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.

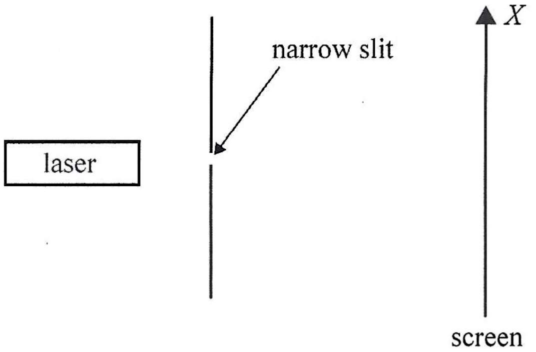
B. Neither sound waves nor electromagnetic waves can travel through a vacuum.

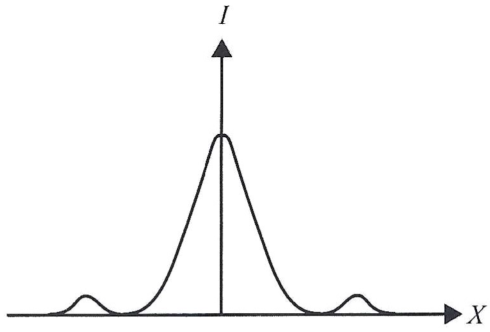
C. Sound waves can travel through a vacuum but electromagnetic waves cannot travel through a vacuum.

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

Question 15

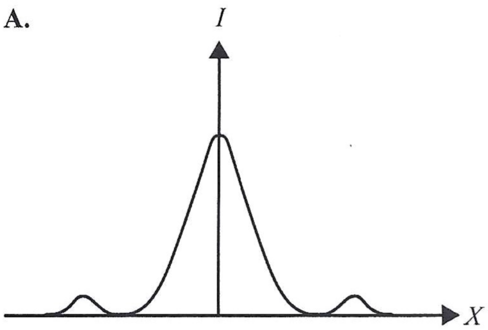
Monochromatic laser light of wavelength 600 nm shines through a narrow slit. The intensity of the transmitted light is recorded on a screen some distance away, as shown below in the diagram on the left. The intensity graph of the pattern seen on the screen is shown below on the right.



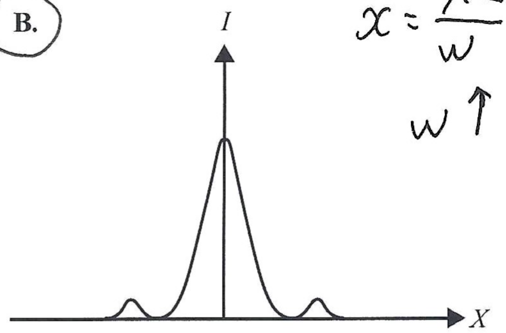


Which one of the following intensity graphs best represents the pattern that would be seen if a slightly wider slit were used?

A.



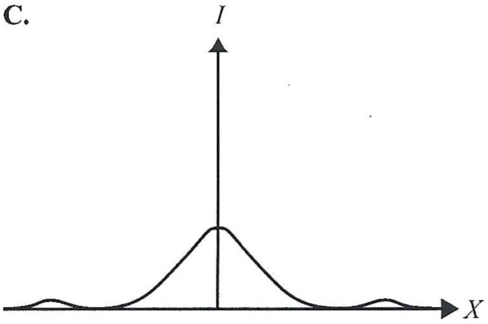
B.



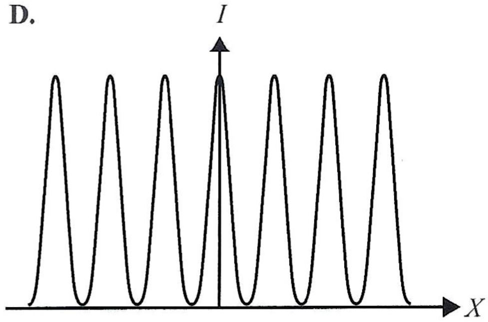
$x = \frac{\lambda L}{w}$

$w \uparrow \; x \downarrow$

C.

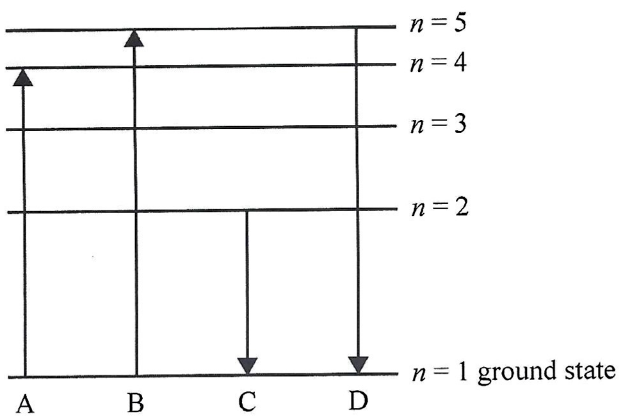


D.



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

Same diffraction pattern means same wavelength. Same wavelength means same momentum $p = \frac{h}{\lambda}$. Same momentum means different energy. $E_{X\text{-ray}} = pc$ $E_{el} = \frac{p^2}{2m}$

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

~~$E_{el} = \frac{mv^2}{2}$ $v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2 \times 5000 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}} = 4.2 \times 10^7 \text{ ms}^{-1}$~~

$p_{el} = \sqrt{2mE} = \sqrt{2 \times 9.1 \times 10^{-31} \times 5000 \times 1.6 \times 10^{-19}}$

$= 3.8 \times 10^{-23}$ Ns

$E_{X Ray} = pc = 3.8 \times 10^{-23} \times 3 \times 10^8 = 1.14 \times 10^{-14}$ J

$\frac{1.14 \times 10^{-14} \text{ J}}{1.6 \times 10^{-19}} = 7.1 \times 10^4$

7.1×10^4 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.

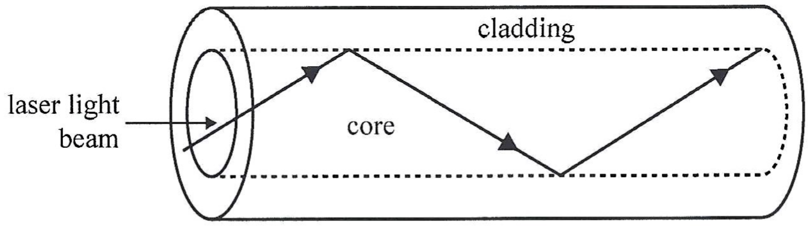


Figure 11

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

The core. Total internal reflection can happen only when light going from higher refractive index

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

$\sin \theta_c = \frac{n_2}{n_1}$

$n_1 = \frac{1.42}{\sin 66^\circ}$

1.55

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.

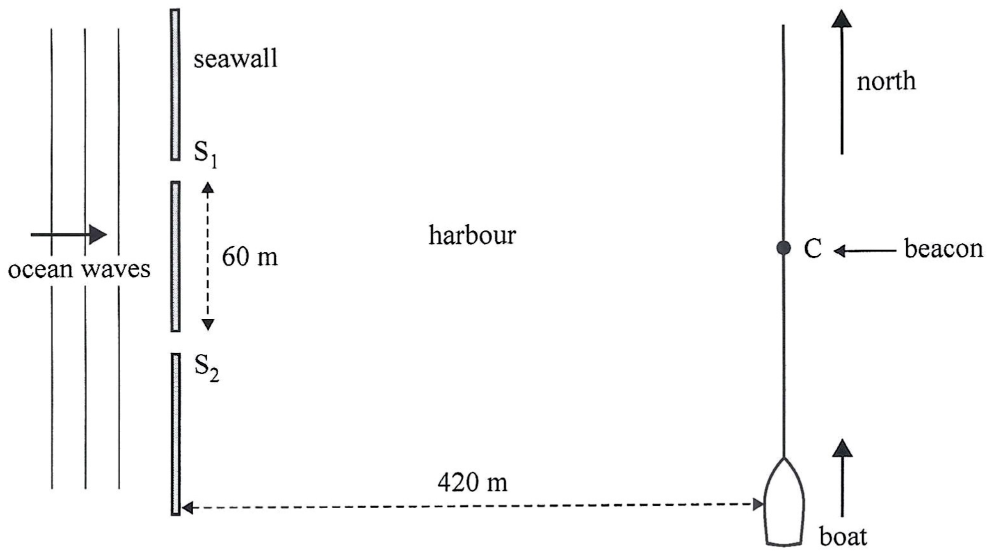


Figure 12

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

Large wave. As the path difference $S_2C - S_1C = 0$ there will be constructive interference.

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

$\Delta x = \frac{\lambda L}{d}$ $\lambda = \frac{d \Delta x}{L} = \frac{60 \times 42}{420} = 6$ m

6 m

Question 14 (6 marks)

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

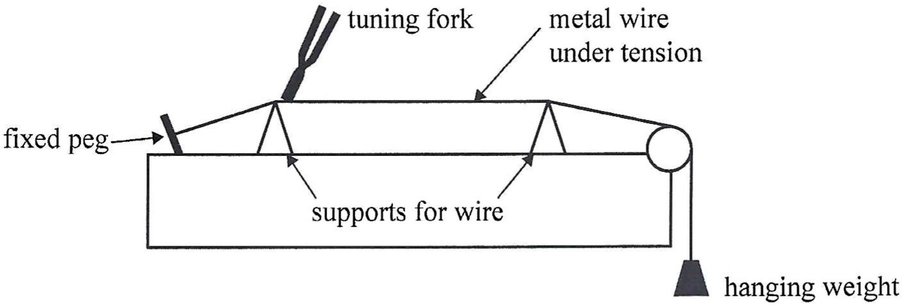
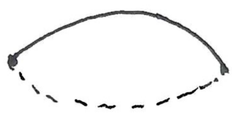


Figure 13

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

$\lambda = 2L = 2 \times 0.92$

$= 1.84$

1.84 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

$v = \lambda f \quad f = \frac{v}{\lambda} = \frac{224}{1.84} = 122$

122 Hz

Question 15 (6 marks)

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

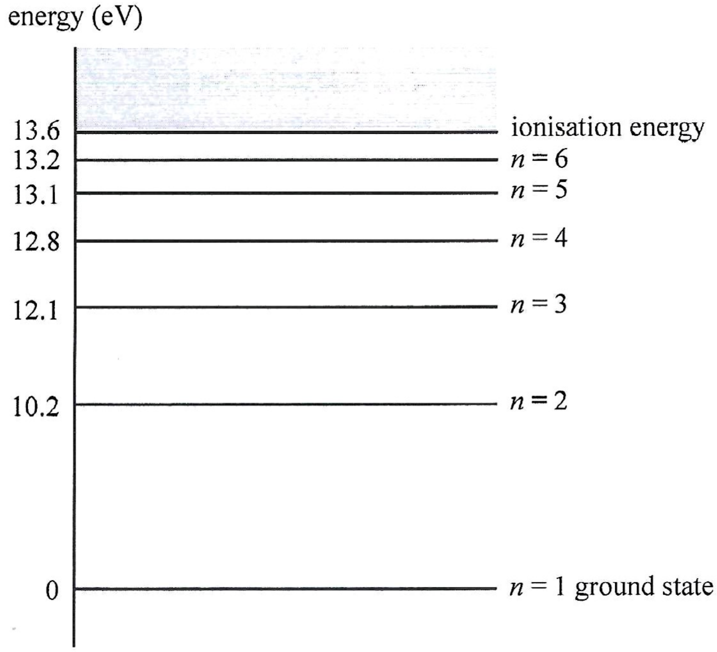


Figure 14

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

$$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{1242 \times 10^{-6}} = 1.0 \text{ eV}$$

$12.1 + 1 \text{ eV} = 13.1 \text{ eV}$

$n =$ 5

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

Electrons can behave as a wave with deBroglie wavelength. Stable energy levels can exist when circumference of the orbit equal to $n\lambda$, where n is a whole number. In this case standing wave is formed.

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.

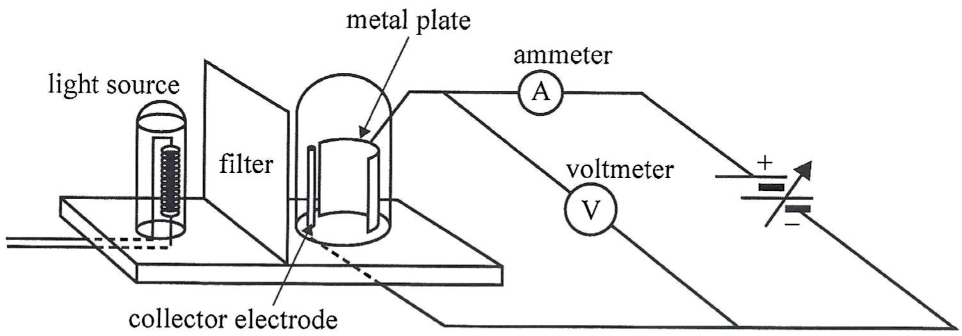


Figure 15

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

$E_{ph} = hf = 4.14 \times 10^{-15} \times 7.13 \times 10^{14} = 2.95\,eV$

$V_{st} = 2.95 - 1.95 = 1\,V$

1 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

$\lambda = \frac{c}{f} = \frac{3 \times 10^{8}}{1.04 \times 10^{15}}$

$= 2.88 \times 10^{-7}$

288 nm