2021 ASSESSMENT RESOURCE

AS
PHYSICS

7407 – Particles and radiation / Waves

Version 0.1

Total number of marks: 46

0 4 A sample of pure boron contains only isotope **X** and isotope **Y**.
A nucleus of **X** has more mass than a nucleus of **Y**.

0 4 . 1 The sample is ionised, producing ions each with a charge of $+1.6 \times 10^{-19}$ C.
The specific charge of an ion of **X** is 8.7×10^{6} C kg^{-1}.

Calculate the mass of an ion of **X**.

[1 mark]

$$\frac{Q}{m} = 8.7 \times 10^{6}$$

$$\frac{1.6 \times 10^{-19}}{8.7 \times 10^{6}} = m = 1.84 \times 10^{-26}$$

mass of ion = 1.84×10^{-26} kg

0 4 . 2 Determine the number of nucleons in a nucleus of **X**.

mass of a nucleon = 1.7×10^{-27} kg

[2 marks]

$$\frac{1.84 \times 10^{-26}}{1.7 \times 10^{-27}} = 10.8$$

∴ 10 nucleons

number of nucleons = 10

0 4 . 3 Compare the nuclear compositions of **X** and **Y**.

[2 marks]

Nucleus X has a higher number of nucleons than Y, and therefore a higher number of neutrons. They both have the same number of protons.

0 4 . 4 Ions of **Y** have the same charge as ions of **X**.

State and explain how the specific charge of an ion of **X** compares with that of an ion of **Y**.

[2 marks]

X & Y have the same charge but due to X's higher mass the specific charge of isotope X is lower than the specific charge of isotope Y.
As specific charge = $\frac{Q}{m}$

0 4 . 5 **Table 1** contains data about two completely ionised samples of pure boron. Each sample contains only isotopes **X** and **Y**.

Table 1

Sample number	Number of ions in sample	Mass of sample / kg	Charge on each ion / C
1	3.50×10^{16}	6.31×10^{-10}	$+1.60 \times 10^{-19}$
2	3.50×10^{7}	6.20×10^{-19}	$+1.60 \times 10^{-19}$

Deduce which sample, **1** or **2**, contains a greater percentage of isotope **Y**.

[3 marks]

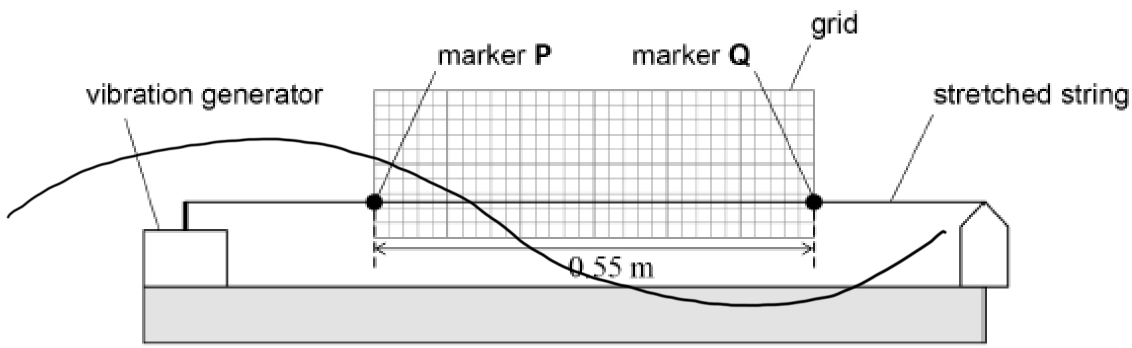
$\frac{6.31\times10^{-10}}{3.5\times10^{16}} = 1.8\times10^{-26}$ $\frac{6.20\times10^{-19}}{3.5\times10^{7}} = 1.8\times10^{-17}$

1.8×10^{-26} kg is mass of one ion of isotope X.
∴ Sample 2 has a higher % of isotope Y.

0 6 **Figure 8** shows the apparatus a student uses to investigate stationary waves in a stretched string.

Two small pieces of adhesive tape are fixed to the string as markers **P** and **Q**. Markers **P** and **Q** are 0.55 m apart and an equal distance from the ends of the string. A graph paper grid is placed behind the string between **P** and **Q**.

Figure 8



not to scale

0 6 . 1 The string is made to vibrate at the second harmonic.

Compare the motion of **P** with that of **Q**.

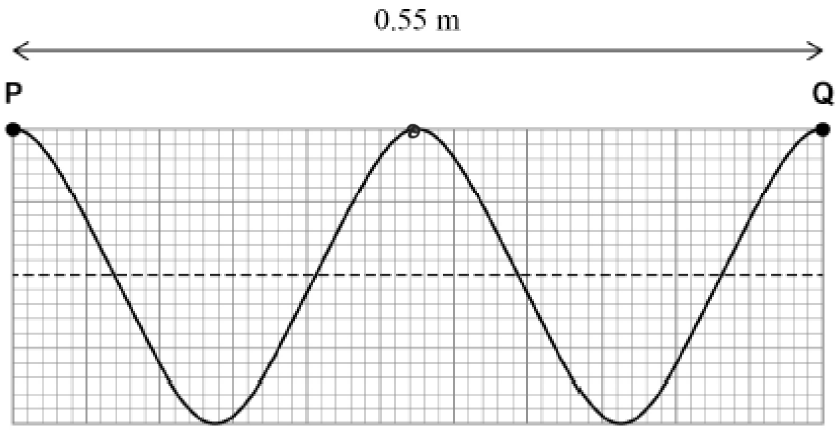
[2 marks]

P & Q are points of maximum displacement from the equilibrium position. P is at the maximum positive point and Q is at the maximum negative point. Both P & Q are antinodes.

0 6 . 2 The frequency of the vibration generator is increased, and a higher harmonic of the stationary wave is formed.

Figure 9 shows the string between **P** and **Q** at an instant in time. The dashed horizontal line indicates the position of the string at rest when the vibration generator is switched off.

Figure 9



The frequency of the vibration generator is 250 Hz.

Calculate the wave speed.

[2 marks]

$2\lambda = 0.55$

$\lambda = 0.275$ m

$v = f\lambda$

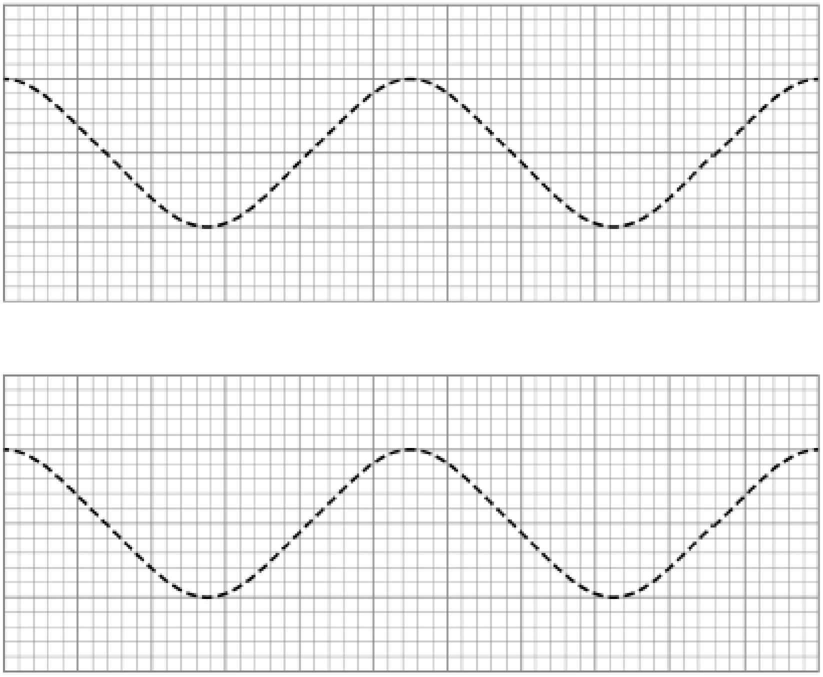
$v = 250 \times 0.275$

$v = 68.75$ m/s

wave speed = 69 $m\ s^{-1}$

0 6 . 3 The instantaneous position of the string in **Figure 9** can be explained by the superposition of two waves. The instantaneous positions of these waves between **P** and **Q** are shown in **Figure 10**.

Figure 10



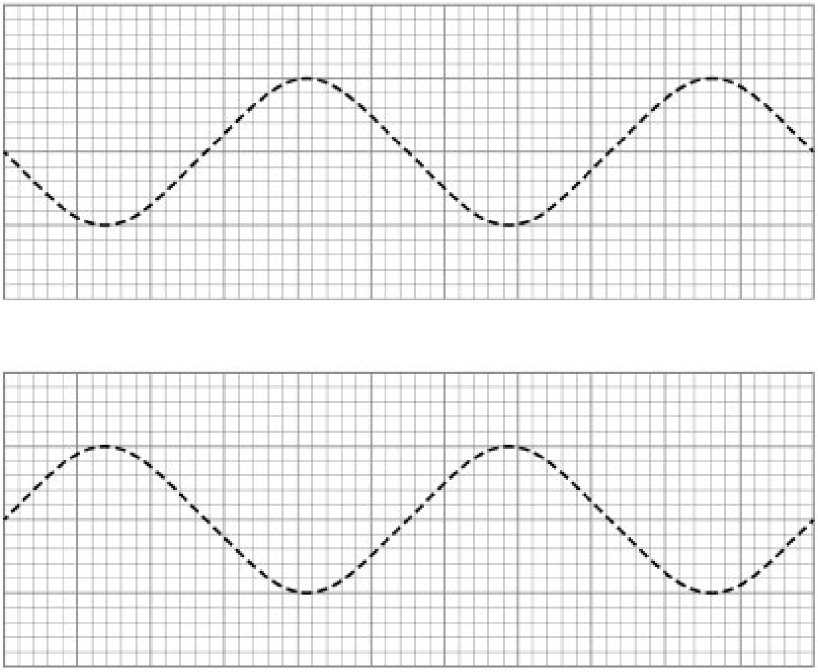
Describe the properties that the waves must have to form the shape shown in **Figure 9**.

[3 marks]

For waves to superpose they must be coherent. This means they must have a constant phase difference, have the same frequency and the same/similar amplitudes.

0 6 . 4 **Figure 11** shows the positions of the two waves between **P** and **Q** a short time later.

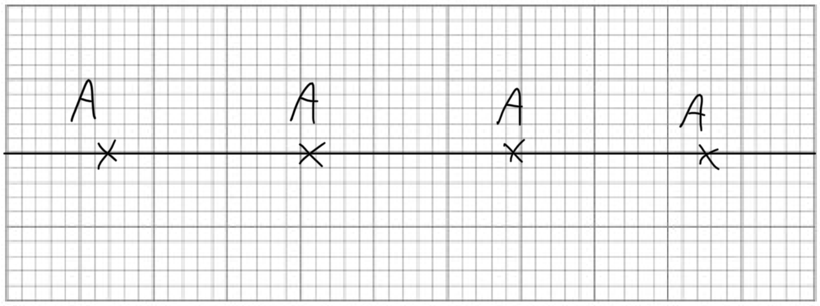
Figure 11



Draw, on **Figure 12**, the appearance of the string between **P** and **Q** at this instant.

[1 mark]

Figure 12

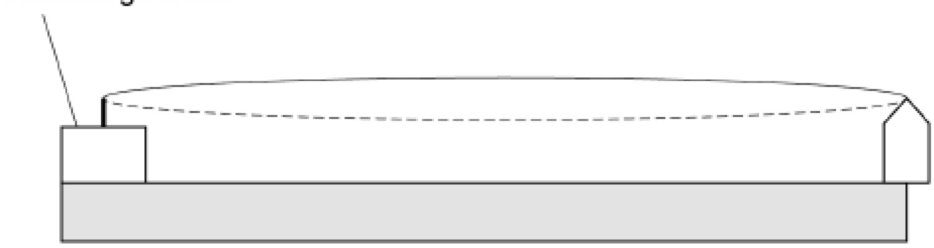


0 6 . 5 Annotate (with an **A**) the positions of any antinodes on your drawing in **Figure 12**.

[2 marks]

0 6 . 6 The frequency of the vibration generator is reduced until the first harmonic is observed in the string, as shown in **Figure 13**.

Figure 13



The string in **Figure 13** is replaced with one that has 9 times the mass per unit length of the original string. All other conditions are kept constant, including the frequency of the vibration generator and the tension in the string.

Deduce the harmonic observed.

[3 marks]

6.6) As the mass per unit length of the string is now 9 times greater, the strings first harmonic is now $f/3$ (due to the equation $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \Rightarrow \frac{f}{3} = \frac{1}{2l}\sqrt{\frac{T}{9\mu}}$

As the frequency, tension and length remain the same, the frequency is $\frac{1}{3}\times$ the first harmonic.

0 1 . 1 Deuterium is an isotope of hydrogen. Its nucleus contains one proton and one neutron.

Calculate the specific charge of the deuterium nucleus.

[2 marks]

specific charge $= \frac{\text{charge}}{\text{mass}} = \frac{1.6\times10^{-19}}{2\times1.661\times10^{-27}} = 4.82\times10^{7}\ C\ kg^{-1}$

specific charge = 4.82×10^{7} $C\ kg^{-1}$

0 1 . 2 The proton and neutron in the deuterium nucleus are held together by the strong nuclear force.

Which is an exchange particle of the strong nuclear force?
Tick (✓) **one** box.

[1 mark]

a type of lepton ∴ not a meson → muon ☐

exchange particle for electromagnetic forces → photon ☐

pion ☑ ✓

W^+ boson ☐ ← exchange particle for weak nuclear force

Exchange particles for strong nuclear force are particles called mesons.

A pion is a type of meson.

0 1 . 3 The deuterium nucleus is stable.

Describe how the variation of the strong nuclear force with distance contributes to the stability of the deuterium nucleus.

01.3 At very small distances the strong nuclear Force is repulsive but very quickly as nucleon separation increases the Force becomes attractive. The nucleons of a deuterium nucleus are close together, such that they are in the attractive region of the strong Force. Hence why deuterium is stable.

* Attractive forces between 0.5 − 3 fm
Distances below 0.5 fm, forces are repulsive
Distance beyond 3 fm, forces of attraction are extremely weak.

0 1 . 4 Tritium is an isotope of hydrogen. Its nucleus contains one proton and two neutrons. Tritium undergoes radioactive decay.

Three modes of radioactive decay are

- alpha decay
- beta minus (β^-) decay
- electron capture.

Deduce which of these modes could produce the nucleus of another element when the tritium nucleus decays.

[3 marks]

$^{3}_{1}T \rightarrow ^{3}_{2}He + ^{0}_{-1}e + \bar{\nu}$

Helium nucleus

β^- decay (Electron)

β^- decay

0 6 Scientists at CERN have produced atoms of antihydrogen.
An atom of antihydrogen contains the antiparticle of the proton and the antiparticle of the electron.

0 6 . 1 State what is meant by an antiparticle.

[2 marks]

An antiparticle has the same mass as its corresponding particle but has the opposite charge.

0 6 . 2 Complete **Table 2** with the names of the antiparticles in an atom of antihydrogen.

[2 marks]

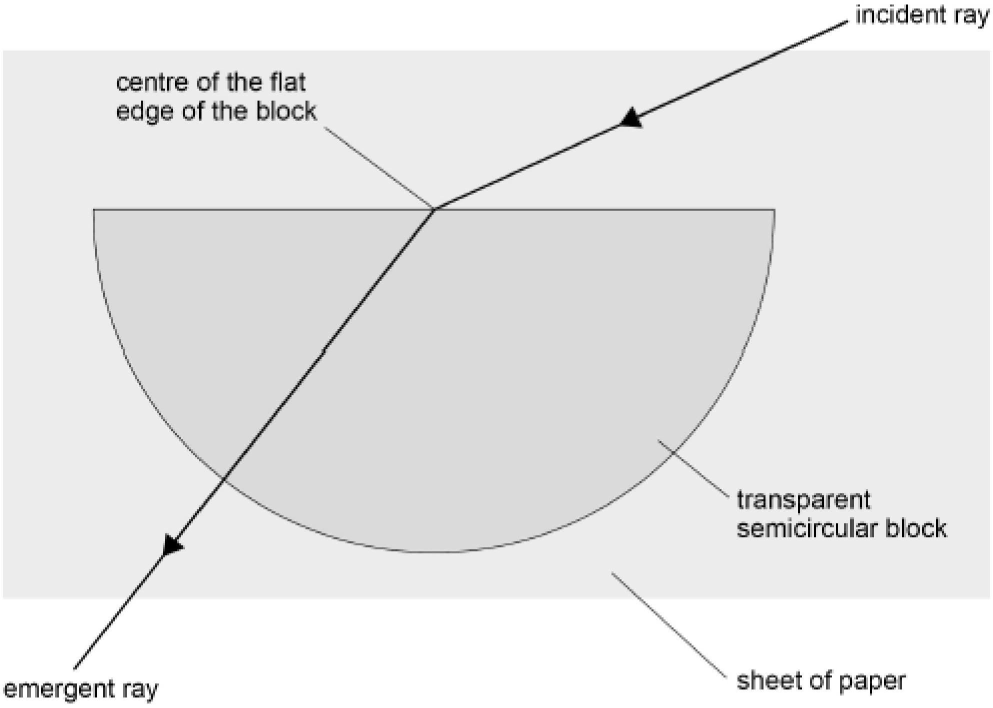
Table 2

Name of particle	Name of antiparticle
proton	anti-proton
electron	positron

0 1 A student places a transparent semicircular block on a sheet of paper and draws around the block. She directs a ray of light at the centre of the flat edge of the block.

Figure 1 shows the path of the ray through the block.

Figure 1



0 1 . 1 State why the emergent ray does not change direction as it leaves the block.

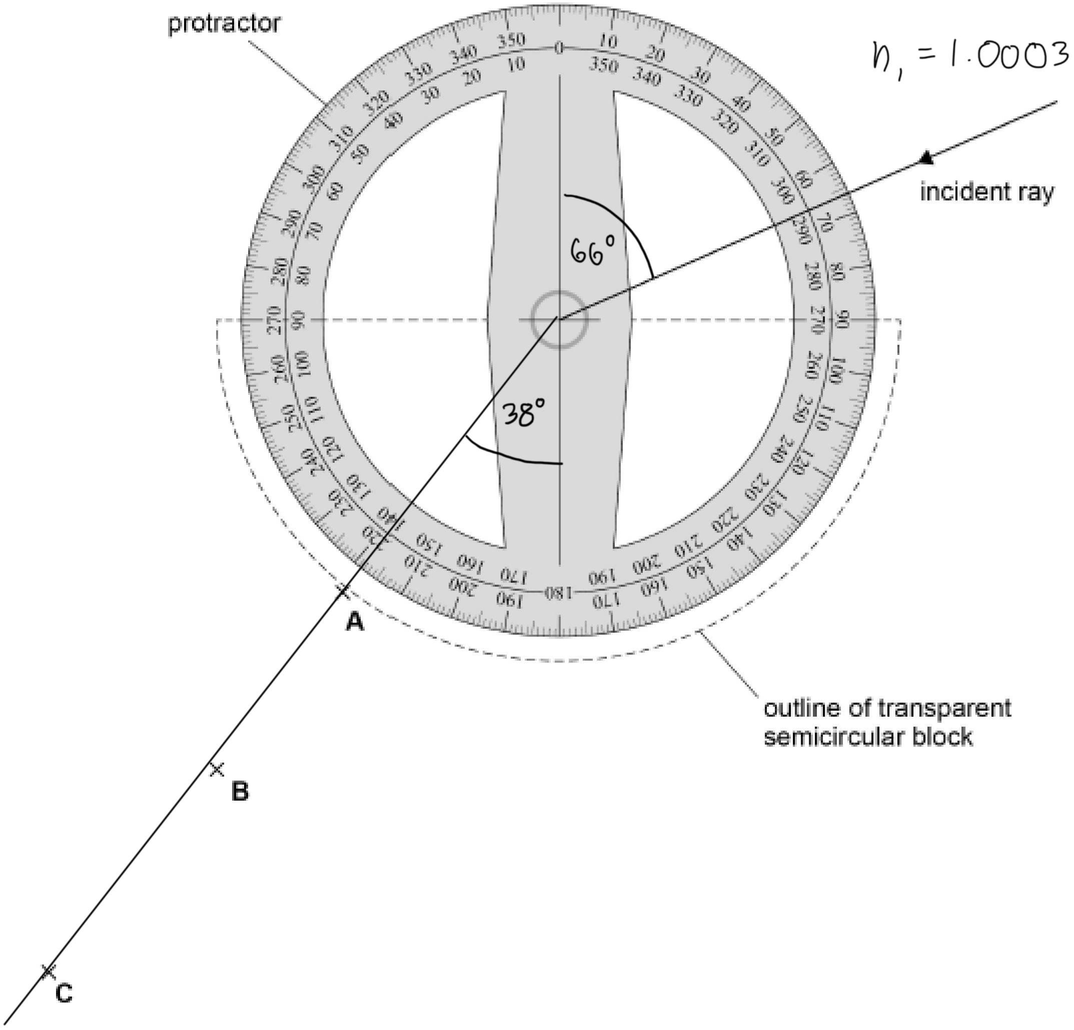
[1 mark]

Because at that exit point, the ray of light is on the normal to the block at that point.

0 1 . 2 The student draws an arrow on the paper to mark the incident ray. She marks the path of the emergent ray with crosses **A**, **B** and **C**.

She removes the block from the paper and places a protractor over the outline of the block, as shown in **Figure 2**.

Figure 2



Determine, using **Figure 2**, the refractive index of the block.

[4 marks]

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

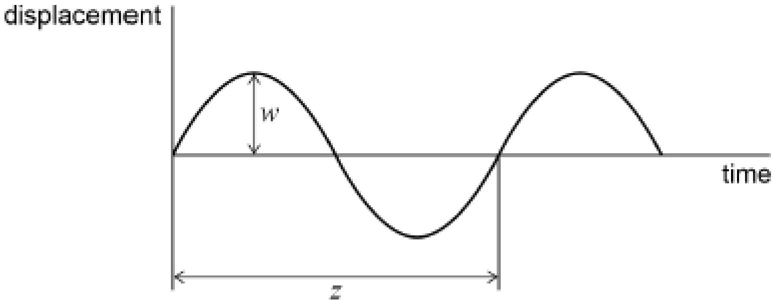
$\frac{n_1 \sin\theta_1}{\sin\theta_2} = n_2 = \frac{1.0003 \times \sin(66)}{\sin(38)} = 1.484$

$= 1.5$

refractive index = 1.5

1 2 A wave travels along a water surface.

The variation with time of the displacement of a water particle at the surface is shown.



What properties of the wave are represented by w and z?

[1 mark]

	w	z	
A	phase	frequency	○
B	amplitude	wavelength	✓
C	wavelength	phase	○
D	amplitude	period	○

1 3 Two points on a progressive wave are out of phase by 0.41 rad.

What is this phase difference?

[1 mark]

A 23° ✓

B 47° ○

C 74° ○

D 148° ○

$180^\circ = \pi$ rad

$\frac{180}{\pi} = 1$ rad

$\frac{180}{\pi} \times 0.41 = 0.41$ rad

$\frac{180}{\pi} \times 0.41 = 23.49^\circ$

1 1 A particle of mass m has a kinetic energy of E.

What is the de Broglie wavelength of this particle?

[1 mark]

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

$$E = \tfrac{1}{2}mv^2$$

$$2E = mv^2$$

$$\sqrt{\frac{2E}{m}} = v$$

$$\lambda = \frac{h}{m\sqrt{\frac{2E}{m}}}$$

$$\lambda = \frac{h}{\sqrt{m^2}\sqrt{\frac{2E}{m}}} = \frac{h}{\sqrt{2Em}}$$

A $\dfrac{h}{\sqrt{(2Em^2)}}$ ☐

B $\dfrac{h}{\sqrt{2E}}$ ☐

C $\dfrac{h}{\sqrt{\left(\dfrac{2E}{m^2}\right)}}$ ☐

D $\dfrac{h}{\sqrt{2Em}}$ ☑

1 2 Which row links both the photoelectric effect and electron diffraction to the properties of waves and particles?

[1 mark]

	Photoelectric effect	Electron diffraction	
A	Particle property	Particle property	☐
B	Wave property	Wave property	☐
C	Particle property	Wave property	☑
D	Wave property	Particle property	☐

1 4 Light of wavelength λ is incident normally on two parallel slits of separation s. Fringes of spacing w are seen on a screen at a distance D from the slits.

Which row gives another arrangement that produces a fringe spacing of w?

[1 mark]

$$\lambda = \frac{ax}{D}$$

$$\lambda = \frac{ws}{D}$$

$$\frac{\lambda D}{s} = w$$

	Wavelength	Slit separation	Distance between slits and screen	
A	2λ	$2s$	$2D$	☐
B	2λ	$4s$	$2D$	☑
C	2λ	$2s$	$4D$	☐
D	4λ	$2s$	$2D$	☐

$$\frac{2\lambda\,2D}{4s} = \frac{4\lambda D}{4s} = \frac{\lambda D}{s} = w$$