Question 10

When light refracts as it passes from one medium to another, which one of the following will change?

A. colour

B. period

C. frequency

D. wavelength

Question 11

Which one of the following best supports the statement that light is a transverse wave rather than a longitudinal wave?

A. Light can be polarised.

B. Light has different colours.

C. Light can travel through a vacuum.

D. Energy in light oscillates in a direction parallel to its propagation direction.

Question 12

Which one of the following statements about electromagnetic radiation is correct?

A. Electromagnetic radiation cannot be produced by atomic-energy-level transitions.

B. Electromagnetic radiation is only produced by atomic-energy-level transitions.

C. Electromagnetic radiation can be produced by accelerating charges.

D. All electromagnetic radiation is produced by accelerating charges.

Question 13

When a mechanical wave moves through a medium, there is a net transfer of

A. mass.

B. energy.

C. particles.

D. mass and energy.

Question 14

Which one of the following statements about sound waves and electromagnetic waves is correct?

A. Both sound waves and electromagnetic waves can travel through a vacuum.

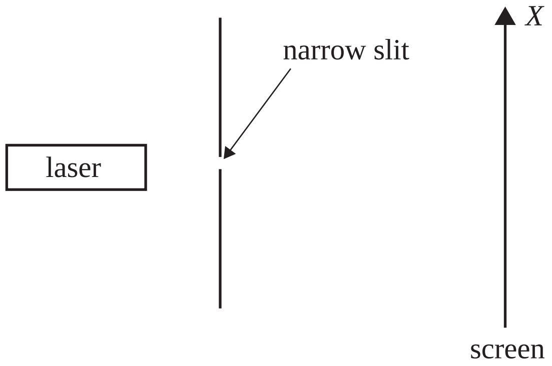
B. Neither sound waves nor electromagnetic waves can travel through a vacuum.

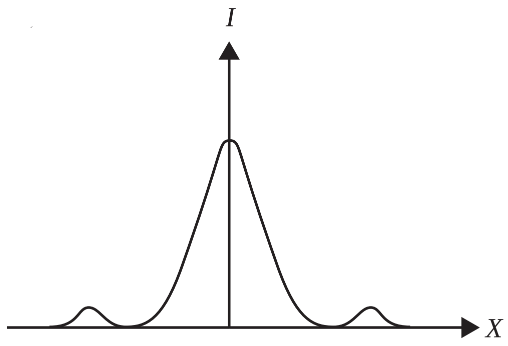
C. Sound waves can travel through a vacuum but electromagnetic waves cannot travel through a vacuum.

D. Sound waves cannot travel through a vacuum but electromagnetic waves can travel through a vacuum.

Question 15

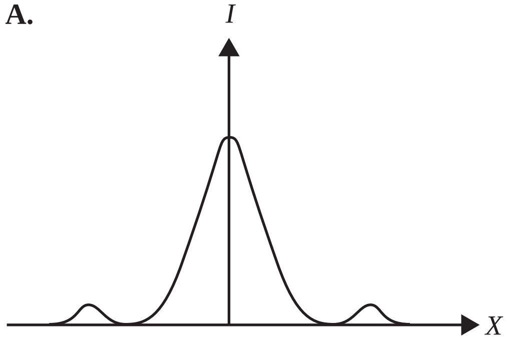
Monochromatic laser light of wavelength 600 nm shines through a narrow slit. The intensity of the transmitted light is recorded on a screen some distance away, as shown below in the diagram on the left. The intensity graph of the pattern seen on the screen is shown below on the right.



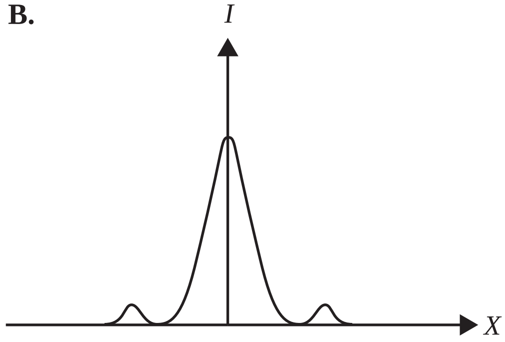


Which one of the following intensity graphs best represents the pattern that would be seen if a slightly wider slit were used?

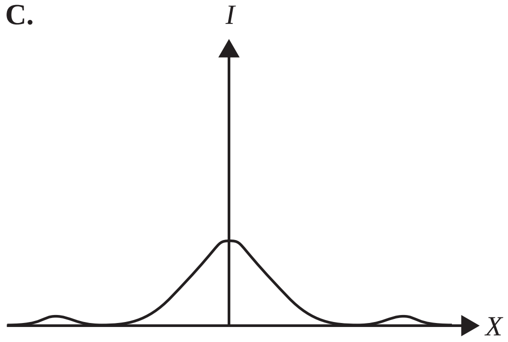
A.



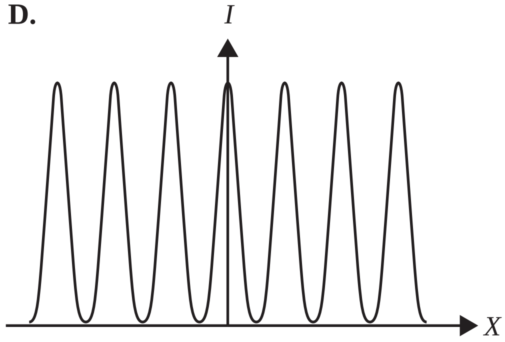
B.



C.

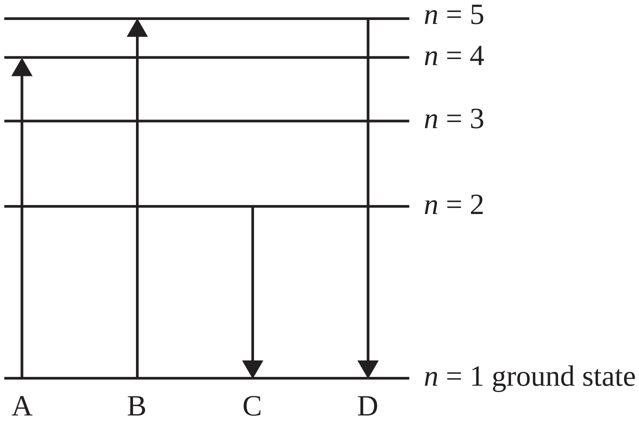


D.



Question 19

Part of the energy-level diagram for an unknown atom is shown below.



Which one of the arrows shows a change of energy level corresponding to the absorption of a photon of highest frequency?

A. A

B. B

C. C

D. D

END OF SECTION A
TURN OVER

Question 11 (6 marks)

Kym and Roger conduct an experiment to observe an electron diffraction pattern. 5000 eV electrons are projected through a diffracting grid and the resulting pattern is observed on a screen.

Kym and Roger want to calculate the wavelength of X-rays that would produce a similarly spaced diffraction pattern.

Kym says that they will need X-rays of 5000 eV.

Roger says that X-rays of a different energy will be needed.

a. Explain why Roger is correct. 2 marks

b. Showing each of the steps involved in your working, calculate the energy of X-rays that would be required to produce the similarly spaced diffraction pattern. 4 marks

eV

Question 12 (3 marks)

Optical fibres are constructed using transparent materials with differing refractive indices. A laser light beam of wavelength 590 nm is shone into the fibre and travels along the arrowed path shown in Figure 11.

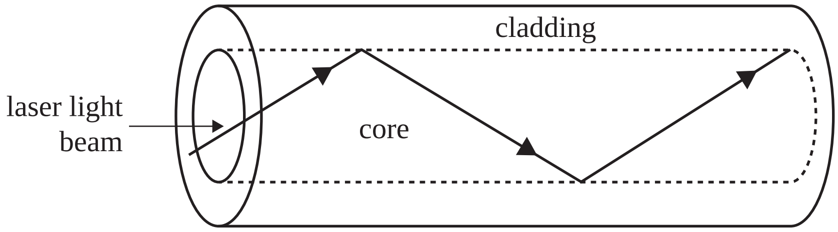


Figure 11

a. For the fibre to operate as designed, which must have the greater refractive index – the cladding or the core? 1 mark

---

b. The refractive index of the cladding is 1.42. The critical angle for light striking the core–cladding boundary is 66.0°.

Calculate the refractive index of the core material. Show your working. 2 marks

---

Question 13 (4 marks)

A seawall that is aligned north–south protects a harbour of constant depth from large ocean waves, as shown in Figure 12.

The seawall has two small gaps, S_1 and S_2, which are 60 m apart. Inside the harbour, a small boat sails north parallel to the seawall at a distance of 420 m from the seawall. At point C sits a beacon, equidistant from the two gaps in the seawall.

The boat's captain notices that, at about every 42 m, there is calm water, while there are large waves between those calm points.

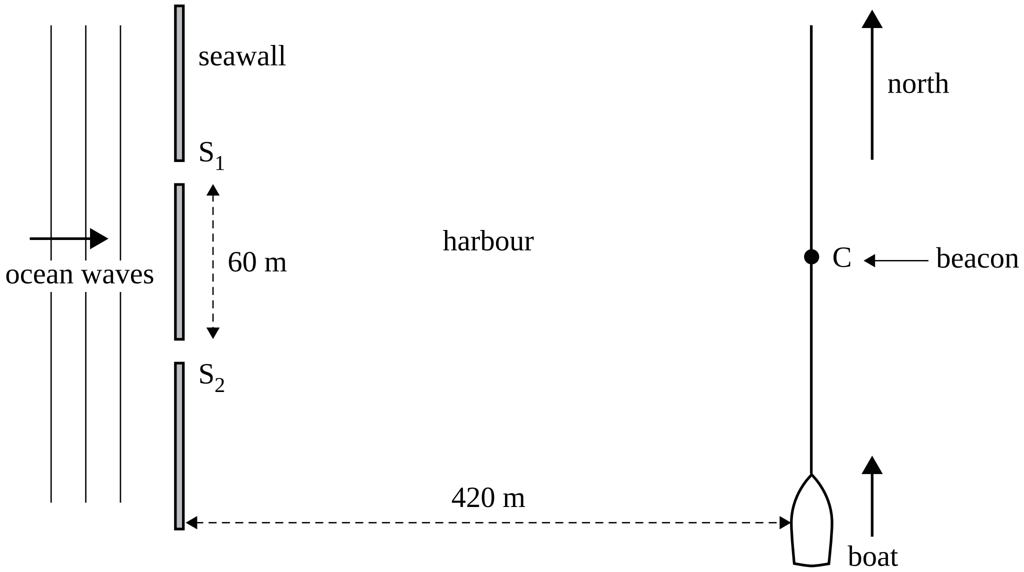


Figure 12

a. Will the beacon at point C be in calm water or large waves? Give a reason for your answer. 2 marks

b. Calculate the wavelength of the ocean waves. Show your working. 2 marks

m

Question 14 (6 marks)

Figure 13 shows a simple apparatus that can be used to determine the frequency of a tuning fork.

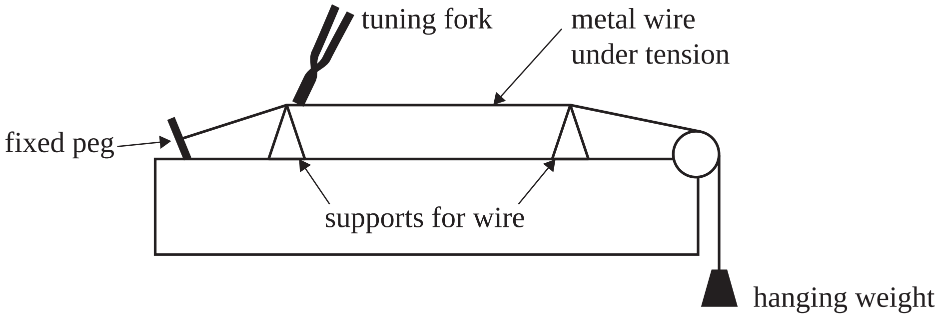


Figure 13

The apparatus consists of two supports and a metal wire that is stretched between a fixed peg and a hanging weight. The wire is under tension.

The tuning fork is set vibrating and is then touched onto the wire close to the left-hand support, which makes the wire vibrate at the same frequency as the tuning fork.

a. Draw a diagram of the simplest standing wave pattern that can exist on the vibrating section of the wire (the fundamental) between the two supports. 2 marks

b. When the distance between the supports is 0.92 m, the fundamental frequency resonates in the wire.

Calculate the wavelength of the fundamental. Show your working. 2 marks

m

c. Calculate the frequency of the tuning fork if the speed of the waves in the wire is 224 m s^{-1}. Show your working. 2 marks

Hz

Question 15 (6 marks)

Figure 14 shows the energy-level diagram for a hydrogen atom.

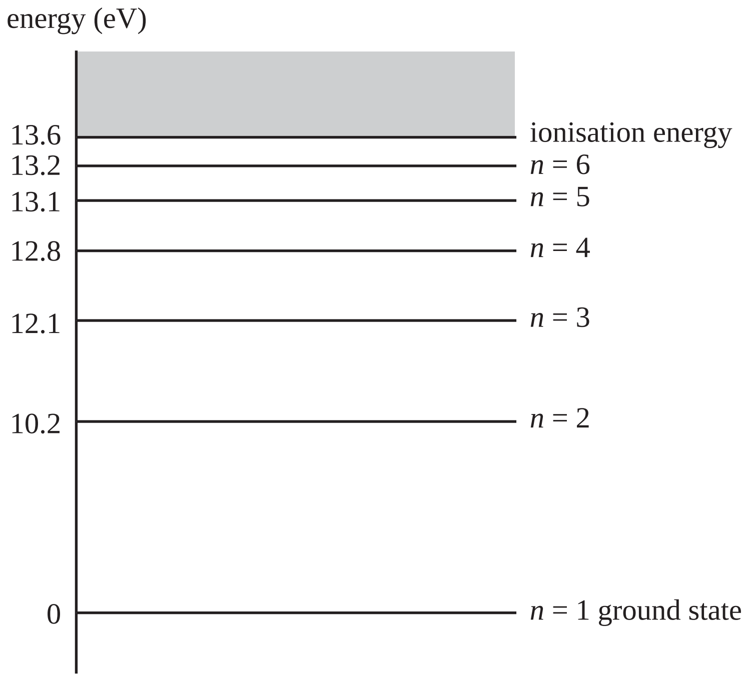


Figure 14

a. The hydrogen atom is excited from the ground state to a higher energy level. Subsequently, it makes a transition from this higher energy level to the $n = 3$ energy level, emitting a photon of wavelength 1242 nm.

What was the number, n, of the energy level before the photon was emitted? Show your working. 3 marks

$n =$

b. The quantised states of the electron of the hydrogen atom provide evidence of the wave–particle duality of the electron.

Describe how an electron in an allowed state is modelled to provide this evidence. You may include a diagram. 3 marks

Question 16 (8 marks)

April sets up the apparatus shown in Figure 15 to investigate the photoelectric effect. She can change the frequency of the light incident on the metal plate by changing the filter and she can change the type of metal of which the plate is made.

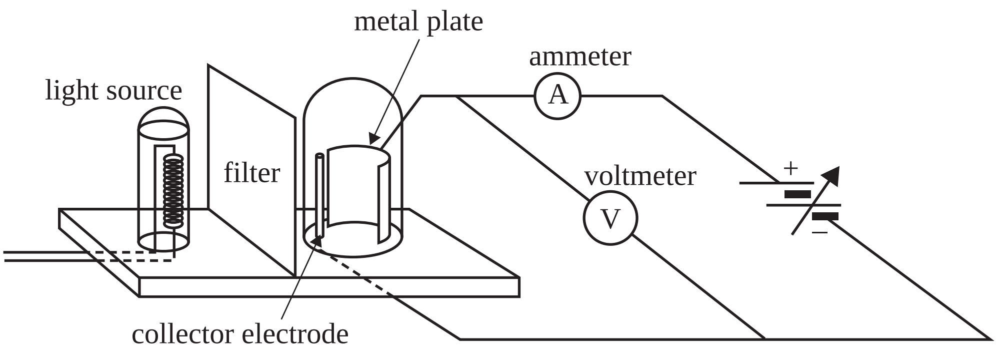


Figure 15

a. For her first experiment, April chooses a filter that gives light of frequency 7.13×10^{14} Hz and a metal plate made of caesium with a work function of 1.95 eV.

April adjusts the voltage of the collector electrode so that the current becomes smaller and smaller.

When the ammeter, A, reaches zero, April records the voltage shown on the voltmeter, V.

Use calculations to determine this voltage. 3 marks

V

b. For her second experiment, April uses a metal plate made of zinc. Zinc has a threshold frequency for emission of photoelectrons of 1.04×10^{15} Hz. Photoelectrons are emitted.

Calculate the maximum wavelength, in nanometres, of the light for photoelectrons to be emitted from the zinc plate. Show your working. 2 marks

nm

c. For her third experiment, April changes the metal plate from the zinc plate used in the second experiment to a plate made of platinum. Platinum has a threshold frequency of 1.53×10^{15} Hz. April uses light of frequency 7.13×10^{14} Hz but does not make any other changes. Photoelectrons are not emitted.

April observes for a longer time and then increases the intensity of the light beam but still finds that photoelectrons are not emitted.

Explain how April's observations support the particle model of light but do not support the wave model of light in explaining the photoelectric effect. 3 marks

Question 15

Electrons pass through a fine metal grid, forming a diffraction pattern.

If the speed of the electrons was doubled using the same metal grid, what would be the effect on the fringe spacing?

A. The fringe spacing would increase.

B. The fringe spacing would decrease.

C. The fringe spacing would not change.

D. The fringe spacing cannot be determined from the information given.

Question 11 (3 marks)

What is the second postulate of Einstein's theory of special relativity regarding the speed of light? Explain how the second postulate differs from the concept of the speed of light in classical physics.

Question 12 (3 marks)

A sinusoidal wave of wavelength 1.40 m is travelling along a stretched string with constant speed *v*, as shown in Figure 11. The time taken for point P on the string to move from maximum displacement to zero is 0.120 s.

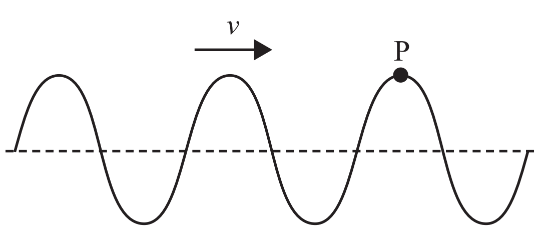


Figure 11

Calculate the speed of the wave, *v*. Give your answer correct to three significant figures. Show your working.

m s^{-1}

Question 13 (3 marks)

In an experimental set-up used to investigate standing waves, a 6.0 m length of string is fixed at both ends, as shown in Figure 12. The string is under constant tension, ensuring that the speed of the wave pulses created is a constant 40 m s^{-1}.

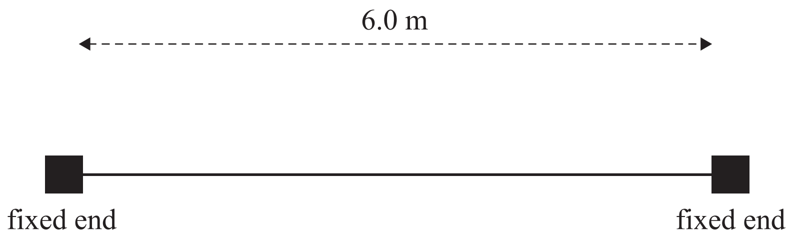


Figure 12

In an initial experiment, a continuous transverse wave of frequency 7.5 Hz is generated along the string.

a. Determine the wavelength of the transverse wave travelling along the string. 1 mark

m

b. Will a standing wave form? Give a reason for your answer. 2 marks

Question 14 (6 marks)

Students have set up a double-slit experiment using microwaves. The beam of microwaves passes through a metal barrier with two slits, shown as S_1 and S_2 in Figure 13. The students measure the intensity of the resulting beam at points along the line shown. They determine the positions of maximum intensity to be at the points labelled P_0, P_1, P_2 and P_3. Take the speed of electromagnetic radiation to be 3.00×10^8 m s^{-1}.

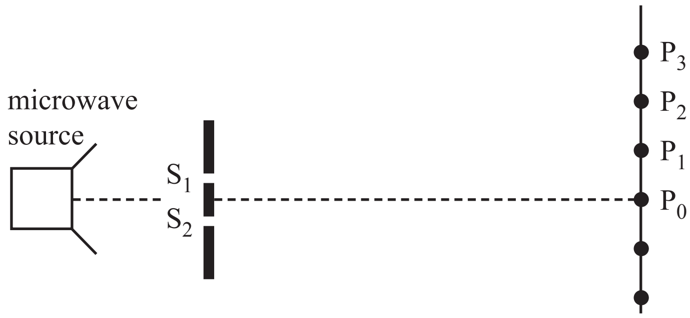


Figure 13

The distance from S_1 to P_3 is 72.3 cm and the distance from S_2 to P_3 is 80.6 cm.

a. What is the frequency of the microwaves transmitted through the slits? Show your working. 2 marks

Hz

b. The signal strength is at a minimum approximately midway between points P_0 and P_1.

Explain the reason why the signal strength would be a minimum at this location. 2 marks

c. The microwaves from the source are polarised.

Explain what is meant by the term ‘polarised’. You may use a diagram in your answer. 2 marks

Question 15 (4 marks)

A student sets up an experiment involving a source of white light, a glass prism and a screen. The path of a single ray of white light when it travels through the prism and onto the screen is shown in Figure 14.

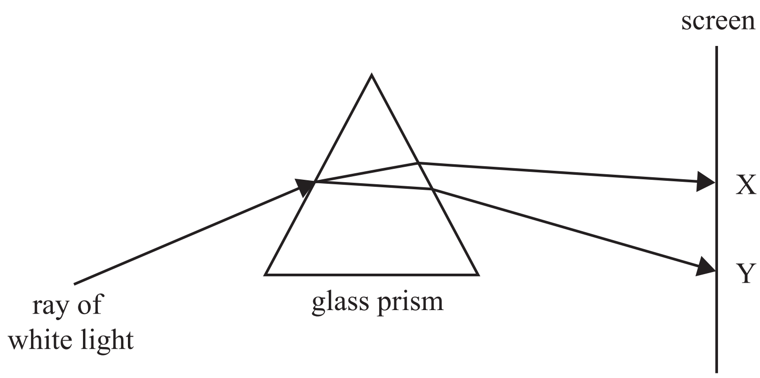


Figure 14

A spectrum of colours is observed by the student on the screen, which is positioned to the right of the prism.

a. Name and explain the effect observed by the student. 3 marks

____

____

____

____

____

b. Points X and Y on Figure 14 represent either end of the visible spectrum observed by the student.

Identify the two visible colours observed at point X and at point Y. 1 mark

Point X ______________ Point Y ______________

Question 16 (6 marks)

Students are studying the photoelectric effect using the apparatus shown in Figure 15.

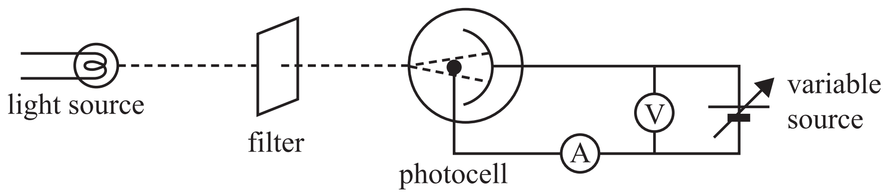


Figure 15

Figure 16 shows the results the students obtained for the maximum kinetic energy ($E_{k\ max}$) of the emitted photoelectrons versus the frequency of the incoming light.

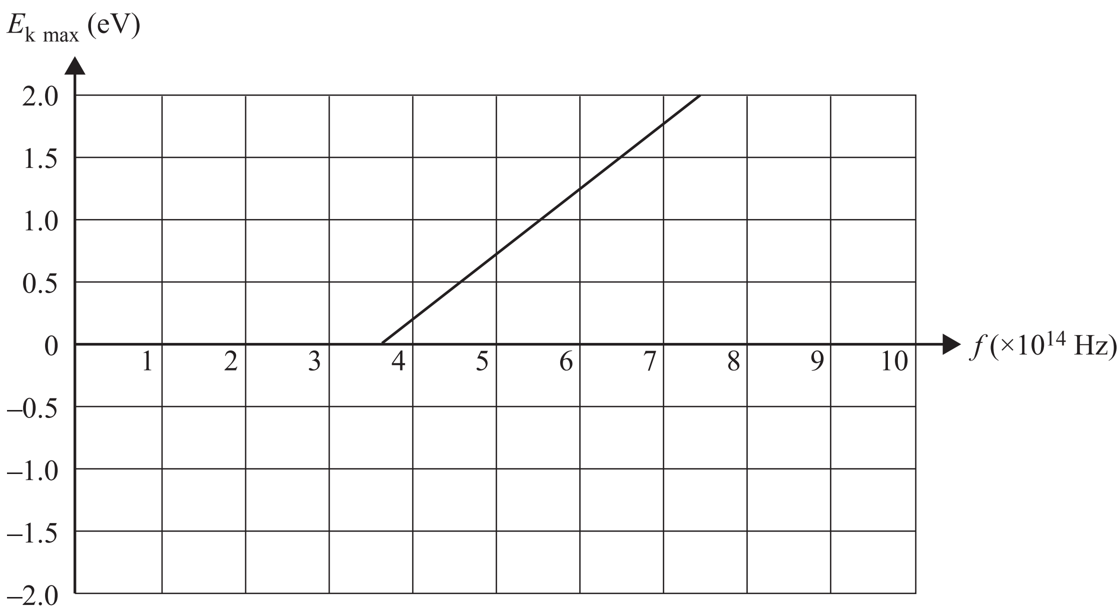


Figure 16

a. Using only data from the graph, determine the values the students would have obtained for

i. Planck's constant, h. Include a unit in your answer — 2 marks

ii. the maximum wavelength of light that would cause the emission of photoelectrons 1 mark

nm

iii. the work function of the metal of the photocell. 1 mark

eV

b. The work function for the original metal used in the photocell is ϕ.

On Figure 17, draw the line that would be obtained if a different metal, with a work function of $\frac{1}{2}\phi$, were used in the photocell. The original graph is shown as a dashed line. 2 marks

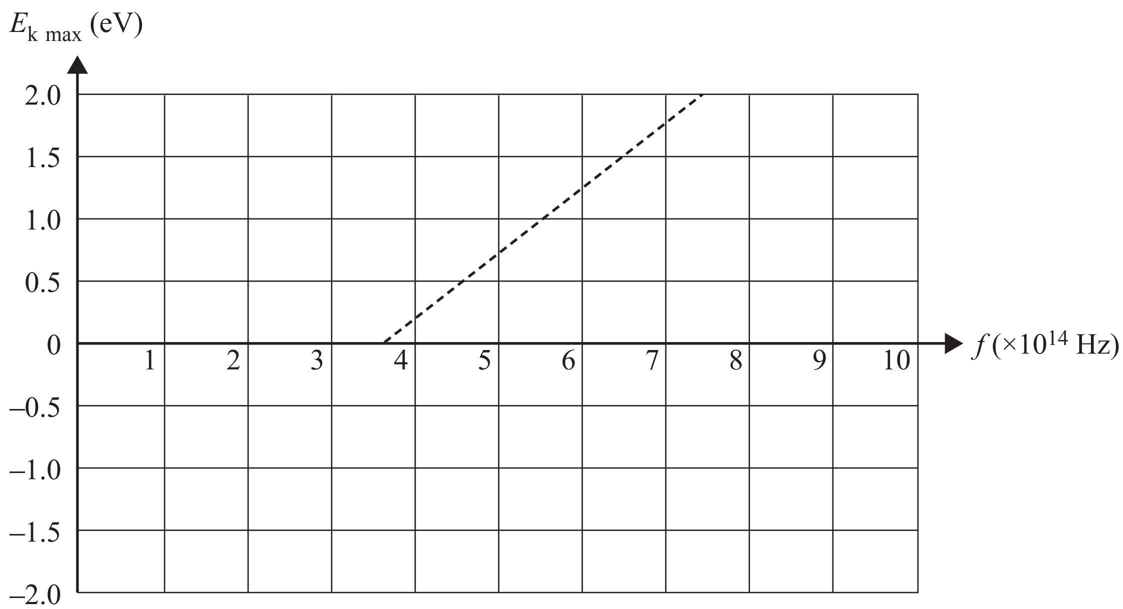
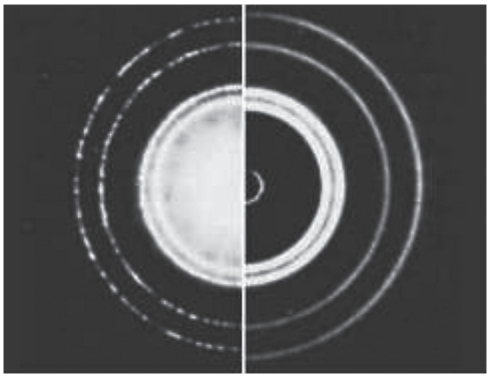


Figure 17

Question 17 (7 marks)

Students are comparing the diffraction patterns produced by electrons and X-rays, in which the same spacing of bands is observed in the patterns, as shown schematically in Figure 18. Note that both patterns shown are to the same scale.



electrons X-rays

Figure 18

The electron diffraction pattern is produced by 3.0×10^3 eV electrons.

a. Explain why electrons can produce the same spacing of bands in a diffraction pattern as X-rays. 3 marks

b. Calculate the frequency of X-rays that would produce the same spacing of bands in a diffraction pattern as for the electrons. Show your working. 4 marks

Hz

Question 18 (5 marks)

The energy level diagram for a hydrogen atom is shown in Figure 19.

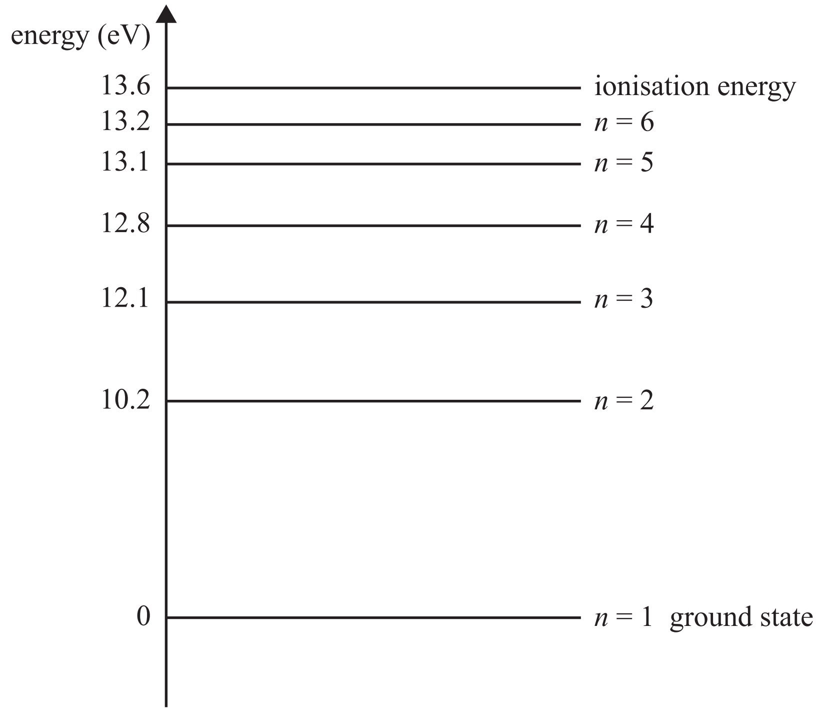


Figure 19

a. A hydrogen atom in the ground state is excited to the $n = 4$ state.

Explain how the hydrogen atom could be excited to the $n = 4$ state in one step. 2 marks

b. List the possible photon energies that could be emitted as the atom goes from the $n = 4$ state to the $n = 2$ state. 3 marks

Question 18

Quantised energy levels within atoms can best be explained by

A. electrons behaving as individual particles with different energies.

B. electrons behaving as waves, with each energy level representing a diffraction pattern.

C. protons behaving as waves, with only standing waves at particular wavelengths allowed.

D. electrons behaving as waves, with only standing waves at particular wavelengths allowed.

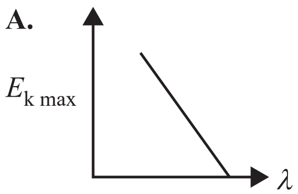
Question 20

When photons with energy E strike a metal surface, electrons may be emitted.

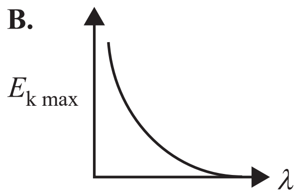
The maximum kinetic energy, $E_{k\ max}$, of the emitted electrons is given by $E_{k\ max} = E - W$, where W is the work function of the metal.

Which one of the following graphs best shows the relationship between the maximum kinetic energy of these electrons, $E_{k\ max}$, and the wavelength of the photons, λ?

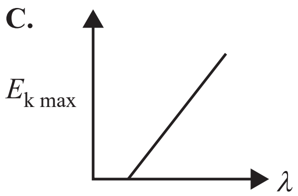
A.



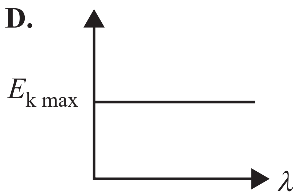
B.



C.



D.



END OF SECTION A

Question 11 (4 marks)

An astronaut has left Earth and is travelling on a spaceship at $0.800c$ ($\gamma = 1.67$) directly towards the star known as Sirius, which is located 8.61 light-years away from Earth, as measured by observers on Earth.

a. How long will the trip take according to a clock that the astronaut is carrying on his spaceship? Show your working. 2 marks

years

b. Is the trip time measured by the astronaut in **part a.** a proper time? Explain your reasoning. 2 marks

Question 12 (5 marks)

In a Young's double-slit interference experiment, laser light is incident on two slits, S_1 and S_2, that are 4.0×10^{-4} m apart, as shown in Figure 11a.

Rays from the slits meet on a screen 2.00 m from the slits to produce an interference pattern. Point C is at the centre of the pattern. Figure 11b shows the pattern obtained on the screen.

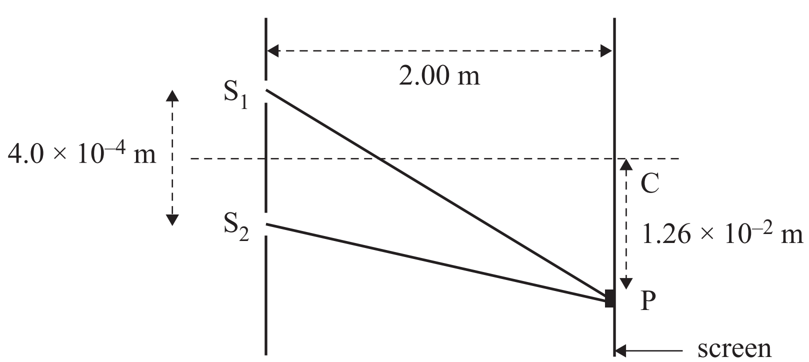


Figure 11a

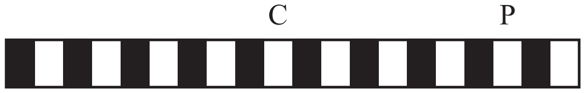


Figure 11b

a. There is a bright fringe at point P on the screen.

Explain how this bright fringe is formed. 2 marks

b. The distance from the central bright fringe at point C to the bright fringe at point P is 1.26×10^{-2} m.

Calculate the wavelength of the laser light. Show your working. 3 marks

nm

Question 14 (3 marks)

Figure 13 shows a representation of an electromagnetic wave.

Correctly label Figure 13 using the following symbols.

E – electric field B – magnetic field c – speed of light λ – wavelength

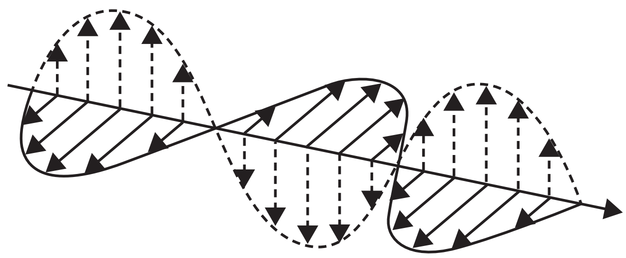


Figure 13

Question 15 (4 marks)

The metal surface in a photoelectric cell is exposed to light of a single frequency and intensity in the apparatus shown in Figure 14.

The voltage of the battery can be varied in value and reversed in direction.

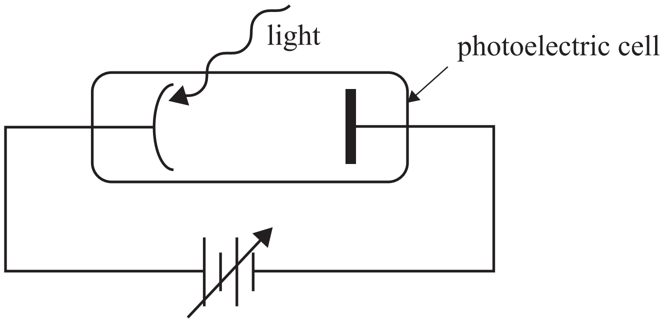


Figure 14

a. A graph of photocurrent versus voltage for one particular experiment is shown in Figure 15.

On Figure 15, draw the trace that would result for another experiment using light of the same frequency but with triple the intensity. 2 marks

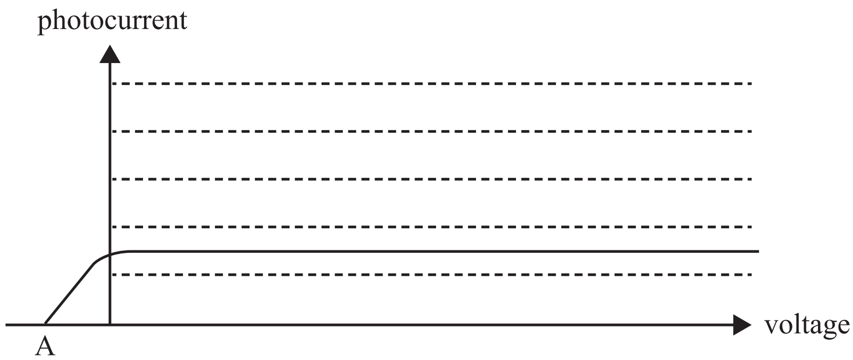


Figure 15

b. What is a name given to the point labelled A on Figure 15? 1 mark

____

c. Why does the photocurrent fall to zero at the point labelled A on Figure 15? 1 mark

____

____

Question 16 (5 marks)

A beam of electrons travelling at 1.72×10^5 m s^{-1} illuminates a crystal, producing a diffraction pattern as shown in Figure 16. Take the mass of an electron to be 9.1×10^{-31} kg. Ignore relativistic effects.

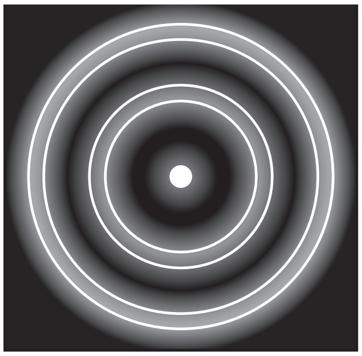


Figure 16

a. Calculate the kinetic energy of one of the electrons. Show your working. 2 marks

eV

b. The electron beam is now replaced by an X-ray beam. The resulting diffraction pattern has the same spacing as that produced by the electron beam.

Calculate the energy of one X-ray photon. Show your working. 3 marks

eV

Question 17 (5 marks)

Figure 17 shows the emission spectrum for helium gas.

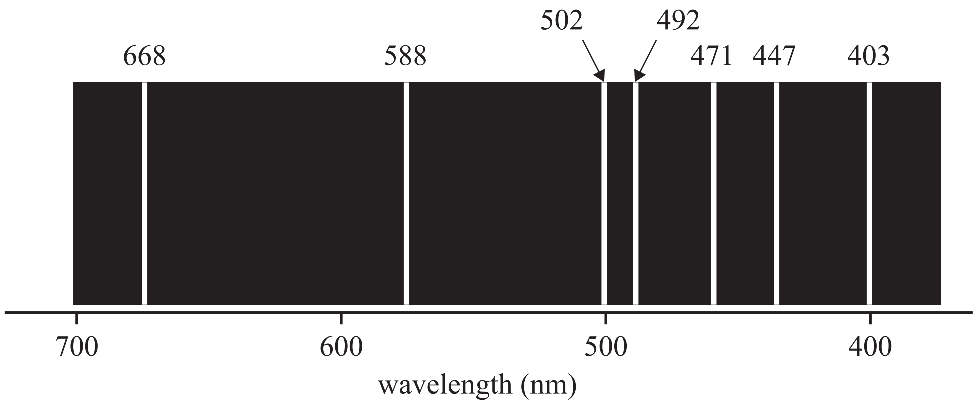


Figure 17

a. Which spectral line indicates the photon with the lowest energy? 1 mark

nm

b. Calculate the frequency of the photon emitted at the 588 nm line. Show your working. 2 marks

Hz

c. Explain why only certain wavelengths and, therefore, certain energies are present in the helium spectrum. 2 marks

Question 11 (4 marks)

A transverse wave is travelling through a medium, as shown in Figure 14. The frequency of the source producing the wave is 40 Hz and the wave travels at a speed of 35 m s^{-1}. The amplitude of the wave is 0.50 m.

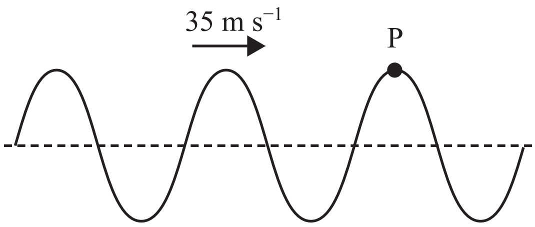


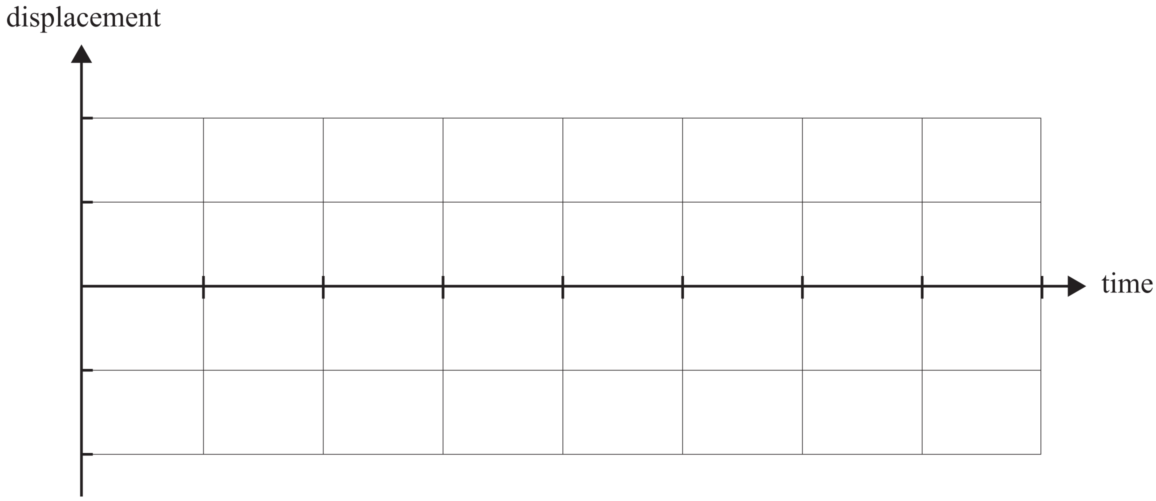
Figure 14

a. What is the period of oscillation for point P in Figure 14? 1 mark

____

ms

b. On the axes below, sketch the displacement versus time graph for the point P of this transverse wave, showing at least **two** complete cycles. Include scales and units on each axis. 3 marks



Question 12 (5 marks)

Students are testing two identical radio transmitters, R1 and R2, on a football field. The transmitters are positioned 24 m apart, as shown in Figure 15. The transmitters are in phase, both emitting crests simultaneously, and emit waves of wavelength 18 m in all directions. The students are standing at point X, which is located 72 m away from the nearest transmitter, R1.

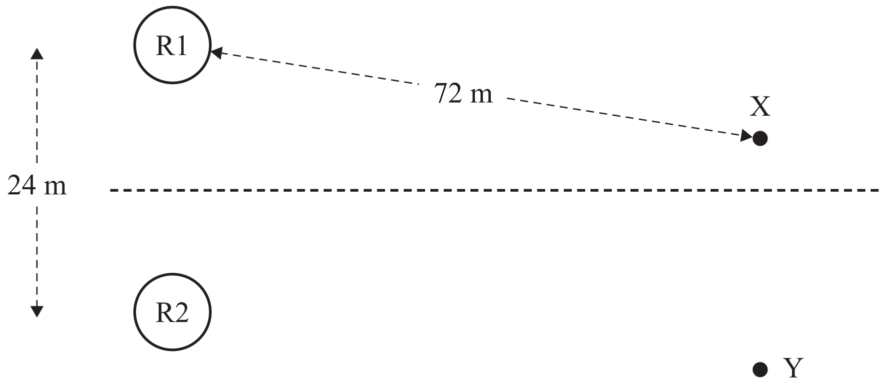


Figure 15

a. During testing, the radio signal received at point X is detected to be a minimum.

Calculate the shortest distance that point X could be from R2. Show your working. 2 marks

m

b. At another location on the football field, point Y, the students detect a maximum.

Explain why the two observations at points X and Y would support the wave model of light. 3 marks

Question 13 (4 marks)

The boundary between two transparent materials, Medium 1 and Medium 2, each having different refractive indices, is shown in Figure 16. An incident ray at an angle θ_i is also shown.

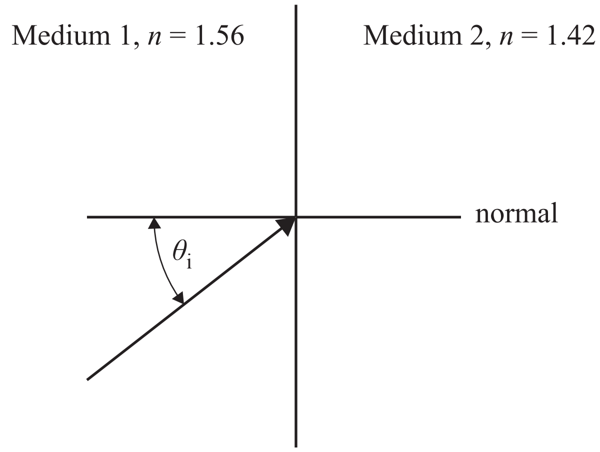


Figure 16

a. The refracted ray appears in Medium 2.

Sketch the approximate direction of the refracted ray in Medium 2 on Figure 16. 1 mark

b. What range of incident angles, θ_i, would result in a light ray emerging in Medium 2? Show your working. 3 marks

Question 14 (2 marks)

To explain different aspects of mechanical waves, a Physics teacher sets up a demonstration in a Physics laboratory using a 0.80 m wide loudspeaker and a microphone. The microphone measures the sound intensity at different positions on a circle around the speaker from position A to position B, as shown in Figure 17.

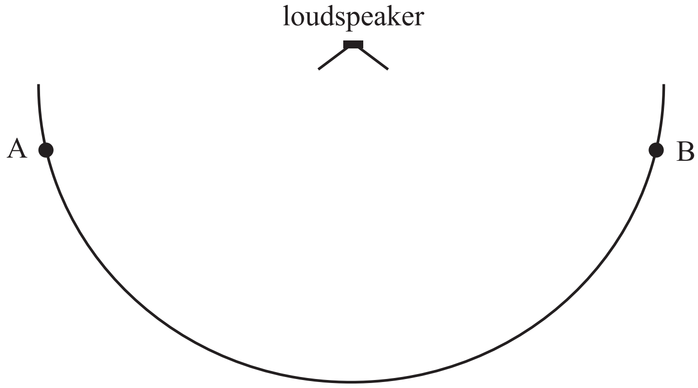


Figure 17

The speed of sound in the Physics laboratory is 334 m s^{-1}. Measurements are made at frequencies of 100 Hz and 10 000 Hz. The loudspeaker emits the 100 Hz and 10 000 Hz frequencies with equal intensity. Figure 18 shows the intensity, *I*, measured for each frequency at positions on the semicircular line shown in Figure 17 between positions A and B.

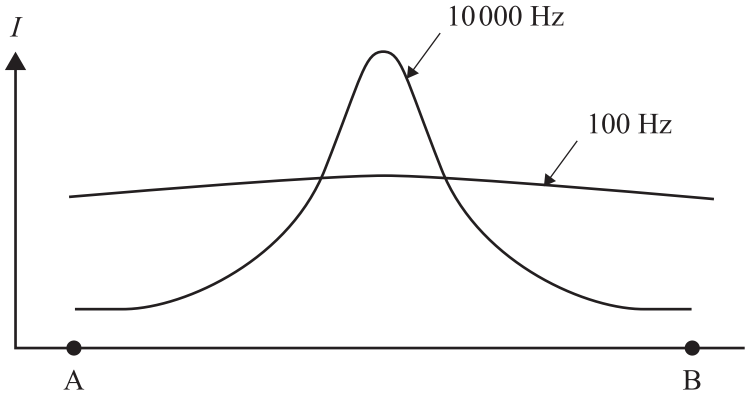


Figure 18

Explain why the response at 10 000 Hz has a greater intensity directly in front of the loudspeaker, while the response at 100 Hz is nearly the same at all positions.

Question 15 (7 marks)

The apparatus shown in Figure 19 is used to investigate the photoelectric effect. Light of various wavelengths is shone onto a silver plate (cathode). The work function of silver is 4.9 eV.

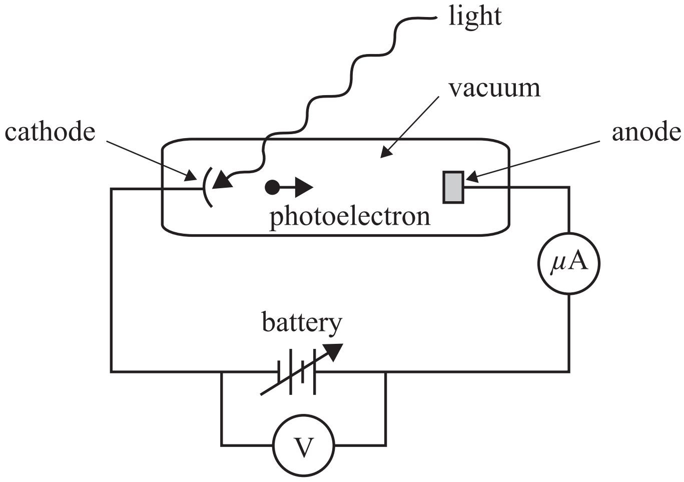


Figure 19

a. Explain what happens when light of wavelength 400 nm hits the silver plate. Use calculations to support your answer. 2 marks

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b. Explain what happens when light with a photon energy of 5.4 eV hits the silver plate. 2 marks

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c. Which model of light does this photoelectric investigation support? Give two reasons to justify your answer. 3 marks

Model of light ____

1. ____

____

2. ____

____

Question 16 (6 marks)

X-rays of wavelength 2.0 nm are emitted from an X-ray source.

a. Calculate the energy of **one** photon of these X-rays. Show your working. 3 marks

eV

b. The 2.0 nm X-rays are incident on a single narrow slit of width 5×10^{-8} m.

Would a diffraction pattern be observed? Justify your answer. 3 marks

Question 17 (5 marks)

Light from a mercury vapour lamp shows a line spectrum related to discrete energy levels. Some of the energy levels for the mercury atom are shown in Figure 20.

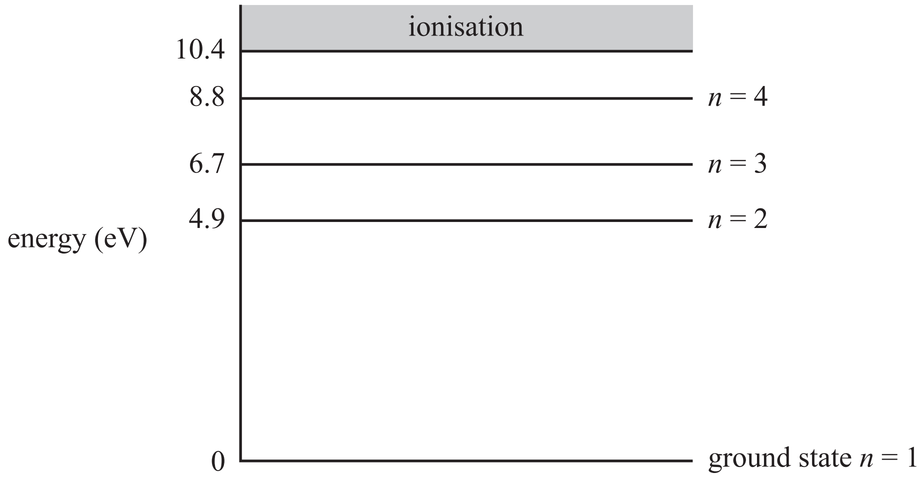

Figure 20

a. Draw an arrow on Figure 20 to indicate the transition between the listed energy states that would produce the lowest frequency of an emitted photon. 1 mark

b. Calculate the energy of the light emitted when the mercury atom makes a transition from the third energy level ($n = 3$) to its ground state ($n = 1$). Show your working. 2 marks

J

c. Explain what happens to a mercury atom in its ground state if a photon of energy 2.1 eV is incident on it. 2 marks