incidence is 0° **Or** The light hits (prism A) at right angles (1)	1
bii	Normal line correctly drawn at right angles to boundary (by eye) (1) Reflected ray in correct direction from boundary (by eye) (1) Refracted ray in correct direction from boundary (by eye) (1) Correct refraction at the right hand side of the glass block (by eye) **and** either TIR or correct direction refraction at the left hand side (by eye) (1)  	4

biii	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) with 30°, 1.40 and 1.55 substituted correctly (1) Angle of refraction = 27° (1) <u>Example of calculation</u> $n_1 \sin \theta_1 = n_2 \sin \theta_2$, so 1.40 (sin 30°) = 1.55 (sin r), r = 26.8°	3
c	Light (emerging) is polarised (1) Only transverse waves can be polarised (1)	2
	Total for question	12

Q16.

Question Number	Answer	Mark
*	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.	

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content

- Photon energy is related to frequency
- One to one interaction between photons and electrons
- A minimum energy/frequency is required (for electron release)
- Release of electrons is instantaneous
- Frequency affects the kinetic energy of the (released) electrons
- Intensity affects the number of electrons (per second)

6

	Total for question	**6**

Q17.

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Question Number	Answer		Mark
a	**Either**		
	Ultrasound is (partially) reflected (from boundaries)	(1)	
	(Measure) the time taken or time delay (for signal to return)	(1)	
	Calculate expected time for pulse to return (if no air gap) **Or** Compare to known time for pulse to return	(1)	
	If time for pulse to return < time calculated, air gap is present	(1)	
	Or		
	Ultrasound is (partially) reflected (from boundaries)	(1)	
	(Measure) the time taken or time delay (for signal to return)	(1)	
	Calculate distance for pulse to travel	(1)	
	If distance pulse returns from < thickness of RSJ, air gap is present **Or** If distance pulse returns from = thickness of RSJ, no air gap	(1)	**4**
b	(Higher frequency) gives smaller wavelength	(1)	
	(Smaller wavelength leads to) high level of detail/resolution	(1)	
	(Smaller wavelength) can detect small(er) objects/gaps **Or** (With 20kHz) the detail would not be sufficient to identify air gaps **Or** (With 20kHz,) air gaps might be smaller than the wavelength	(1)	**3**
	Total for question		7

Q18.

Question Number	Answer	Mark
	B is the correct answer as diffraction is a wave property A is not the correct answer as diffraction is not a particle property. C is not the correct answer as diffraction is not a particle property. D is not the correct answer as diffraction is a wave property.	**(1)**

Q19.

Question Number	Answer		Mark
a	Conversion of eV into J Use of $E = hf$ Use of $v = f\lambda$ with $v = 3.00 \times 10^8\ \text{ms}^{-1}$ $\lambda = 654$ (nm), so light (for this transition) is red Example of calculation $1.9\ \text{eV} \times (1.60 \times 10^{-19}\ \text{JeV}^{-1}) = 3.04 \times 10^{-19}\ \text{J}$ $f = \frac{E}{h} = \frac{3.04 \times 10^{-19}\ \text{J}}{6.63 \times 10^{-34}\text{Js}} = 4.59 \times 10^{14}\ \text{Hz}$ $\lambda = \frac{v}{f} = \frac{3.00 \times 10^8\ \text{ms}^{-1}}{4.59 \times 10^{14}\ \text{Hz}} = 6.54 \times 10^{-7}\ \text{m}$	(1) (1) (1) (1)	4
b	Converts 8.60 light years into metres Use of $I = P/A$ Use of $A = 4\pi r^2$ Power of Sirius A $= 9.73 \times 10^{27}$ W Example of calculation $8.60 \times 365 \times 24 \times 60 \times 60 \times (3.00 \times 10^8\ \text{ms}^{-1}) = 8.14 \times 10^{16}\ \text{m}$ $P = I \times A = (1.17 \times 10^{-7}\ \text{Wm}^{-2})\ (4\pi)\ (8.14 \times 10^{16}\ \text{m})^2 = 9.73 \times 10^{27}\ \text{W}$	(1) (1) (1) (1)	4
c	Atoms have fixed/certain/discrete energy levels **Or** Emitted photons have discrete energy Only certain transitions are possible (in a hydrogen atom) **Or** Some transitions are not possible (in a hydrogen atom) (For MP2, allow "differences in energy (levels)" for "transitions")	(1) (1)	2
	Total for question		10

Q20.

Question Number	Answer	Mark
	A is the correct answer as, for total internal reflection to take place, the angle of incidence should be greater than the critical angle, when travelling from a substance with a higher refractive index towards a substance with a lower refractive index. B is not the correct answer as total internal reflection cannot take place if the light travels towards a boundary beyond which the refractive index increases. C is not the correct answer as total internal reflection cannot take place if the angle of incidence is less than the critical angle. D is not the correct answer as total internal reflection cannot take place if the angle of incidence is less than the critical angle.	**(1)**

Q21.

Question Number	Answer	Mark
	B is the correct answer as the light bends towards the normal when travelling from L to M (so $v_L > v_M$) but bends away from the normal when travelling from M to N, but there is not as much of a change of direction as there was from L to M. A is not the correct answer as light bends away from the normal travelling from M to N so v_N must be greater than v_M C is not the correct answer as light bends towards the normal travelling from L to M so v_L must be greater than v_M D is not the correct answer as light bends away from the normal travelling from M to N, so v_N must be greater than v_M	**(1)**

Q22.

Question Number	Answer	Mark
	B is the correct answer as Power = Intensity × Area where area = $4\pi r^2$. A is not the correct answer as the area in this equation is not πr^2. C is not the correct answer as Power is not Intensity/Area D is not the correct answer as Power is not Intensity/Area	**(1)**

Q23.

Question Number	Answer	Mark
	D is the correct answer as, for a first order maximum, $\lambda = d \sin\theta$, where d is $\frac{1}{\text{number of lines per m}}$ and $\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$ or $\frac{(0.378)}{(2.035)}$ A is not the correct answer as the distance between adjacent slits is not 300,000m. B is not the correct answer as the distance between adjacent slits is not 300,000m. C is not the correct answer as $\sin\theta$ is not $\frac{(0.378)}{(2.000)}$	**(1)**

Q24.

Question Number	Answer	Mark
	B is the correct answer, as $g = \frac{GM}{r^2}$ and $M = \frac{4}{3}\pi\rho r^3$	**(1)**

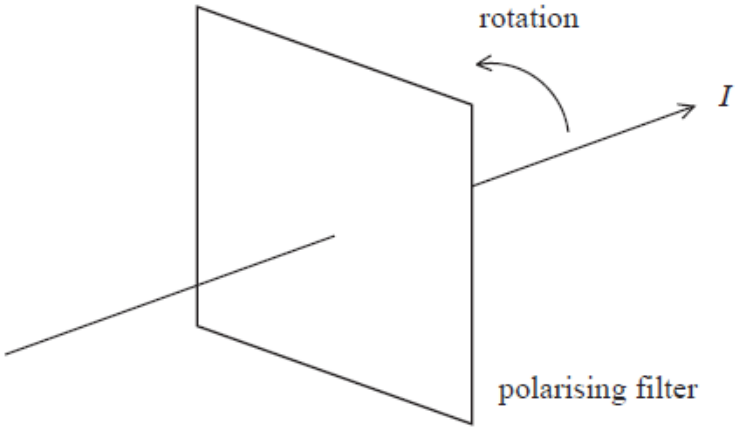
Q25.

Question Number	Answer	Mark
	B is the correct answer, as $F = \frac{GMm}{r^2}$	**(1)**

Q1.

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

A ray of unpolarised light is incident on a polarising filter. The polarising filter transmits light of intensity *I*, as shown.



The polarising filter is then rotated in the direction shown on the diagram.

Which of the following gives the intensity of light transmitted after the filter has been rotated 90°?

☒ **A** 0

☒ **B** $\frac{I}{4}$

☒ **C** $\frac{I}{2}$

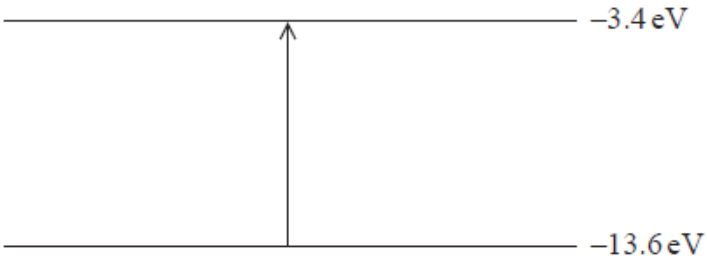
☒ **D** I

(Total for question = 1 mark)

Q2.

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

The diagram shows an electron transition between two energy levels in a hydrogen atom.



Which of the following could **not** have caused this transition?

☒ **A** The atom absorbing a photon with an energy of 13.6 eV.

☒ **B** The atom absorbing a photon with an energy of 10.2 eV.

☒ **C** An electron with a kinetic energy of 13.6 eV colliding with the atom.

☒ **D** An electron with a kinetic energy of 10.2 eV colliding with the atom.

(Total for question = 1 mark)

Q3.

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

Which of the following does **not** have the base unit s^{-1}?

☒ **A** angular velocity

☒ **B** frequency

☒ **C** redshift

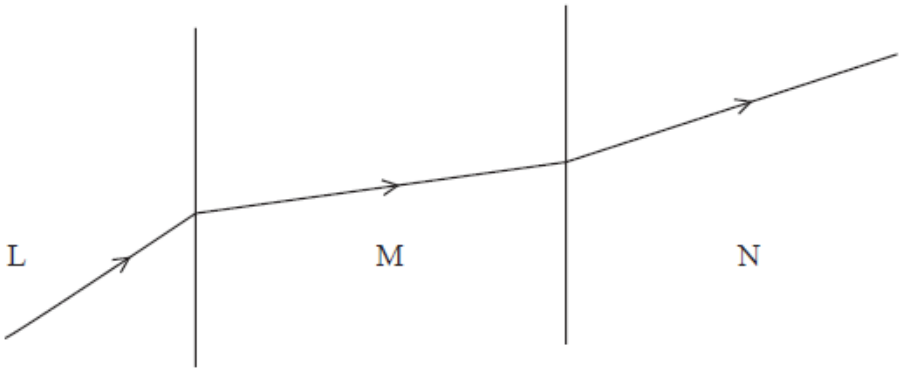
☒ **D** rate of decay

(Total for question = 1 mark)

Q4.

Select one answer from A to D and put a cross in the box ☒. 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 shows refraction of a ray of light as it passes through three transparent substances, L, M and N. The speeds of light in the three substances are v_L, v_M and v_N, respectively.



Which of the following could result in a ray of light undergoing total internal reflection?

☒ **A** light travelling from L to M

☒ **B** light travelling from L to N

☒ **C** light travelling from M to L

☒ **D** light travelling from N to M

(Total for question = 1 mark)

Q5.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The de Broglie wavelength for a moving electron is 5.47×10^{-10} m.

Which of the following expressions gives the speed of the electron in m s^{-1}?

☒ **A** $\frac{(6.63 \times 10^{-34})}{(9.11 \times 10^{-31})(5.47 \times 10^{-10})}$

☒ **B** $\frac{(6.63 \times 10^{-34})}{(1.60 \times 10^{-19})(5.47 \times 10^{-10})}$

☒ **C** $\frac{(9.11 \times 10^{-31})(5.47 \times 10^{-10})}{(6.63 \times 10^{-34})}$

☒ **D** $\frac{(1.60 \times 10^{-19})(5.47 \times 10^{-10})}{(6.63 \times 10^{-34})}$

(Total for question = 1 mark)

Q6.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The spectrum of electromagnetic radiation from a galaxy is observed to have a redshift.

Which of the following is a correct statement about lines in this spectrum?

☒ **A** All the lines are in the red part of the spectrum.

☒ **B** All the lines are observed to have longer wavelengths than expected.

☒ **C** Lines with wavelengths at the red end of the spectrum are the most intense.

☒ **D** Light for all the lines was emitted with longer wavelengths than expected.

(Total for question = 1 mark)

Q7.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Sirius and α-Centauri are two of our closest stars. Sirius has a luminosity about 16 times greater than the luminosity of α-Centauri. Sirius is twice as far away from the Earth as α-Centauri.

The intensity of light from Sirius is I_s and the intensity of light from α-Centauri is I_α.

Which of the following is the value of $\frac{I_s}{I_\alpha}$?

☒ **A** $\frac{1}{4}$

☒ **B** 4

☒ **C** 8

☒ **D** 16

(Total for question = 1 mark)

Q8.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Two waves with wavelength λ are produced by the same source. The waves travel different distances and then meet.

At the point where they meet, the path difference between the two waves is $\frac{\lambda}{8}$.

Which of the following is the phase difference, in radians, between the two waves?

☒ **A** $\frac{\pi}{2}$

☒ **B** $\frac{\pi}{4}$

☒ **C** $\frac{\pi}{8}$

☒ **D** $\frac{\pi}{16}$

(Total for question = 1 mark)

Q9.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Current theory suggests that the universe is expanding.

Which of the following is evidence to support this theory?

☒ **A** All galaxies appear to be rotating in space.

☒ **B** Dark matter has been detected in the universe.

☒ **C** All distant stars are observed to be increasing in size.

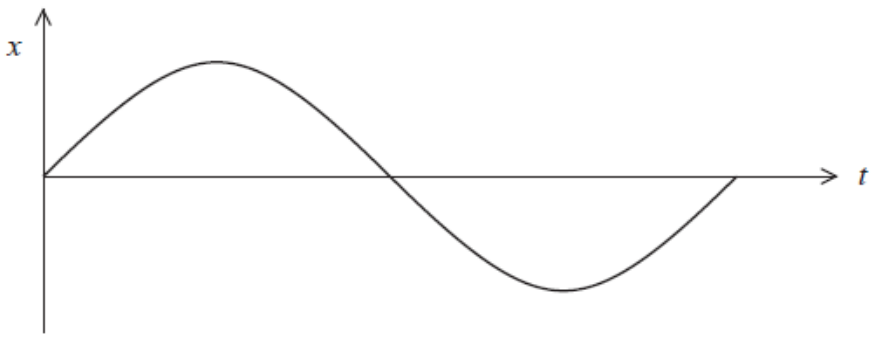
☒ **D** The further a galaxy is from the Earth, the faster it recedes.

(Total for question = 1 mark)

Q10.

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

The graph shows how the displacement *x* of particles in a wave varies with time *t*. The speed of the wave is not known.



Which of the following can **not** be determined from a graph of displacement against time for the particles in a wave?

☒

A amplitude

☒ **B** frequency

☒ **C** period

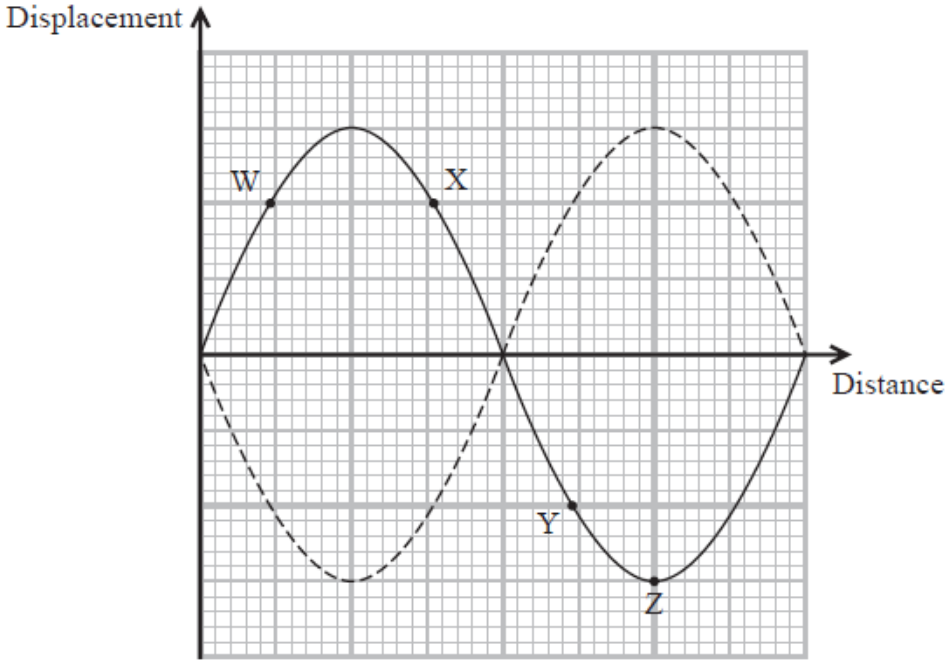
☒ **D** wavelength

(Total for question = 1 mark)

Q11.

Select one answer from A to D and put a cross in the box ☒. 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 shows how the displacement varies with distance along a stationary wave at two instants of time.



Which of the following statements is correct?

☒ **A** Points W and X are in antiphase.

☒ **B** Points W and Y are in phase.

☒ **C** Points X and Y are in phase.

☒ **D** Points X and Z are in antiphase.

(Total for question = 1 mark)

Q12.

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 luminosity axis of a Hertzsprung-Russell diagram has a logarithmic scale.

Which of the following is the reason for this?

☒ **A** Stars all have very large luminosities.

☒ **B** The range of luminosities of stars is very large.

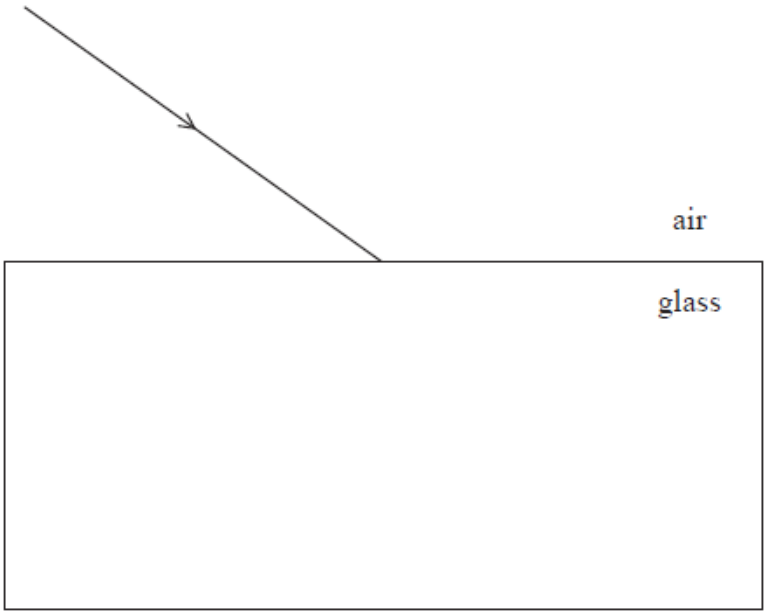
☒ **C** The range of distances to stars is very large.

☒ **D** The temperature axis has a logarithmic scale.

(Total for question = 1 mark)

Q13.

The diagram shows a ray of light incident on a glass block.



(a) Complete the diagram to show the path of the ray as it enters the block. Use the space below for any calculations.

refractive index of glass = 1.58

(5)

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(b) The speed of light in a different type of glass is 1.96×10^8 m s^{-1}.

Calculate the value of the critical angle at a boundary between this type of glass and air.

(3)

.....

.....

.....

.....

.....

Critical angle = ...

(Total for question = 8 marks)

Mark Scheme

Q1.

Question Number	Answer	Mark
	D is the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter. A is not the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter. B is not the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter. C is not the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter.	**(1)**

Q2.

Question Number	Answer	Mark
	A is the correct answer as a photon cannot be partially absorbed by an atom. B is not the correct answer as a photon of 10.2eV would use all of its energy to transfer an electron from the −13.6eV level to the −3.4eV level. C is not the correct answer as an electron of 13.6eV would use 10.2eV to transfer the electron and retain 3.4eV as its own kinetic energy. D is not the correct answer as an electron of 10.2eV could give all its energy to transfer an electron from the −13.6eV level to the −3.4eV level.	**(1)**

Q3.

Question Number	Answer	Mark
	C is the correct answer A is not the correct answer, as angular velocity has units (rad) s^{-1} B is not the correct answer, as frequency has units Hz = s^{-1} D is not the correct answer, as rate of decay has units Bq = s^{-1}	**(1)**

Q4.

Question Number	Answer	Mark
	C is the correct answer as light travels faster in L than in M A is not the correct answer as light travels faster in L than in M B is not the correct answer as light travels faster in L than in N D is not the correct answer as light travels faster in N than in M	**(1)**

Q5.

Question Number	Answer	Mark
	A is the correct answer as $v = h/m\lambda$ B is not the correct answer as v is not = $h/q\lambda$ C is not the correct answer as v is not = $m\lambda/h$ D is not the correct answer as v is not = $q\lambda/h$	**(1)**

Q6.

Question Number	Answer	Mark
	B is the correct answer A is incorrect, as the lines may be shifted into any region of the spectrum C is incorrect, as the intensity of the lines is not related to the redshift D is incorrect, as the wavelengths of the emitted lines is not affected	**(1)**

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Q7.

Question Number	Answer	Mark
	B is the correct answer, as $I = \frac{L}{4\pi d^2}$	**(1)**

Q8.

Question Number	Answer	Mark
	B is the correct answer as λ/8 is one eighth of a full wave cycle, and so is π/4 radians A is not the correct answer as this is equivalent to a path difference of λ/4 C is not the correct answer as this is equivalent to a path difference of λ/16 D is not the correct answer as this is equivalent to a path difference of λ/32	**(1)**

Q9.

Question Number	Answer	Mark
	D is the correct answer, as this is a statement of Hubble's law	**(1)**

Q10.

Question Number	Answer	Mark
	D is the correct answer as wavelength cannot be determined from a graph of displacement against time (only displacement against distance graphs) A is not the correct answer as amplitude is the maximum displacement from the equilibrium position for a wave. B is not the correct answer as the frequency can be calculated from $1/T$ C is not the correct answer as T is the time between two peaks on a displacement against time graph.	**(1)**

Q11.

Question Number	Answer	Mark
	D is the correct answer as X and Z are in two adjacent node to node sections, which will always be in antiphase with each other A is not the correct answer as W and X are between the same pair of nodes, between which all points are in phase B is not the correct answer as W and Y are in two adjacent node to node sections, which will always be in antiphase with each other C is not the correct answer as X and Y are in two adjacent node to node sections, which will always be in antiphase with each other	**(1)**

Q12.

Question Number	Answer	Mark
	B is the correct answer A is not the correct answer, as large values could fit on a linear scale C is not the correct answer, as distance from the star only affects the intensity D is not the correct answer, as the temperature and luminosity scales are independent	**(1)**

Q13.

Question Number	Answer		Mark
a	Angle of incidence measured from diagram in range 54-56(°) Use of $n_1\sin\theta_1 = n_2\sin\theta_2$ with their measured angle of incidence θ_2 = 30-32(°) Normal line drawn correctly at point of incidence Ray refracted towards normal Example of calculation Angle of incidence measured as 55° $n_1\sin\theta_1 = n_2\sin\theta_2$ so $1.00 \times \sin 55° = 1.58 \times \sin\theta_2$ $\theta_2 = \sin^{-1}\left(\frac{1.00 \times \sin 55°}{1.58}\right) = 31.2°$	(1) (1) (1) (1) (1)	**5**
b	Use of $n = c/v$ with $c = 3.00 \times 10^8\ \text{m s}^{-1}$ Use of $\sin C = 1/n$ $C = 41°$ Example of calculation $n = \frac{c}{v} = \frac{3.00 \times 10^8 \text{ms}^{-1}}{1.96 \times 10^8 \text{ms}^{-1}} = 1.53$ $\sin^{-1}(C) = \frac{1}{1.53}$ so $C = 40.8°$	(1) (1) (1)	**3**
	Total for question		**8**