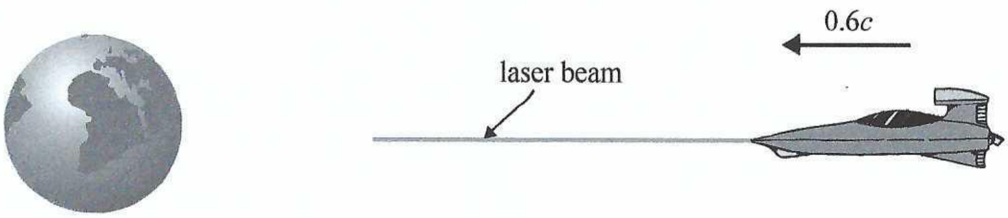
Question 11

An alien spaceship has entered our solar system and is heading directly towards Earth at a speed of $0.6c$, as shown in the diagram below. When it reaches a distance of 3.0×10^{11} m from Earth (in Earth's frame of reference), the aliens transmit a 'be there soon' signal via a laser beam.



How long will it take for the signal to reach Earth according to an observer on Earth?

A. 1.0 s

B. 1.7 s

C. 625 s

D. 1000 s

Question 12

A golf club strikes a stationary golf ball of mass 0.040 kg. The golf club is in contact with the ball for one millisecond. The ball moves off at 50 m s^{-1}.

The average force exerted by the club on the ball is closest to

A. 2.0 N

B. 1.0×10^3 N

C. 2.0×10^3 N

D. 1.0×10^6 N

✓

Question 13

Which one of the following statements about the polarisation of waves is **true**?

A. Only electromagnetic waves can be polarised.

B. Both longitudinal and transverse waves can be polarised.

C. Longitudinal waves can be polarised but transverse waves cannot be polarised.

D. Transverse waves can be polarised but longitudinal waves cannot be polarised.

✓

Question 14

Which one of the following best describes electromagnetic waves?

A. They all travel at the same speed in all mediums.

B. They all travel at the same speed in a vacuum.

C. They are not reflected by a surface.

D. They always travel in straight lines.

✓

Question 15

Which of the following best gives the different regions of the electromagnetic spectrum in order from longest wavelength to shortest wavelength?

A. ultraviolet, visible light, infra-red, microwaves

B. microwaves, ultraviolet, visible light, infra-red

C. visible light, ultraviolet, infra-red, microwaves

D. microwaves, infra-red, visible light, ultraviolet

✓ **Question 11** (7 marks)

Students are using a microwave set to study wave interference.

The set consists of:

- a microwave transmitter that can be set to produce microwaves of wavelength 3.0 cm or 6.0 cm
- a receiver that measures the intensity of the received signal and the wavelength
- plates that can be used to give single or double slits of various widths and separations
- a ruler.

Take the speed of microwaves to be 3.0×10^8 m s^{-1}.

✓ **a.** Calculate the frequency of the 3 cm microwaves. 1 mark

$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{3 \times 10^{-2}}$

10^{10} Hz

✓ **b.** The students set up the equipment using 3.0 cm microwaves, placing the receiver at X on the second nodal line (minima) out from the centre, as shown in Figure 9.

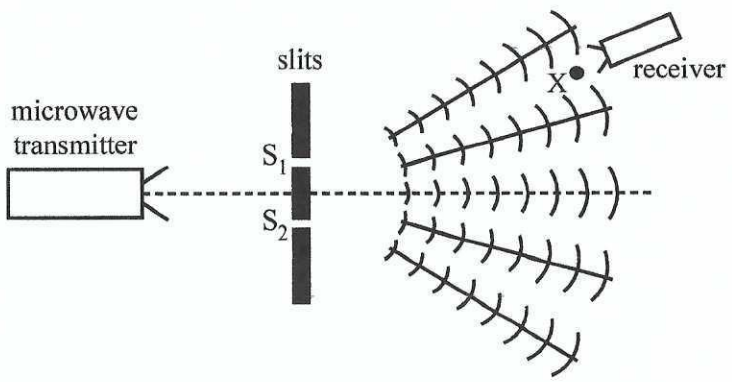


Figure 9

Calculate the path difference $S_2X - S_1X$. Show your working. 2 marks

X is second minimum

$pd = \frac{3\lambda}{2}$

4.5 cm

✓ **c.** The students now replace the two slits with a slit of width *w*, as shown in Figure 10.

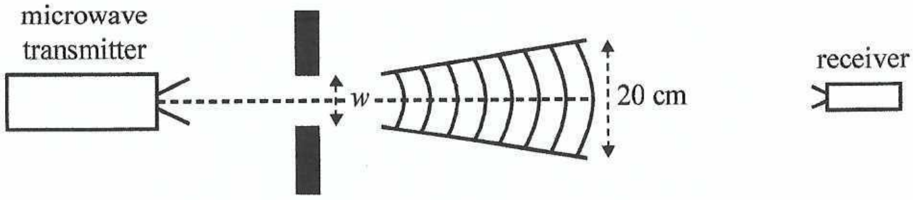


Figure 10

With the transmitter set to a wavelength of 3.0 cm, the students measure the width of the diffraction pattern to be 20 cm at a particular distance from the slit, as shown in Figure 10. They then switch to a 6.0 cm wavelength on the transmitter.

What effect will this have on the width of the pattern? Explain your answer. 2 marks

Width of the pattern proportional to $\frac{\lambda}{w}$.
$\lambda \uparrow \rightarrow$ width $\uparrow$

✓ **d.** With the transmitter reset to a wavelength of 3.0 cm, the students place the receiver on a cart. With the cart stationary, the receiver measures the wavelength to be 3.0 cm exactly. The cart is now set moving away from the transmitter, as shown in Figure 11.

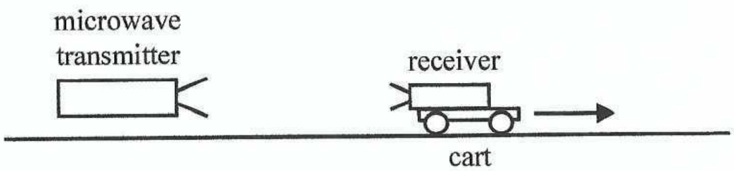


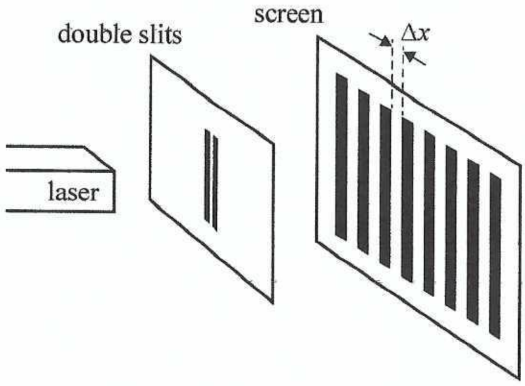
Figure 11

Will this movement increase, decrease or leave unchanged the wavelength as measured by the receiver on the cart? Explain your answer and name the physical principle involved. 2 marks

Wavelength will be measured as longer. This is due to the Doppler effect

Question 12 55%

A teacher sets up an apparatus to demonstrate Young's double-slit experiment. A pattern of bright and dark bands is observed on the screen, as shown below.



Which one of the following actions will increase the distance, Δx, between the adjacent dark bands in this interference pattern?

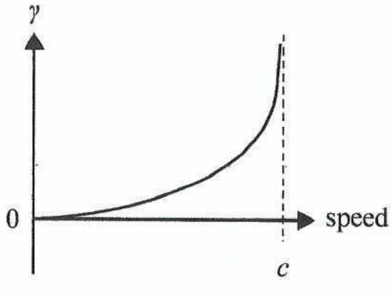
A. Decrease the distance between the slits and the screen.
B. Decrease the wavelength of the light.
(C.) Decrease the slit separation.
D. Decrease the slit width.

$\Delta x = \frac{\lambda L}{d}$

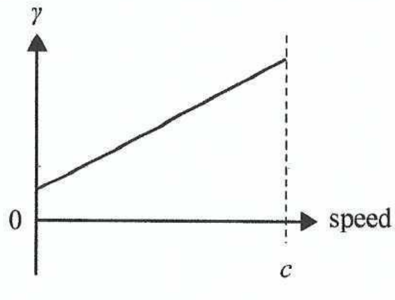
Question 13

Which one of the following diagrams best represents the graph of γ (the Lorentz factor) versus speed for an electron that is accelerated from rest to near the speed of light, c?

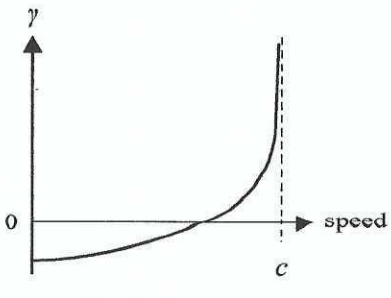
A.



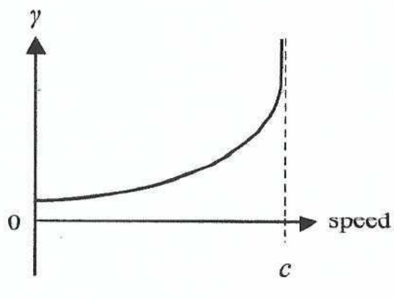
B.



C.



D.



✓ **Question 11** (4 marks)

Figure 13 shows two speakers, A and B, facing each other. The speakers are connected to the same signal generator/amplifier and the speakers are simultaneously producing the same 340 Hz sound.

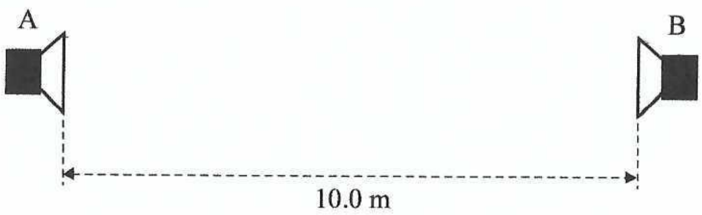


Figure 13

Take the speed of sound to be 340 m s^{-1}.

a. Calculate the wavelength of the sound. 1 mark

92%

$\lambda = \frac{v}{f} = \frac{340}{340}$

1 m

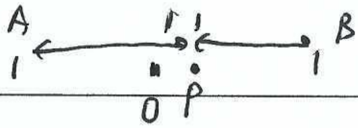
b. A student stands in the centre, equidistant from speakers A and B. He then moves towards speaker B and experiences a sequence of loud and quiet regions. He stops at the second region of quietness.

How far has the student moved from the centre? Explain your reasoning. 3 marks

5%

0.75 m

$Pd = \frac{3\lambda}{2} = 1.5$ m



AO = OB

AP − PB = 1.5 m

AP = AO + OP

BP = BO − OP

AP − BP = 2|OP|

|OP| = 0.75

✓ **Question 13** (7 marks)

Physics students studying interference set up a double-slit experiment using a 610 nm laser, as shown in Figure 15.

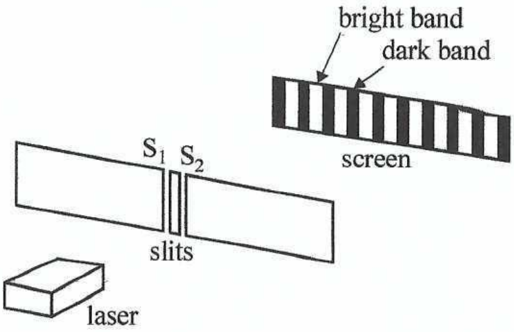


Figure 15

The light power output of the laser is 5.03×10^{-3} J s^{-1}.

✓ **a.** Calculate the number of photons leaving the laser each second. Show your working. 3 marks

Energy of 1 photon $E = \frac{hc}{\lambda} = \frac{6.63\times10^{34} \times 3\times10^{8}}{6.1\times10^{-7}} = 3.26\times10^{-19}$ J 31%

Number of photons $n = \frac{\text{total energy per second}}{\text{energy of 1 photon}}$ ~~number of~~

$= \frac{5.03\times10^{-3}}{3.26\times10^{-19}}$

1.54×10^{16}

A section of the interference pattern observed by the students is shown in Figure 16. There is a bright band at point C, the centre point of the pattern.

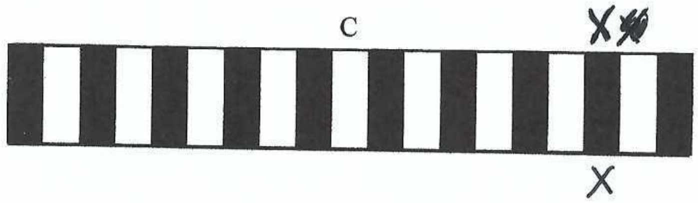


Figure 16

b. Explain why point C is in a bright band rather than in a dark band. 2 marks

Path difference $S_1C - S_2C = 0$ so constructive interference occure at C

32 %

c. Another point on the pattern to the right of point C is further from S_1 than S_2 by a distance of 2.14×10^{-6} m.

Mark this point on Figure 16 by writing an X above the point. You must use a calculation to justify your answer. 2 marks

$Pd = 2.14 \times 10^{-6}$ ~~$\frac{2.14 \times 10^{-6}}{5.05 \times 10^{-7}}$~~ $\frac{2.14 \times 10^{-6}}{6.1 \times 10^{-7}} = 3.5$

4th minimum

45 %

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.

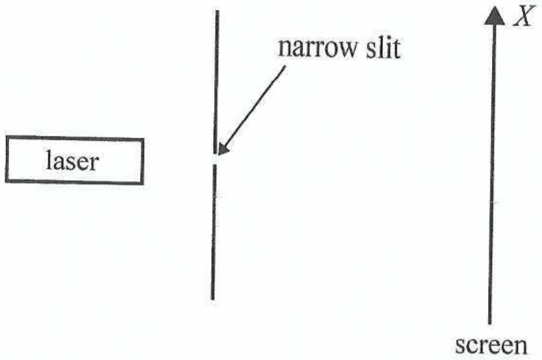
B. Neither sound waves nor electromagnetic waves can travel through a vacuum.

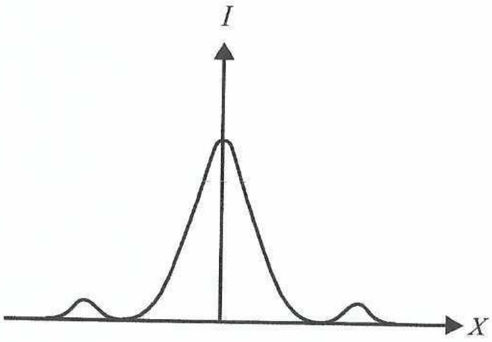
C. Sound waves can travel through a vacuum but electromagnetic waves cannot travel through a vacuum.

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

Question 15

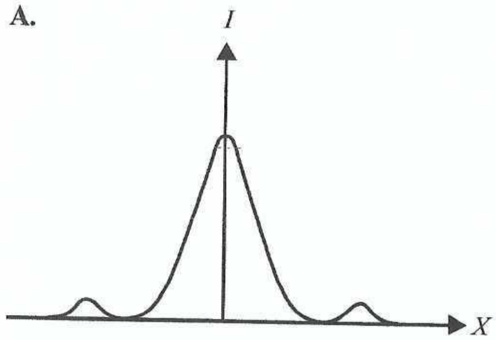
Monochromatic laser light of wavelength 600 nm shines through a narrow slit. The intensity of the transmitted light is recorded on a screen some distance away, as shown below in the diagram on the left. The intensity graph of the pattern seen on the screen is shown below on the right.



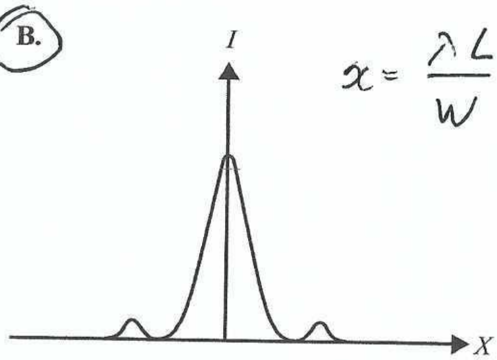


Which one of the following intensity graphs best represents the pattern that would be seen if a slightly wider slit were used?

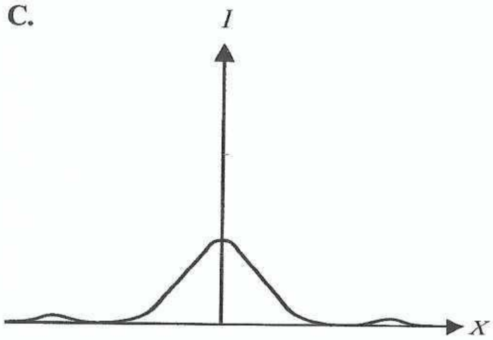
A.



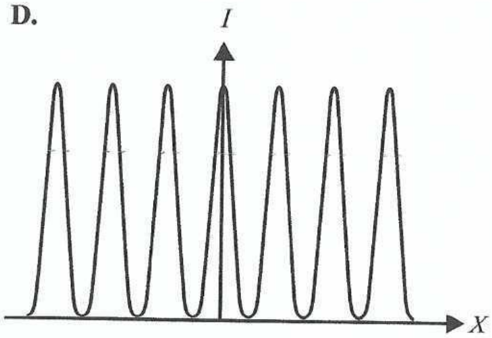
B.



C.



D.



✓ **Question 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.

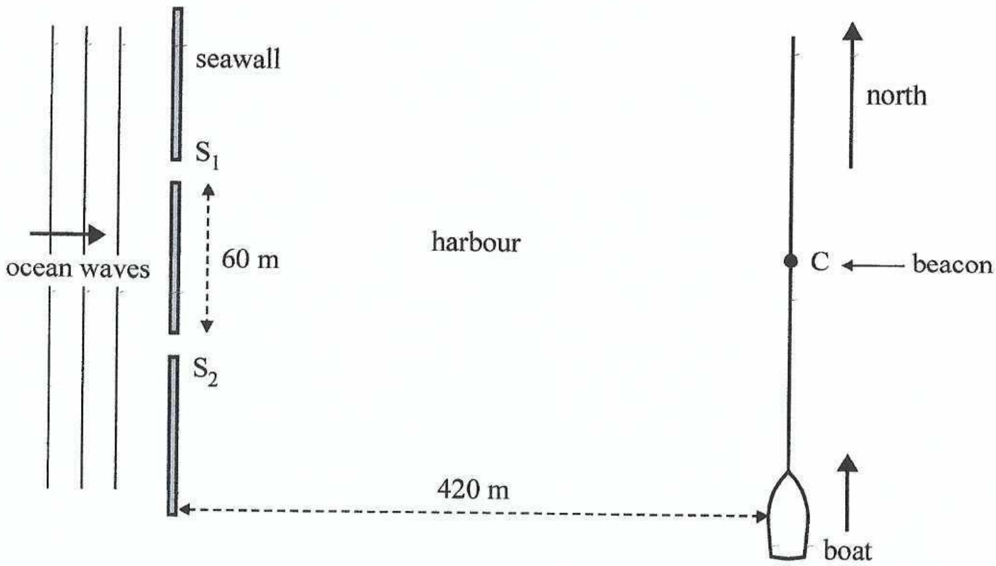


Figure 12

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

As path difference = 0, constructive interference → large waves.

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

$\Delta x = \frac{\lambda L}{w}$ $42 = \frac{\lambda \times 420}{60}$

$\lambda = \frac{60 \times 42}{420} = 6$ 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.

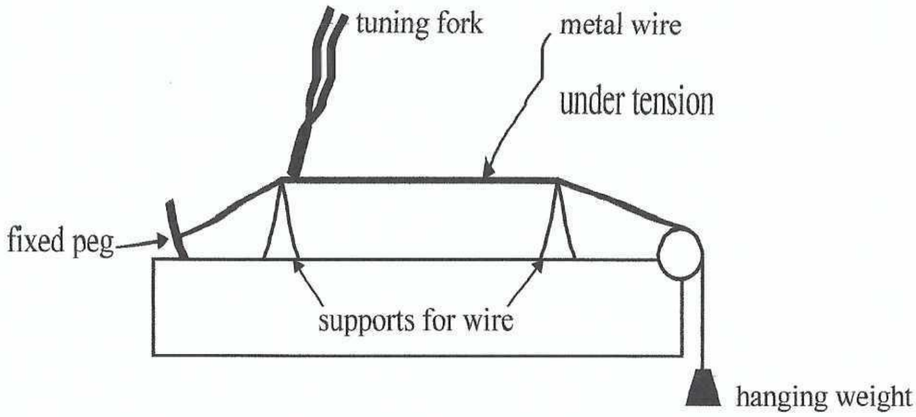


Figure 13

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

$\lambda = 2L$

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

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

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}.

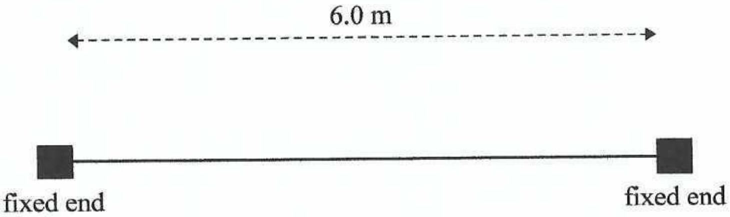


Figure 12

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

81%

$\lambda = \frac{v}{f} = \frac{40}{7.5}$

5.3 m

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

17%

No.

$\lambda = \frac{2L}{n}$

$L = n\frac{\lambda}{2}$

$\frac{\lambda}{2} = 2.65$

$\frac{6}{2.65}$ not a whole number

✓ **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}.

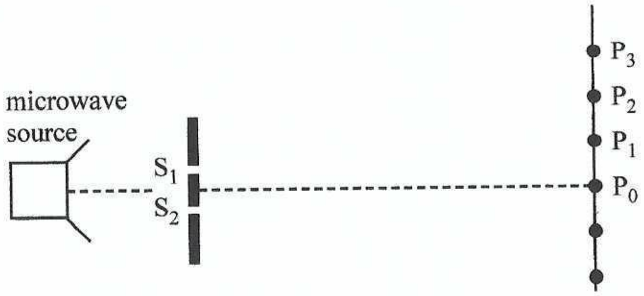


Figure 13

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

26 %

$Pd = 0.806 - 0.723 = 0.083$

At P_3 $Pd = 3\lambda$ $\lambda = \frac{0.083}{3} = 2.77 \times 10^{-2}$

$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{2.77 \times 10^{-2}}$

1.08×10^{10} 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

17 %

$Pd = \frac{\lambda}{2}$ so destructive interference at that point.