Questions

Q1.

When laser light is shone through a diffraction grating a series of maxima is formed on a screen.

Assuming all other factors remain constant, which of the following changes would increase the distance between adjacent maxima?

(1)

☒ **A** Decreasing the distance between the diffraction grating and the screen.

☒ **B** Decreasing the distance between the lines on the diffraction grating.

☒ **C** Decreasing the intensity of the laser light used.

☒ **D** Decreasing the wavelength of the laser light used.

(Total for question = 1 mark)

Q2.

*In 1921, Albert Einstein was awarded the Nobel Prize for Physics "for his discovery of the law of the photoelectric effect".

To explain this effect, Einstein proposed that electromagnetic radiation should be modelled as a particle rather than as a wave.

Explain why, when considering the photoelectric effect, treating electromagnetic radiation as a particle is a more successful model than treating electromagnetic radiation as a wave.

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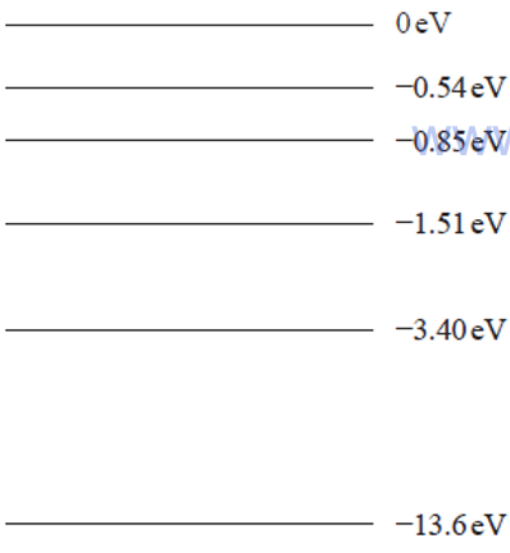
(Total for question = 6 marks)

Q3.

The diagram shows some of the energy levels for an atom of hydrogen.



Determine the transition between energy levels that would result in the release of a photon with

a frequency of 7.48×10^{13} Hz.

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Transition from ..... eV to ..... eV

(Total for question = 3 marks)

Q4.

The orbits of planets around the Sun are elliptical.

The intensity of radiation received at the top of the Earth's atmosphere is monitored during one orbit of the Earth around the Sun.

The following data is recorded:

maximum intensity of radiation = 1.41 kWm^{-2}
minimum intensity of radiation = 1.32 kWm^{-2}

(a) Calculate the minimum distance between the Earth and the Sun.

power of the Sun = 3.83×10^{26}W

(3)

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Minimum distance = ...

(b) As Mars orbits the Sun, the intensity of radiation received at the top of its atmosphere varies from 491 W m^{-2} to 711 W m^{-2}.

Explain two differences between the orbits of Mars and Earth that can be deduced from this data.

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(Total for question = 6 marks)

Q5.

Solar panels are devices that use sunlight as a source of energy to generate electricity.
A solar panel has a surface area of 1.54 m^2. The intensity of radiation incident on the Earth's surface is 1050 W m^{-2}. The manufacturer states that the maximum output power of the solar panel is 250 W.

Which of the following could be used to calculate the maximum efficiency of the solar panel?

☒ **A** $\frac{250 \times 1.54}{1050}$

☒ **B** $\frac{1050}{250 \times 1.54}$

☒ **C** $\frac{1050 \times 1.54}{250}$

☒ **D** $\frac{250}{1050 \times 1.54}$

(Total for question = 1 mark)

Q6.

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

Which of the following has the largest de Broglie wavelength?

☒ **A** an electron travelling at 3.0×10^5 m s^{-1}

☒ **B** an electron travelling at 4.0×10^5 m s^{-1}

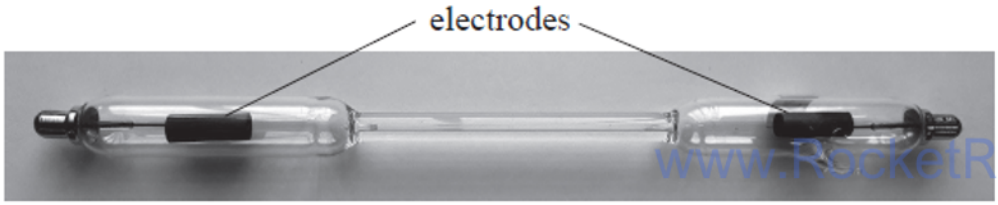
☒ **C** a neutron travelling at 3.0×10^5 m s^{-1}

☒ **D** a neutron travelling at 4.0×10^5 m s^{-1}

(Total for question = 1 mark)

Q7.

In 1857, Heinrich Geissler invented the first gas discharge tube. A sodium gas discharge tube is shown.



When a high potential difference is applied between the electrodes, electrons move through the sodium gas in the tube. The electrons collide with the sodium atoms. The tube then gives out visible light with a wavelength of 589 nm.

(a) Describe the process by which visible light is emitted from the sodium atoms.

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(b) Calculate the energy, in eV, of a photon of visible light with a wavelength of 589 nm.

(3)

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Photon energy = ... eV

(c) Light from the tube was directed through a diffraction grating, labelled as having

300 lines per mm. The diffraction pattern produced was displayed on a flat screen. The student measured the distance s between the central maximum and the first-order maximum on the screen. He also measured the distance D from the diffraction grating to the screen.

Determine whether the labelling of the diffraction grating as having 300 lines per mm was correct.

s = 0.234 m
D = 1.30 m
λ = 589 nm

(3)

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(Total for question = 9 marks)

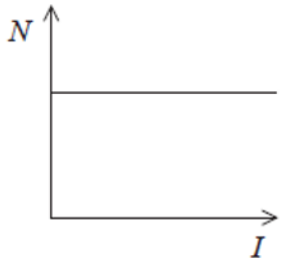
Q8.

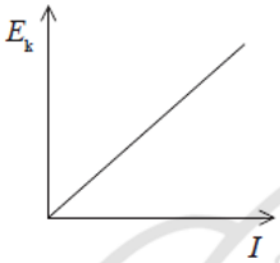
Ultraviolet light is incident on a metal surface and photoelectrons are released.

The number of photoelectrons released per second is N and the maximum kinetic energy of the released electrons is E_k.

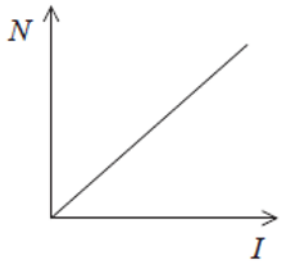
Which of the following pairs of graphs shows how N and E_k vary with the intensity I of the incident light?

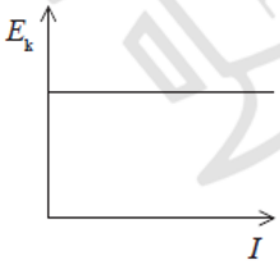
☒ **A**



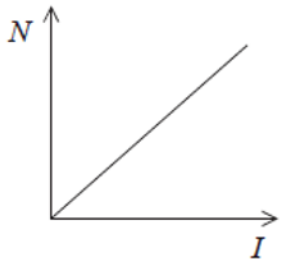


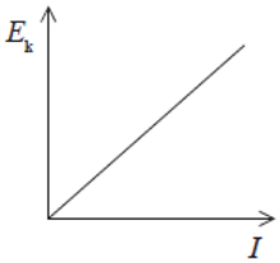
☒ **B**



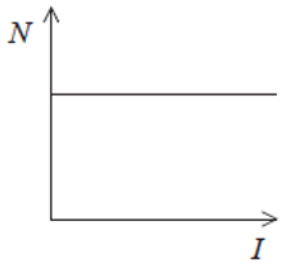


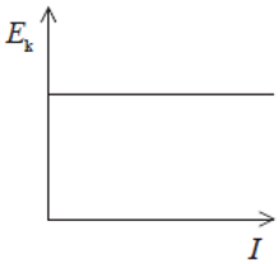
☒ **C**





☒ **D**





(Total for question = 1 mark)

Q9.

A student is reading about the wave nature of electrons.

He writes a statement about wave-particle duality:

If every particle has a de Broglie wavelength, it should be possible for a moving car to have the same de Broglie wavelength as a fast moving electron, although the car would be moving very slowly.

(a) Determine whether the student's statement about the speed of the car is mathematically correct.

speed of electron = 1.5×10^{7} m s^{-1}
mass of car = 900 kg

(3)

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(b) Suggest why the de Broglie wavelength is not a useful property for a car.

(1)

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(Total for question = 4 marks)

Q10.

The work functions of four metals are shown in the table.

Metal	Work function / J
potassium	3.62×10^{-19}
magnesium	5.89×10^{-19}
tungsten	7.18×10^{-19}
iron	7.41×10^{-19}

(a) State what is meant by work function.

(1)

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(b) When light with a frequency of 6.32×10^{15} Hz is incident on a metal, photoelectrons are released with a maximum kinetic energy of 3.60×10^{-18} J.

Determine which of the four metals the light is incident on.

(3)

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(c) Ultraviolet radiation is incident on a potassium plate. If the radiation behaved as a wave, there would be a time delay before electrons were emitted from the plate.

(i) Calculate the time taken for a potassium atom to absorb enough energy to release an electron.

intensity of ultraviolet radiation = 38.0 mW m^{-2}

area over which a potassium atom absorbs energy = 8.10×10^{-20} m^2

(3)

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Time taken = ...

(ii) In practice, electrons are emitted from the plate as soon as the ultraviolet radiation is incident on the plate.

Explain how this provides evidence for the particle nature of electromagnetic radiation.

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(Total for question = 9 marks)

Q11.

The evidence for the wave nature of electrons came from experiments involving

☒ **A** diffraction.

☒ **B** polarisation.

☒ **C** reflection.

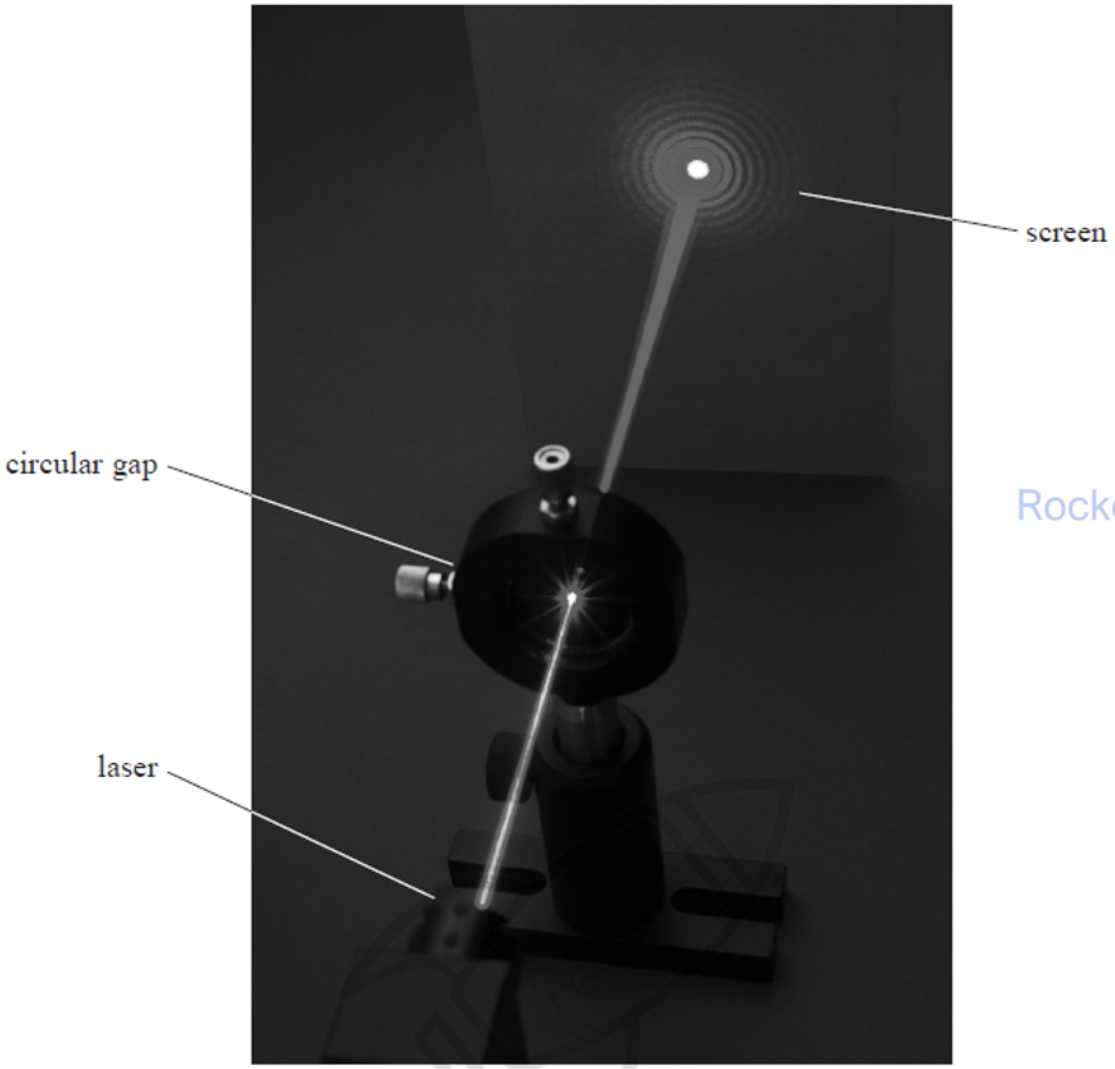
☒ **D** refraction.

(Total for question = 1 mark)

Q12.

When laser light is directed through a small circular gap, a diffraction pattern can be observed

on a screen as shown.



(Source: © GIPHOTOSTOCK / SCIENCE PHOTO LIBRARY)

(a) Explain, using Huygens' construction, how diffraction occurs as waves pass through a gap.

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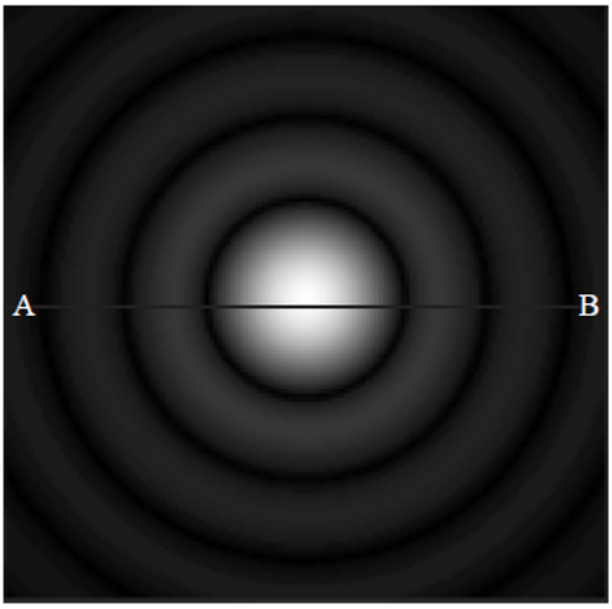
(b) The diffraction pattern consists of a central bright spot surrounded by concentric circles of light of decreasing intensity. A close-up of the pattern is shown below.



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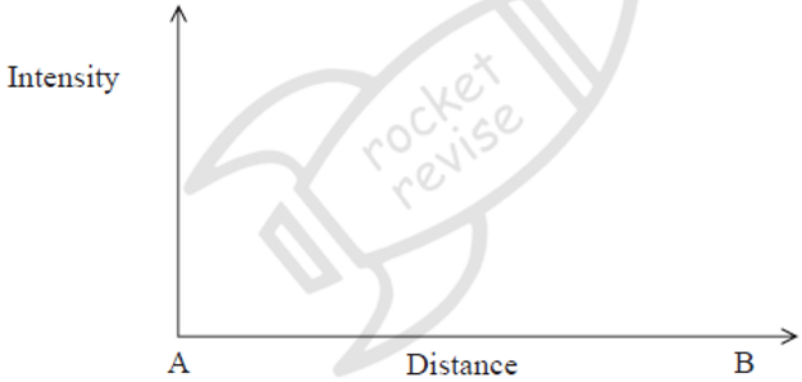
Sketch a graph showing how the intensity of the light in the diffraction pattern on the screen varies along the line AB.

(3)



(Total for question = 5 marks)

Q13.

Solar panels generate electricity when sunlight is incident on the surface of the panel.

(a) The total generation of electricity worldwide in the year 2014 was approximately 23 800 TWh (1 TWh = 3.6×10^{15} J).

Some scientists claim that if the Sahara Desert were covered with solar panels, sufficient electricity could be generated to supply the whole world.

(i) Calculate the maximum energy received by the solar panels in one hour.

maximum intensity of solar radiation at the Earth's surface = 1100 Wm^{-2} area of Sahara Desert = 9.2×10^{12} m^2

(2)

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Maximum energy received in one hour = ...

(ii) Determine whether covering the Sahara Desert with solar panels would be able to generate enough electricity for the whole world.

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(b) Sand storms are common in the Sahara Desert.

Explain why sand storms reduce the power generated by the solar panels.

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(Total for question = 6 marks)

Q14.

Niels Bohr developed an early model of the atom where electrons could only exist in fixed orbits around a nucleus.

When an atom is ionised, an electron moves from its orbit around the nucleus to be free of the atom. Bohr derived an expression for the ionisation energy E, in joules, for a hydrogen atom:

$$\left(\frac{e^2}{kh}\right)^2 \times \frac{m}{8}$$

where

m = mass of electron
e = charge of electron
$k = 8.85 \times 10^{-12}$ C V^{-1} m^{-1}
h = Planck constant

(a) Calculate E for a hydrogen atom, in eV.

(3)

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E = ... eV

(b) The Bohr model can also be used to predict an approximate radius for an atom. The equation for the radius r of the hydrogen atom is:

$$r = \frac{h^2 k}{\pi m e^2}$$

where

m = mass of electron

A student suggests that, for a speed of 1.4×10^7 m s^{-1}, neutrons would have a wavelength similar to the radius of a hydrogen atom.

Determine whether the student is correct.

mass of neutron = 1.67×10^{-27} kg

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(Total for question = 8 marks)

Q15.

When the photoelectric effect occurs, light incident on the surface of a metal releases electrons.

Which of the following is an experimental observation of the photoelectric effect?

☒ **A** Electrons are only released after light has been incident for a long time.

☒ **B** Increasing the frequency of the light increases the maximum kinetic energy of the released electrons.

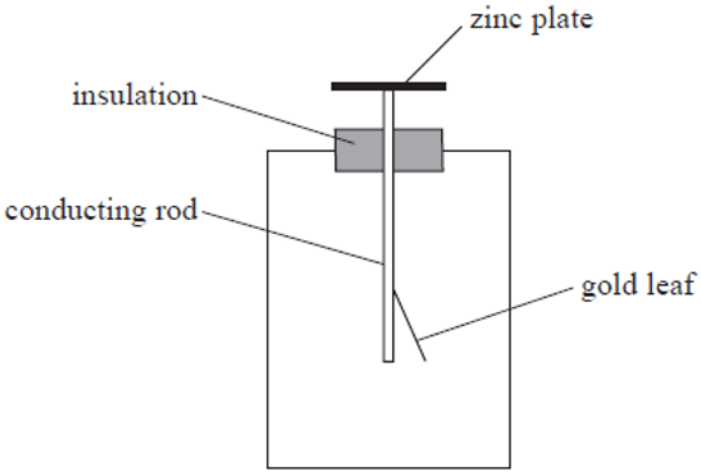
☒ **C** Increasing the intensity of the light increases the maximum kinetic energy of the released electrons.

☒ **D** Only light with a wavelength above a threshold value releases electrons.

(Total for question = 1 mark)

Q16.

A gold leaf electroscope is used to demonstrate the photoelectric effect. When the zinc plate of the electroscope is given a negative charge, the conducting rod and gold leaf also become negatively charged. The gold leaf deflects away from the metal stem as shown. The deflection of the gold leaf depends on the amount of charge on the zinc plate and the conducting rod.



A beam of ultraviolet radiation is incident on the zinc plate. The gold leaf immediately begins to fall back to the conducting rod.

(a) Explain why this observation cannot be explained by the wave model of electromagnetic radiation.

(2)

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(b) Photons of ultraviolet radiation with an energy of 9.3×10^{-19} J are directed towards the zinc plate.

(i) Calculate the maximum speed with which electrons are released from the plate.

work function of zinc = 4.3 eV

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Maximum speed of electrons = ...

(ii) A student suggests that a greater maximum speed of electrons could have been achieved if both:

– a metal with a lower work function than zinc was used
– ultraviolet radiation with a greater wavelength was used.

Discuss the student's suggestion.

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(Total for question = 9 marks)

Q17.

A 'smart meter' collects information about the use of electricity in the home. This information is transmitted to the electricity company using radio waves.

(a) A typical smart meter emits radio waves with a power output of 1.00 W.
An intensity of radiation greater than 4.5 W m^{-2} is dangerous to people.

A person stands 25 cm from a smart meter.

Deduce whether the radiation emitted by this smart meter would be dangerous to the person at this distance.

(3)

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(b) It is suggested that the energy per photon could be important in determining if the radiation emitted by the smart meter
is dangerous.

The smart meter transmits radio waves of frequency 902 MHz.

Calculate the energy per photon, in eV, of the photons emitted by the smart meter.

(3)

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Energy per photon = ... eV

(c) The display of the smart meter in one household is shown. This shows the total electrical energy used in one day.

1 kW h is a unit of energy equivalent to 1 kW of power used for 1 hour.

The kettle in this house has a power of 1200 W. The kettle takes 125 seconds to heat the water to boiling. The kettle then switches off.

A student suggests that boiling the kettle once uses less than 1% of the total energy shown on the smart meter display.

Assess the student's suggestion.

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(Total for question = 9 marks)

Q18.

After an atom of hydrogen has been exposed to suitable electromagnetic radiation, the atom can emit visible light. The emitted light contains a small number of different wavelengths of visible light.

* (a) Explain the process that results in the emission of different wavelengths of visible light. Your answer should include reference to energy levels in atoms.

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(b) It is also possible to make the atoms in a sample of air emit visible light.

Explain why the light emitted by the air has a large number of different wavelengths.

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(Total for question = 8 marks)

Q19.

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

A light bulb with an efficiency of 12% is positioned 2.0 m above a light sensor.
The intensity of light at the light sensor is 0.14 W m^{-2}.

Which of the following could be used to calculate the power of the light bulb?

☒ **A** $(0.14) \times (0.12) \times (4\pi) \times (2.0)^2$

☒ **B** $\dfrac{(0.14) \times (4\pi) \times (2.0)^2}{0.12}$

☒ **C** $(0.14) \times (0.12) \times (\pi) \times (2.0)^2$

☒ **D** $\dfrac{(0.14) \times (\pi) \times (2.0)^2}{0.12}$

(Total for question = 1 mark)

Q20.

Ultraviolet light of wavelength 20.0 nm is incident on a metal surface. The metal has a work function of 3.68 eV. Electrons are released by the photoelectric effect.

(a) Calculate the maximum speed of the electrons as they are released from the metal surface.

(5)

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Maximum speed = ...

(b) A student suggests that if the wavelength and intensity of the light used are both increased, the maximum speed of the electrons released from the metal surface also increases.

Explain whether the student's suggestion is correct.

(4)

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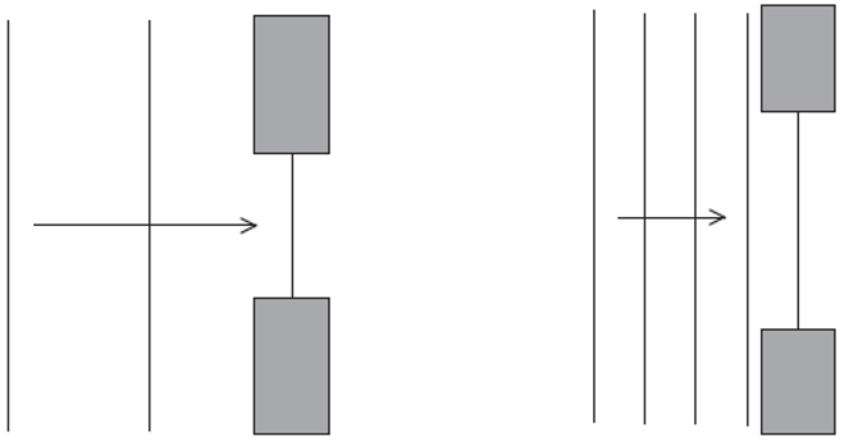
(Total for question = 9 marks)

Q21.

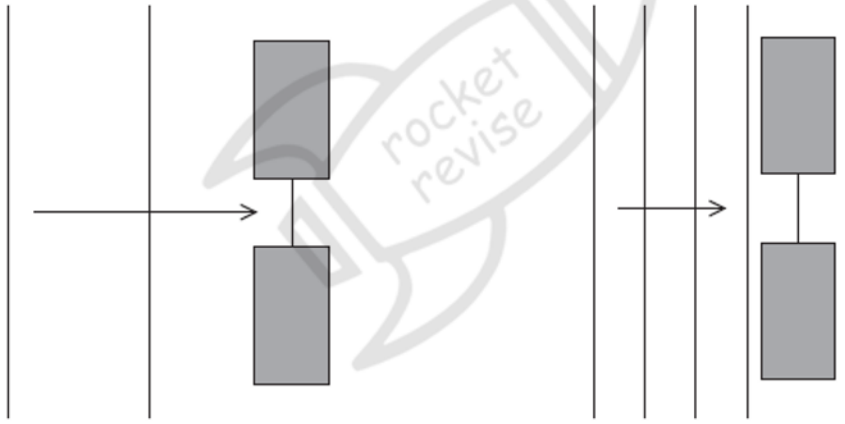
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The wavefront diagrams show consecutive waves approaching gaps of different sizes.



A

B



C

D

The wavefronts diffract as they pass through each gap.

In which diagram will the diffracted wavefronts **not** be semicircular?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q22.

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 shows some of the energy levels of a hydrogen atom.

An excited electron in the level –0.54 eV drops to the level –13.60 eV, resulting in the release of at least one photon.

Which of the following photon energy values could **not** be produced from this electron transition?

☒ **A** 0.31 eV

☒ **B** 0.54 eV

☒ **C** 12.09 eV

☒ **D** 13.06 eV

(Total for question = 1 mark)

Q23.

ICESat-2 is a satellite launched into space by NASA in 2018. One purpose of the satellite is to measure the thickness of ice on the Earth's surface. The satellite is powered using solar panels. A laser in the satellite produces a beam of photons, which travel to the Earth and back.

(a) Calculate the intensity of solar radiation as it reaches ICESat-2.

distance from the Sun to ICESat-2 = 1.50×10^{11} m
power of the Sun = 3.83×10^{26} W

(3)

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Intensity of solar radiation = ...

(b) The laser emits light with a wavelength of 532 nm. Calculate the energy, in J, of each photon.

(3)

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Energy of photon = ... J

(c) The photons released by the laser are directed towards the Earth. The mean time for these photons to return to the satellite is 3.20 ms.

(i) Calculate the height that ICESat-2 orbits above the surface of the Earth.

(2)

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Height above Earth = ...

(ii) When photons arriving at the satellite are detected, only those with a wavelength of exactly 532 nm are used in the analysis of the results.

Suggest why.

(1)

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(d) At one point, ICESat-2 passes over a flat ice sheet. The ice sheet is 1000 m above sea level.

Explain how the measurements taken by ICESat-2 can be used to show that the ice sheet has a flat surface and is higher than sea level.

(2)

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(Total for question = 11 marks)

Q24.

The diagram shows some of the energy levels for an atom of hydrogen.

0 eV

− 0.85 eV

− 1.5 eV

− 3.4 eV

− 13.6 eV

When an electron with a kinetic energy of 12.3 eV interacts with this atom, an electron in the atom moves from the
−13.6 eV level to the −1.5 eV level.

When a photon with a photon energy of 12.3 eV is incident on this atom, the electron in the atom at the −13.6 eV level remains at the 13.6 eV level.

Explain these observations.

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(Total for question = 4 marks)

Q25.

Electromagnetic radiation can be described in terms of a photon model.

Which of the following demonstrates the photon model of light?

☒ **A** diffraction patterns

☒ **B** Huygens' construction

☒ **C** photoelectric effect

☒ **D** plane polarisation

(Total for question = 1 mark)

Q26.

In 1924 de Broglie suggested that electrons have wave properties.
The de Broglie equation states:

$$\lambda = \frac{h}{p}$$

Which of the following is correct?

☒ **A** The de Broglie wavelength is independent of the mass of the particle.

☒ **B** The de Broglie equation can be used to calculate the momentum of a photon.

☒ **C** The term *p* represents the mass of an electron multiplied by the speed of light.

☒ **D** The value of *h* depends on the particle involved.

(Total for question = 1 mark)

Q27.

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 moving electron has a de Broglie wavelength of 656 nm.

Which of the following could be used to determine the speed of the electron?

☒ **A** $\dfrac{6.63\times10^{-34}}{(656\times10^{-9})(9.11\times10^{-31})}$

☒ **B** $\dfrac{(656\times10^{-9})(9.11\times10^{-31})}{6.63\times10^{-34}}$

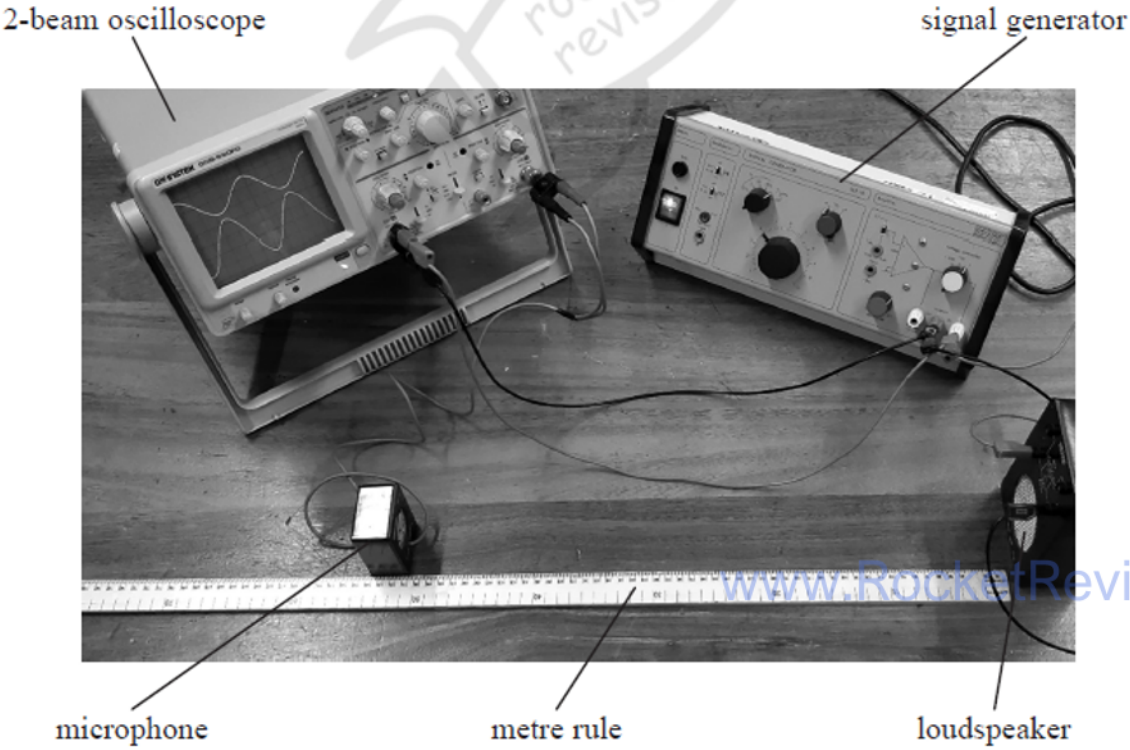
☒ **C** $\dfrac{(656\times10^{-9})(6.63\times10^{-34})}{9.11\times10^{-31}}$

☒ **D** $\dfrac{9.11\times10^{-31}}{(656\times10^{-9})(6.63\times10^{-34})}$

(Total for question = 1 mark)

Q28.

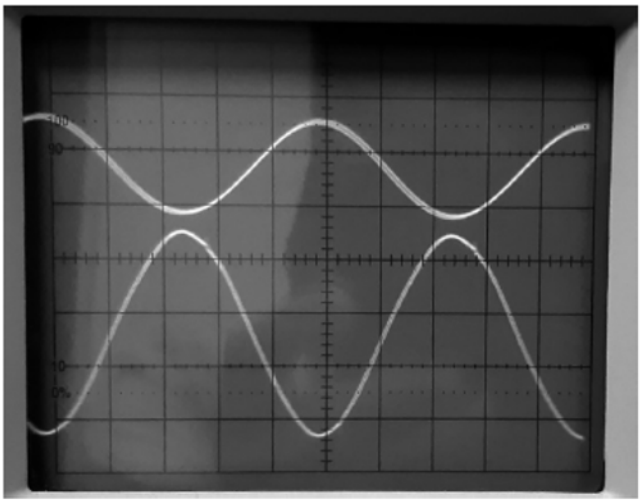
A student used the apparatus shown in Photograph 1 to determine the speed of sound in air.



Photograph 1

The student switched on the signal generator. The oscilloscope showed one trace from the signal generator and another trace from the microphone.

Initially the peaks of one trace were directly above the troughs of the other trace, as shown in Photograph 2.



Photograph 2

The horizontal axis of the oscilloscope screen represents time. The number of milliseconds per division on the horizontal scale is known.

(a) Explain how the apparatus shown in Photograph 1 could be used to determine the speed of sound in air.

(5)

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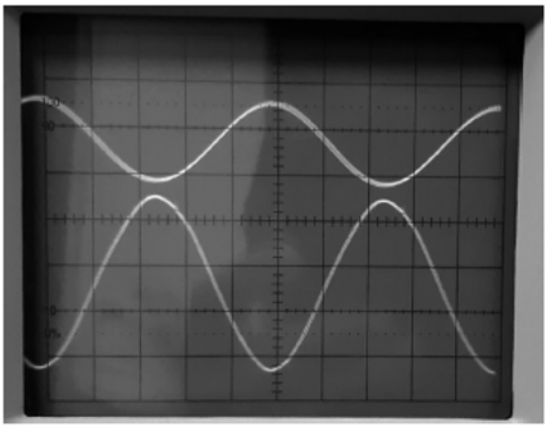
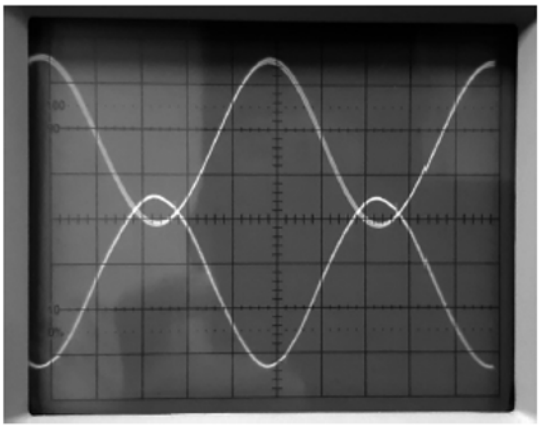
(b) The student changed the position of the microphone. The traces on the oscilloscope screen before and after changing the position of the microphone are shown in Photograph 2 and Photograph 3.



Photograph 2



Photograph 3

Explain what change the student made to the position of the microphone between Photograph 2 and Photograph 3.

(3)

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(Total for question = 8 marks)

Q29.

A student used two sources, A and B, of electromagnetic radiation to investigate the photoelectric effect. Radiation from A has a photon energy of 2.0 eV.

(a) The radiation from B has a wavelength of 280 nm.

Show that this radiation has a photon energy of about 4.4 eV.

(4)

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*(b) The student used the two sources of radiation to investigate the photoelectric effect for two different metals, copper and zinc.

The following statements were made by the student.

> When radiation of photon energy 2.0 eV from source A is directed towards either of the metal plates no electrons are released, even when the intensity of the radiation is increased.
>
> When radiation of photon energy 4.4 eV from source B is directed towards the copper plate, no electrons are released. However, when the radiation is directed towards the zinc plate, electrons are released. As the intensity of radiation is increased, electrons are released at a greater rate.

Explain the conclusions that can be made from these statements.

(6)

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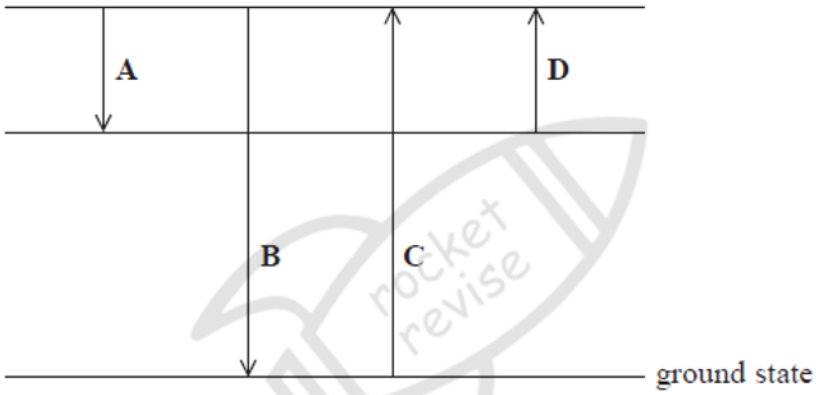
(Total for question = 10 marks)

Q30.

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 shows four possible transitions of electrons in an atom.



Which of the transitions will result in the emission of a photon with the longest wavelength?

☒ **A**

☒ **B**

☒ **C**

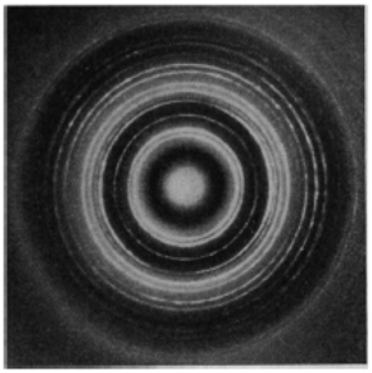
☒ **D**

(Total for question = 1 mark)

Q31.

A beam of electrons is directed at a thin metal foil. After passing through the foil the electrons are detected by a fluorescent screen.

The image shows the pattern produced on the fluorescent screen.



(Source: © Reading Room 2020/Alamy Stock Photo)

Explain how the pattern produced on the screen is evidence for wave behaviour, rather than particle behaviour of the electrons.

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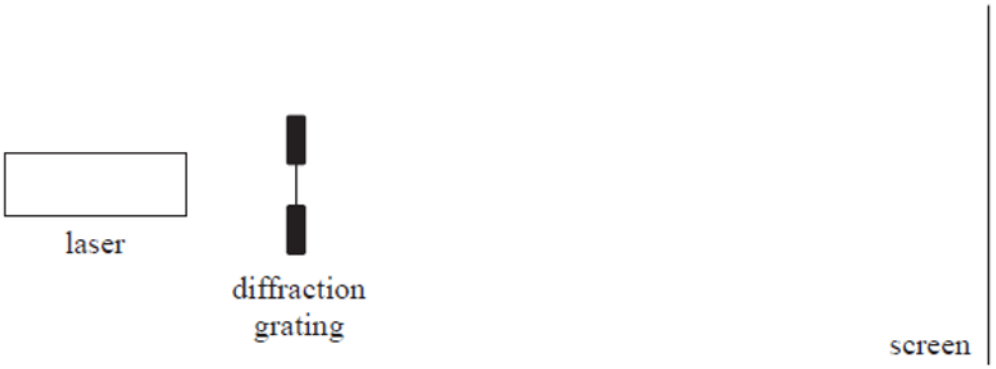
(Total for question = 3 marks)

Q32.

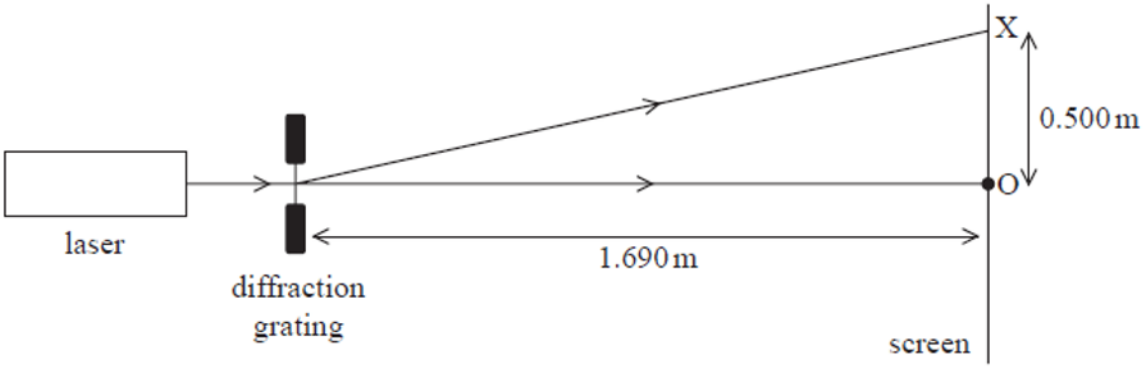
A laser, a diffraction grating and a screen are set up as shown. The laser emits monochromatic light.



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.

(4)

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Wavelength = ...

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

(3)

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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.

(2)

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(Total for question = 9 marks)

Q33.

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

(6)

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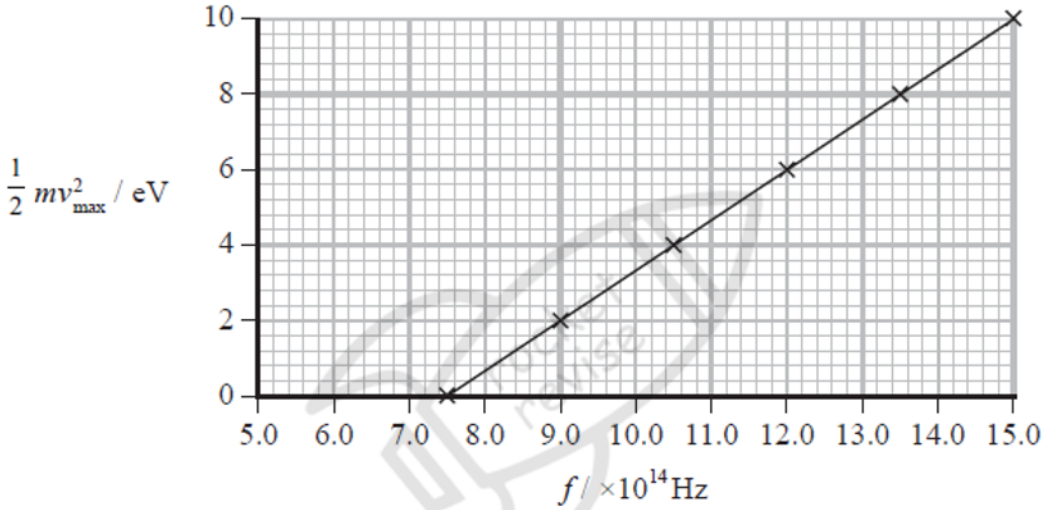
(c) A student used a zinc plate and UV light of different frequencies in an experiment. The student's graph of maximum kinetic energy of the released electrons against the frequency of the incident UV light is shown.



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)

Q34.

* 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)

Q35.

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.

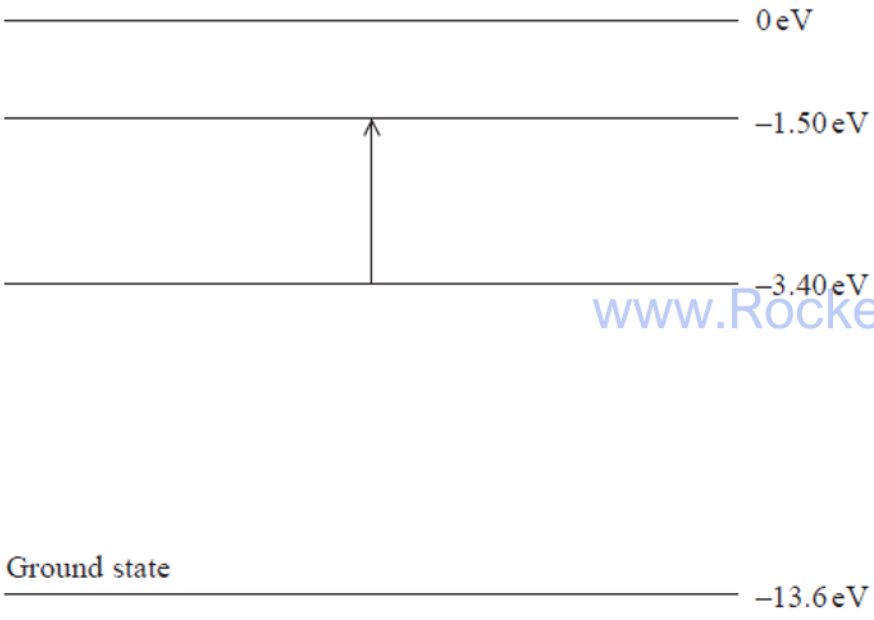
☒ **D** Electrons behave as neither particles nor waves.

(Total for question = 1 mark)

Q36.

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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(Total for question = 10 marks)

Q37.

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

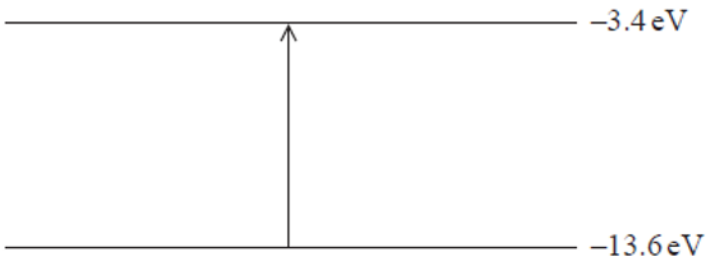
☒ **D** $\dfrac{(1.45 \times 10^{4})}{(4\pi)(4.60 \times 10^{10})^{2}}$

(Total for question = 1 mark)

Q38.

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)

Q39.

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

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

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

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

(Total for question = 1 mark)

Q40.

Monochromatic light is incident on the surface of a magnesium plate. Electrons are released with a range of kinetic energies.

(a) Explain why the maximum kinetic energy of a released electron is less than the energy of each photon of light incident on the surface.

(3)

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(b) The frequencies of three different sources of light, A, B and C, are shown in the table below.

Light source	Frequency / 10^{15} Hz
A	1.11
B	1.23
C	1.34

The light from one of these sources was incident on the magnesium plate, and electrons were released with a maximum speed of 5.70×10^5 m s^{-1}.

Deduce which of the three sources of light was used.

work function of magnesium = 3.68 eV

(4)

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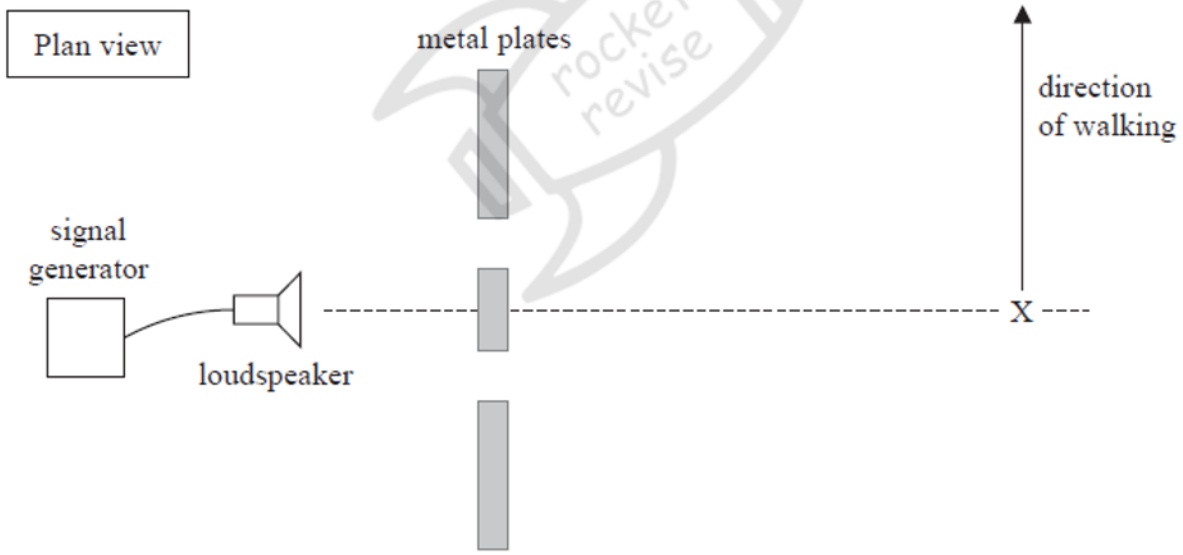
(Total for question = 7 marks)

Q41.

A student connected a signal generator to a loudspeaker. The student arranged metal plates in front of the loudspeaker, as shown. The student left gaps between the metal plates.

Sound waves from the loudspeaker passed through the gaps. The gaps were approximately the same size as the wavelength of the sound waves.



The student stood at point X and heard a loud sound. The student walked in a straight line in the direction of the arrow. As her position changed, the sound became quieter until she heard no sound.

*(a) Explain why the sound became quieter until there was no sound.

Your explanation should refer to interference.

(6)

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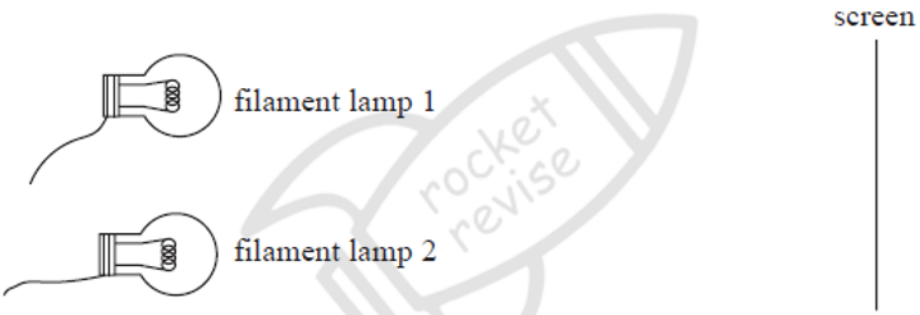
(b) Interference can be demonstrated using visible light.

A student connects two filament lamps to the same power supply. A screen is placed at a distance from the lamps, as shown.



Explain why it is **not** possible to create a consistent interference pattern on the screen using this arrangement.

(2)

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(Total for question = 8 marks)

Q42.

An irrigation system uses a pump to move water from a lower level to a higher level. The electricity for the pump is generated using a panel of solar cells.

(a) The panel of solar cells is 1.20 m long and 0.80 m wide. To pump water from the lower level to the higher level the pump needs a minimum power of 140 W.

(i) Calculate the minimum efficiency of the panel of solar cells that will operate the pump.

intensity of sunlight on solar cells = 1040 W m^{-2}

(4)

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Minimum efficiency = ...

(ii) Suggest **two** reasons why the value calculated in (i) is the minimum efficiency that will operate the pump.

(2)

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(b) Light from the Sun arriving at the solar cells is unpolarised.

(i) Explain the difference between unpolarised light and plane polarised light.

(3)

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(ii) Describe how a student can demonstrate that light from the Sun is unpolarised.

(2)

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(Total for question = 11 marks)

Q43.

A particle travelling at a speed of 9.89×10^{5} m s^{-1} has a de Broglie wavelength of 7.37×10^{-10} m.

Deduce whether this particle has a mass equal to the electron mass.

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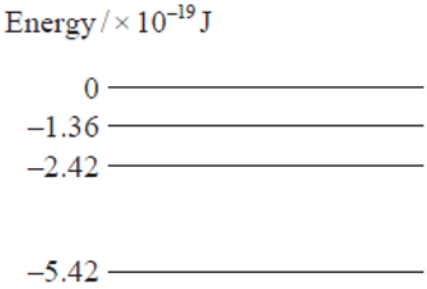
(Total for question = 3 marks)

Q44.

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 shows some of the energy levels for a hydrogen atom.



Which of the following expressions is equal to the lowest frequency of light possible from a transition between these energy levels?

☒ **A** $\frac{5.42 \times 10^{-19}}{6.63 \times 10^{-34}}$

☒ **B** $\frac{1.36 \times 10^{-19}}{6.63 \times 10^{-34}}$

☒ **C** $\frac{2.42 \times 10^{-19} + 1.36 \times 10^{-19}}{6.63 \times 10^{-34}}$

☒ **D** $\frac{2.42 \times 10^{-19} - 1.36 \times 10^{-19}}{6.63 \times 10^{-34}}$

(Total for question = 1 mark)

Q45.

(a) In an experiment to demonstrate the photoelectric effect, ultraviolet light is incident on a metal plate.

(i) Photoelectrons are released from the plate with a maximum speed of 3.51×10^5 m s^{-1}.

Calculate the energy of these photoelectrons in eV.

(3)

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Energy = ... eV

(ii) The table shows typical values of work function for four different metals.

Metal	Work function / 10^{-19} J
Magnesium	5.89
Aluminium	6.53
Zinc	6.88
Iron	7.20

The ultraviolet light used in the experiment had a wavelength of 310 nm.

Deduce which of the metals was most likely to have been used as the metal plate.

(4)

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(b) Photoelectrons are only emitted from a given metal surface if the frequency of the incident radiation is above a particular value.

Explain why.

(4)

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(c) A student makes the following statement.

'It does not matter what the value of the work function is for a particular metal. Photoelectrons can always be released if the intensity of the incident light is high enough.'

Criticise the student's statement.

(2)

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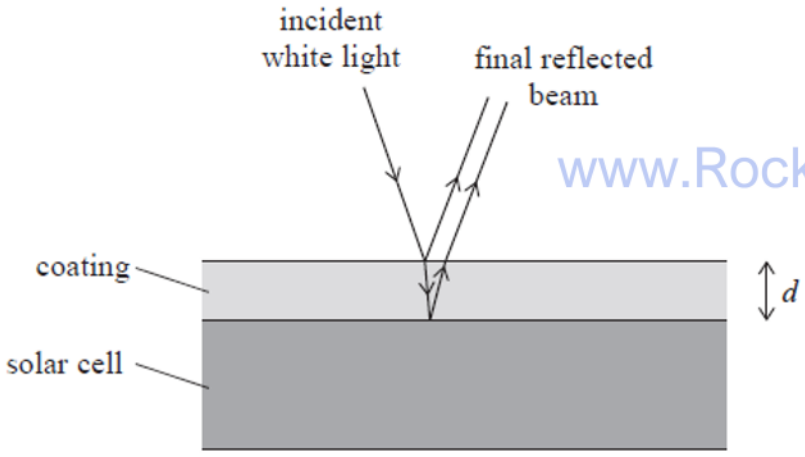
(Total for question = 13 marks)

Q46.

A solar cell has a thin coating of thickness *d* to reduce the reflection of light. White light incident on the coating is reflected from the top and bottom surfaces of the coating. This produces a final reflected beam, as shown.



(a) Explain why some wavelengths of the incident white light will be missing from the final reflected beam.

(3)

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(b) White light is incident perpendicular to the surface of the coating.

Calculate the wavelength that would be missing from the final reflected beam.
Assume the refractive index is 2.3 for all visible wavelengths.

$d = 6.5 \times 10^{-8}$ m

(4)

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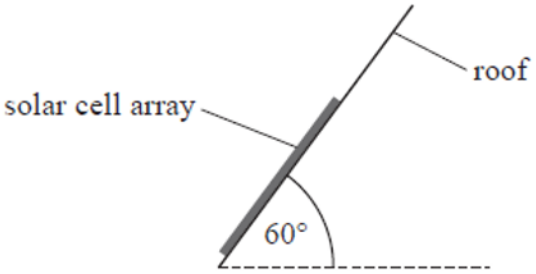
Wavelength = ...

(c) A solar cell array is placed on the roof of a house as shown.

The area of the solar cell array is 8.7 m^2. The roof of the house slopes at an angle of 60° to the horizontal as shown below.



When the intensity of radiation from the Sun perpendicular to the surface of the Earth is 1.1 kW m^{-2}, the output of the solar cell array is 5.4×10^6 J per hour.

Calculate the efficiency of the solar cell array.

(4)

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Efficiency = ...

(Total for question = 11 marks)

Q47.

The diagram shows the energy levels for an atom of hydrogen.

———————— 0.00 eV

———————— −0.54 eV

———————— −0.85 eV

———————— −1.51 eV

———————— −3.40 eV

———————— −13.6 eV

An electron is in the −13.6 eV (ground state) level of this atom.

(a) A photon interacts with this electron.

Explain why this interaction causes the emission of another photon.

(2)

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(b) A photon has a wavelength of 218 nm.

(i) Determine the energy, in eV, of this photon.

(4)

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Photon energy = ... eV

(ii) Explain whether the atom of hydrogen could emit a photon with this energy.

(2)

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(c) Photons with energy 1.63×10^{-18} J are incident upon the surface of a metal plate.

The metal surface releases electrons due to the photoelectric effect.

(i) Calculate the maximum possible speed of the electrons.

work function = 5.89×10^{-19} J

(3)

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Maximum possible speed of the electrons = ...

(ii) Explain why the photoelectric effect demonstrates light behaving as a particle, rather than a wave.

(3)

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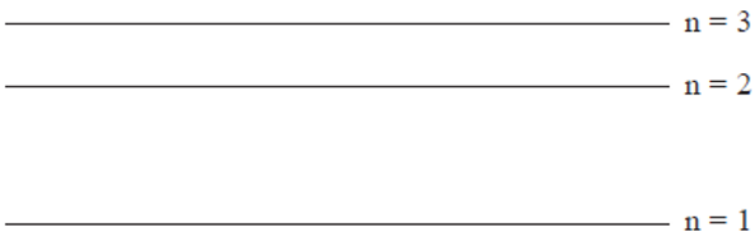
(Total for question = 14 marks)

Q48.

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 shows some of the energy levels in an atom.



Electrons in this atom are excited from the ground state to the energy level n = 3.

How many different frequencies of radiation can be emitted from this atom as electrons return to the ground state?

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(Total for question = 1 mark)

Q49.

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

An electron has a de Broglie wavelength of 1.55×10^{-9} m.

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

☒ **A** $\frac{9.11 \times 10^{-31}}{6.63 \times 10^{-34} \times 1.55 \times 10^{-9}}$

☒ **B** $\frac{1.55 \times 10^{-9} \times 9.11 \times 10^{-31}}{6.63 \times 10^{-34}}$

☒ **C** $\frac{6.63 \times 10^{-34} \times 1.55 \times 10^{-9}}{9.11 \times 10^{-31}}$

☒ **D** $\frac{6.63 \times 10^{-34}}{1.55 \times 10^{-9} \times 9.11 \times 10^{-31}}$

(Total for question = 1 mark)

Q50.

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 ☒.

Waves may spread out as they pass an object.

Which of the following is the name of this process?

☒ **A** diffraction

☒ **B** interference

☒ **C** reflection

☒ **D** refraction

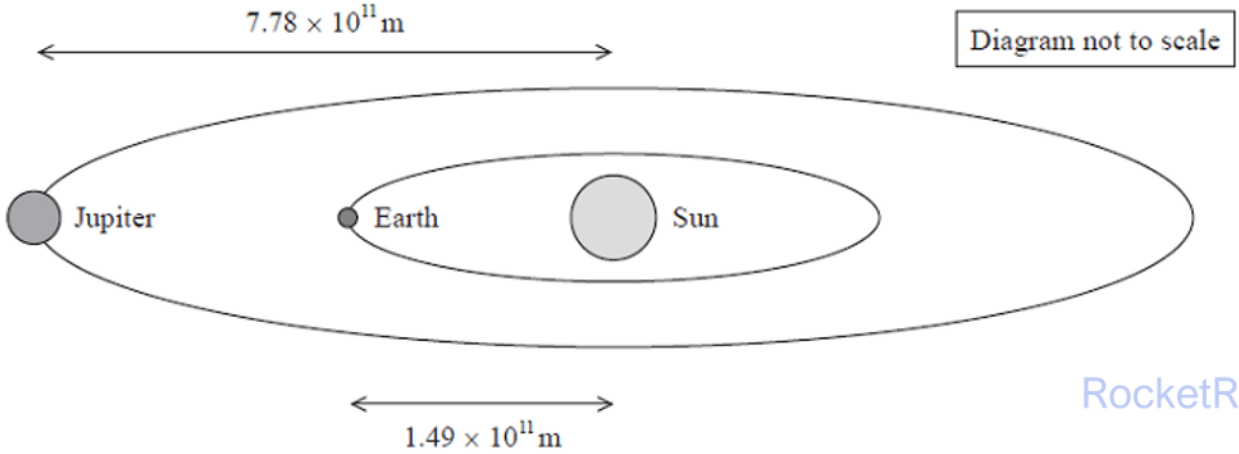
(Total for question = 1 mark)

Q51.

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 ☒.

Earth and Jupiter orbit the Sun, as shown.

The distance from Earth to the Sun is 1.49×10^{11} m.
The distance from Jupiter to the Sun is 7.78×10^{11} m.



The intensity of sunlight at Jupiter is I_J.

Which of the following can be used to calculate the intensity of the sunlight at Earth?

☒ **A** $I_J \times \frac{(7.78 \times 10^{11})^2}{(1.49 \times 10^{11})^2}$

☒ **B** $I_J \times 4\pi \times \frac{(7.78 \times 10^{11})^2}{(1.49 \times 10^{11})^2}$

☒ **C** $I_J \times \frac{7.78 \times 10^{11}}{1.49 \times 10^{11}}$

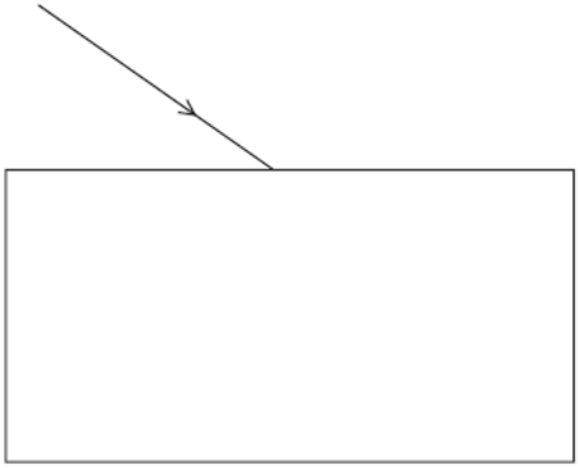
☒ **D** $I_J \times 4\pi \times \frac{7.78 \times 10^{11}}{1.49 \times 10^{11}}$

(Total for question = 1 mark)

Q52.

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

A ray of light is incident on a glass block, as shown.



Which of the following does **not** occur when the ray of light is incident on the glass block?

- ☒ **A** diffraction
- ☒ **B** polarisation
- ☒ **C** reflection
- ☒ **D** refraction

(Total for question = 1 mark)