NATIONAL QUALIFICATIONS CURRICULUM SUPPORT

Physics

Quanta and Waves

Numerical Examples

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Numerical questions

Quantum theory

1. The uncertainty in an electron's position relative to an axis is given as $\pm 5.0 \times 10^{-12}$ m.
Calculate the least uncertainty in the simultaneous measurement of the electron's momentum relative to the same axis.

2. An electron moves along the x-axis with a speed of 2.05×10^{6} m s^{-1} ± 0.50%.
Calculate the minimum uncertainty with which you can simultaneously measure the position of the electron along the x-axis.

3. An electron spends approximately 1.0 ns in an excited state.
Calculate the uncertainty in the energy of the electron in this excited state.

4. The position of an electron can be predicted to within ±40 atomic diameters. The diameter of an atom can be taken as 1.0×10^{-10} m.
Calculate the simultaneous uncertainty in the electron's momentum.

5. Calculate the de Broglie wavelength of:

(a) an electron travelling at 4.0×10^{6} m s^{-1}
(b) a proton travelling at 6.5×10^{6} m s^{-1}
(c) a car of mass 1000 kg travelling at 120 km per hour.

6. An electron and a proton both move with the same velocity of 3.0×10^{6} m s^{-1}.
Which has the larger de Broglie wavelength and by how many times larger (to 2 significant figures)?

7. Gamma rays have an energy of 4.2×10^{-13} J.

(a) Calculate the wavelength of the gamma rays.
(b) Calculate the momentum of the gamma rays.

8. An electron is accelerated from rest through a p.d. of 200 V in a vacuum.

   (a) Calculate the final speed of the electron.
   (b) Calculate the de Broglie wavelength of the electron at this speed.
   (c) Would this electron show particle or wave-like behaviour when passing through an aperture of diameter 1 mm?

9. An electron is accelerated from rest through a p.d. of 2.5 kV. Calculate the final de Broglie wavelength of this electron.

10. An electron microscope accelerates electrons until they have a wavelength of 40 pm (40×10^{-12} m).
    Calculate the p.d. in the microscope required to do this assuming the electrons start from rest.

11. Relativistic effects on moving objects can be ignored provided the velocity is less than 10% of the speed of light.
    What is the minimum wavelength of an electron produced by an electron microscope where relativistic effects can be ignored?

12. An electron moves round the nucleus of a hydrogen atom.
    (a) Calculate the angular momentum of this electron:
        (i) in the first stable orbit
        (ii) in the third stable orbit.
    (b) Starting with the relationship
        $mrv = \frac{nh}{2\pi}$
        show that the circumference of the third stable orbit is equal to three electron wavelengths.
    (c) The speed of an electron in the second stable orbit is 1.1×10^6 m s^{-1}.
        (i) Calculate the wavelength of the electron.
        (ii) Calculate the circumference of the second stable orbit.

Particles from space

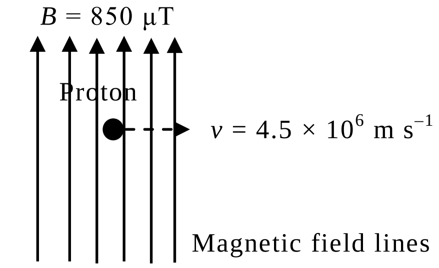
1. An electron moves with a speed of 4.8×10^6 m s^{-1} at right angles to a uniform magnetic field of magnetic induction 650 mT.
   Calculate the magnitude of the force acting on the electron.

2. A proton moves with a speed of 3.0×10^4 m s^{-1} at right angles to a uniform magnetic field. The magnetic induction is 0.8 T. The charge on the proton is +1e.

Calculate the magnitude of the force acting on the proton.

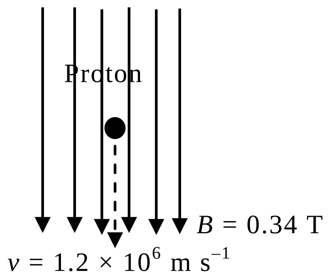
3. A neutron moves at right angles to a uniform magnetic field.
Explain why the neutron's motion is unaffected by the magnetic field.

4. (a) A proton moves through a uniform magnetic field as shown in the diagram.



Calculate the magnetic force exerted on the proton.

(b) Another proton moves through this uniform magnetic field.



What is the magnetic force exerted on the proton? Explain your answer.

5. An electron experiences a force of 2.5×10^{-13} N as it moves at right angles to a uniform magnetic field of magnetic induction 350 mT. Calculate the speed of the electron.

6. A muon experiences a force of 1.5×10^{-16} N when travelling at a speed of 2.0×10^7 m s^{-1} at right angles to a magnetic field. The magnetic induction of this field is 4.7×10^{-5} T.
What is the magnitude of the charge on the muon?

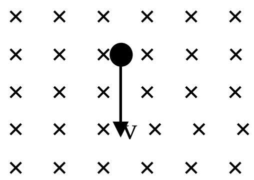
7. An alpha particle is a helium nucleus containing two protons and two neutrons. The alpha particle experiences a force of 1.4×10^{-12} N when moving at 4.8×10^5 m s^{-1} at right angles to a uniform magnetic field. Calculate the magnitude of the magnetic induction of this field.

8. An electron moves at right angles to a uniform magnetic field of magnetic induction 0.16 T.
The speed of the electron is 8.2×10^6 m s^{-1}.

(a) Calculate the force exerted on the electron.
(b) Explain why the electron moves in a circle.
(c) Calculate the radius of this circle.

9. A proton moves through the same magnetic field as in question 8 with the same speed as the electron (8.2×10^6 m s^{-1}).
Calculate the radius of the circular orbit of the proton.

10. An electron moves with a speed of 3.8×10^6 m s^{-1} perpendicular to a uniform magnetic field.



B = 480 μT (into page)

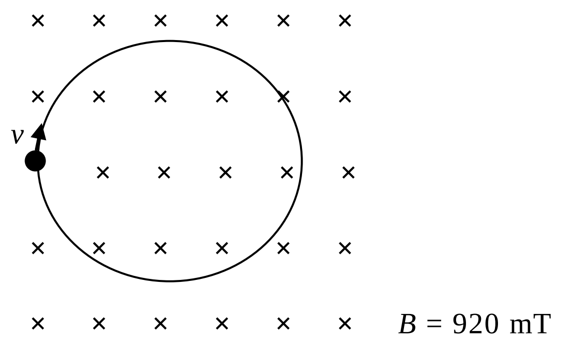
Calculate:

(a) the radius of the circular orbit taken by the electron
(b) the central force acting on the electron.

11. An alpha particle travels in a circular orbit of radius 0.45 m while moving through a magnetic field of magnetic induction 1.2 T. The mass of the alpha particle is 6.645×10^{-27} kg. Calculate:

(a) the speed of the alpha particle in the orbit
(b) the orbital period of the alpha particle
(c) the kinetic energy of the alpha particle in this orbit.

12. A proton moves in a circular orbit of radius 22 mm in a uniform magnetic field as shown in the diagram.

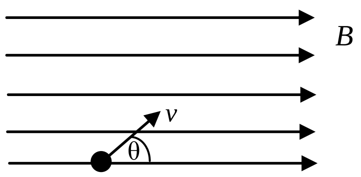


Calculate the speed of the proton.

13. An electron moves with a speed of 5.9×10^5 m s^{-1} in a circular orbit of radius 5.5 μm in a uniform magnetic field.
Calculate the magnetic induction of the magnetic field.

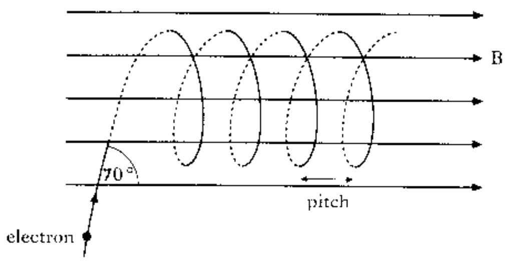
14. A sub-atomic particle moves with a speed of 2.09×10^6 m s^{-1} in a circular orbit of radius 27 mm in a uniform magnetic field. The magnetic induction is 0.81 T.
Calculate the charge to mass ratio of the sub-atomic particle and suggest a name for the particle. Give a reason for your answer.

15. A charged particle enters a uniform magnetic field with a velocity *v* at an angle θ as shown.



(a) Write down an expression for the horizontal component of velocity.
(b) Write down an expression for the vertical component of velocity.
(c) Which of these components will stay unchanged as the charged particle continues its journey? Give a reason for your answer.

16. An electron travelling at a constant speed of 6.8×10^6 m s^{-1}enters a uniform magnetic field at an angle of 70° as shown and subsequently follows a helical path.



The magnetic induction is 230 mT.
Calculate:

(a) the component of the electron's initial velocity parallel to B
(b) the component of the electron's initial velocity perpendicular to B
(c) the central force acting on the electron
(d) the radius of the helix
(e) the period of electron rotation in the helix
(f) the pitch of the helix.

17. A proton travelling at 5.8×10^5 m s^{-1} enters a uniform magnetic field at an angle of 40° to the horizontal (similar to the diagram in question 16). The proton subsequently follows a helical path.

The magnetic induction is 0.47 T.
Calculate:

(a) the component of the proton's initial velocity parallel to B
(b) the component of the proton's initial velocity perpendicular to B
(c) the central force acting on the proton
(d) the radius of the helix
(e) the period of proton rotation in the helix
(f) the pitch of the helix.

18. An electron travelling at 1.3×10^7 m s^{-1} enters a uniform magnetic field at an angle of 55° and follows a helical path similar to that shown in question 16.

The magnetic induction is 490 mT.
Calculate:
(a) the radius of the helix
(b) the pitch of the helix.

19. Explain why most charged particles from the Sun enter the Earth's atmosphere near the north and south poles.

20. Explain what causes the Aurora Borealis to occur.

Simple harmonic motion

1. A particle moves with simple harmonic motion. The displacement of the particle is given by the expression $y = 40\cos 4\pi t$, where y is in millimetres and t is in seconds.

   (a) State the amplitude of the motion.
   (b) Calculate:
       (i) the frequency of the motion
       (ii) the period of the motion.
   (c) Calculate the displacement of the particle when:
       (i) $t = 0$
       (ii) $t = 1.5$ s
       (iii) $t = 0.4$ s.

2. The displacement, y mm, of a particle is given by the expression $y = 0.44 \sin 28t$.

   (a) State the amplitude of the particle motion.
   (b) Calculate the frequency of the motion.
   (c) Calculate the period of the motion.
   (d) Find the time taken for the particle to move a distance of 0.20 mm from the equilibrium position.

3. An object is moving in simple harmonic motion. The amplitude of the motion is 0.05 m and the frequency is 40 Hz.

   (a) Calculate the period of the motion.
   (b) Write down an expression which describes the motion of the object if the displacement is zero at $t = 0$.
   (c) Calculate the acceleration of the object:
       (i) at the midpoint of the motion
       (ii) at the point of maximum displacement.
   (d) (i) Calculate the maximum speed of the object.
       (ii) At which displacement in the motion does the maximum speed occur?

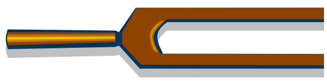
4. An object of mass 0.65 kg moves with simple harmonic motion with a frequency of 5.0 Hz and an amplitude of 40 mm.

   (a) Calculate the unbalanced force on the mass at the centre and extremities of the motion.
   (b) Determine the velocity of the mass at the centre and extremities of the motion.
   (c) Calculate the velocity and acceleration of the mass when its displacement is 20 mm from the centre.

5. An object of mass 0.50 kg moves with simple harmonic motion of amplitude 0.12 m. The motion begins at +0.12 m and has a period of 1.5 s.

   (a) Calculate the following after the object has been moving for 0.40 s.
      (i) The displacement of the object.
      (ii) The unbalanced force on the object (magnitude and direction).
   (b) Calculate the time taken for the object to reach a displacement of –0.06 m after starting.

6. A point on the tip of a tuning fork oscillates vertically with simple harmonic motion.



The displacement y of this point in millimetres is given by
$y = 2.0 \sin(3.22 \times 10^3 t)$

   (a) Calculate the frequency of the sound created by the tuning fork.
   (b) Calculate the maximum acceleration of the tip of the tuning fork.
   (c) A student states that the period of any object undergoing simple harmonic motion will not change as the motion dies away. Which experimental observation of the tuning fork supports the student’s statement?

7. An object of mass 0.20 kg oscillates with simple harmonic motion of amplitude 100 mm and frequency 0.50 Hz.

   (a) Calculate the maximum value of the kinetic energy of the object and state where this occurs.

(b) State the minimum value of the kinetic energy of the object and state where this occurs.

(c) Calculate the maximum value of the potential energy of the object and state where this occurs.

(d) State the minimum value of the potential energy of the object and state where this occurs.

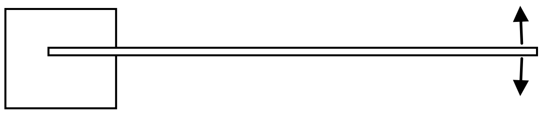
(e) Calculate the potential and kinetic energy of the object when its displacement is:

(i) 20 mm

(ii) 50 mm.

(f) Predict the value of the sum of the kinetic and potential energies of the object at all displacements of its motion.

8. A metal ruler is clamped at one end and is made to vibrate with simple harmonic motion in the vertical plane as shown.



The frequency of vibration is 8.0 Hz.

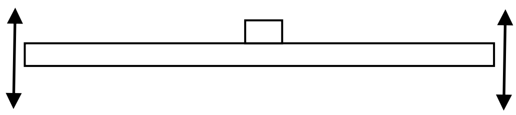
(a) (i) One point on the ruler oscillates with an amplitude of 3.0 mm.
Calculate the maximum downward acceleration of this point.

(ii) Would a small mass sitting on the ruler at this point lose contact with the surface of the ruler? Explain your answer.

(b) (i) Another point on the oscillating ruler has an amplitude of 4.0 mm.
Calculate the maximum downward acceleration of this point.

(ii) Would a small mass sitting on the ruler at this point lose contact with the surface of the ruler? Explain your answer.

9. A horizontal platform oscillates vertically with simple harmonic motion with a slowly increasing amplitude.
A small mass rests on the platform and the period of oscillation is 0.10 s.



Calculate the maximum amplitude which will allow the mass to always remain in contact with the platform.

10. A vertical spring stretches 0.10 m when a 1.2 kg mass is hung from one end.
The mass is then pulled down a further distance of 0.08 m below the previous equilibrium position and released.

(a) Show that the spring oscillates with a frequency of 1.6 Hz.
(b) Calculate the total energy of the oscillating system.

Waves

1. A travelling wave is represented by the equation
$y = 30 \sin 2\pi(10t - 0.2x)$ where y is in millimetres.
For this wave state or calculate:

(a) the amplitude
(b) the frequency
(c) the period
(d) the wavelength
(e) the speed.

2. A travelling wave is represented by the equation
$y = 0.60 \sin \pi(150t - 0.40x)$ where y is in metres.

(a) What is the amplitude of this wave?
(b) Calculate the frequency of this wave.
(c) What is the period of the wave?
(d) Calculate the wavelength of the wave.
(e) What is the speed of the wave?

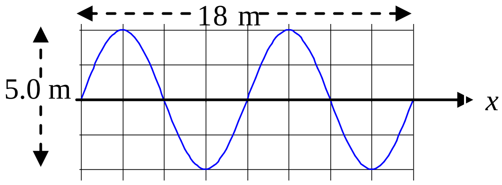
3. A travelling wave is represented by the equation
$y = 0.35 \sin(20t - 1.5x)$ where y is in metres.
For this wave calculate:

(a) the frequency
(b) the wavelength
(c) the wave speed.

4. A plane wave of amplitude 0.30 m, frequency 20 Hz and wavelength 0.50 m travels in the $+x$ direction. The displacement of the wave is zero at $t = 0$.
Write down the equation of this wave.

5. A wave of frequency 40 Hz travels with a speed of 12 m s^{-1} in the $+x$ direction. The amplitude of the wave is 1.5 m.
Write down the equation of this wave.

6. The diagram shows the profile of a wave travelling in the $+x$ direction at 36 m s^{-1}.



Write down the equation of the travelling wave.

7. A travelling wave is represented by the equation
$y = 0.20 \sin 2\pi(110t - 15x)$ (x and y are measured in metres).
Write the equation for the displacement y_R of a wave travelling in the opposite direction that has twice the frequency, double the amplitude and the same wavelength as the original wave.

8. A travelling wave is represented by the equation
$y_1 = 0.24 \sin(42t - 3.6x)$ (x and y are measured in metres).

(a) Write down the equation for the displacement y_2 of another wave travelling in the opposite direction to the original wave and with the same amplitude, half the frequency and twice the wavelength.
(b) Is the new wave faster, slower or the same speed as the original wave? Justify your answer.

9. A travelling wave is represented by the equation
$y_1 = 0.40 \sin(8.5t - 0.80x)$ (x and y are measured in meters).
Write down the equation of the displacement y_2 of another wave travelling in the opposite direction to the original wave and with three times the amplitude, twice the frequency and half the speed.

10. The following equation represents a wave travelling in the $+x$ direction:

$$y = A \sin 2\pi(ft - \frac{x}{\lambda})$$

Using the relationships $f = \frac{1}{T}$, $v = f\lambda$, $\omega = 2\pi f$ and $k = \frac{2\pi}{\lambda}$ show that the following are also possible equations for this wave:

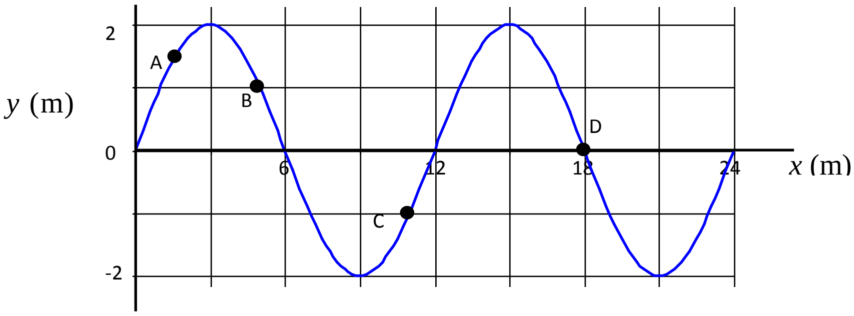
(a) $y = A\sin 2\pi(\frac{t}{T} - \frac{x}{\lambda})$

(b) $y = A\sin(\omega t - kx)$

(c) $y = A\sin 2\pi f(t - \frac{x}{v})$

(d) $y = A\sin\frac{2\pi}{\lambda}(vt - x)$

11. The diagram shows the profile of a wave travelling in the $+x$ direction.



Calculate the phase difference between points:

(a) A and B
(b) B and C
(c) A and C
(d) C and D
(e) A and D.

12. A wave has a velocity of 350 m s^{-1} and a frequency of 500 Hz.

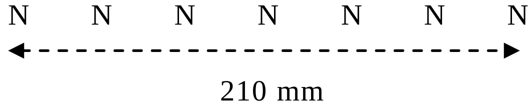
(a) Two points on the wave are $\frac{\pi}{3}$ (or 60°) out of phase.
What is the closest horizontal distance between these two points?

(b) Another two points on the wave have a phase difference of 0.18 rad.
What is the closest horizontal distance between these two points?

13. A travelling wave has a speed of 24 m s^{-1} and a frequency of 60 Hz. Calculate the phase difference between the leading edge of the wave and the same leading edge of the wave 2.0 ms later.

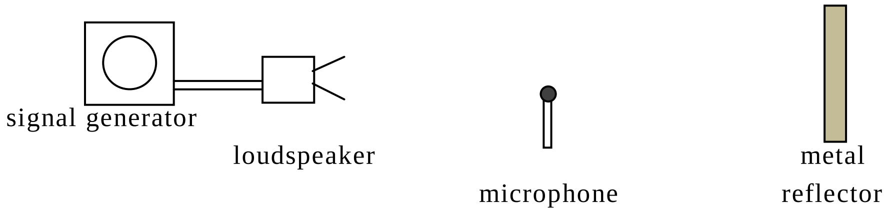
14. Nodes are 12 cm apart in a standing wave.
State the wavelength of the interfering waves.

15. The diagram shows the distance between several nodes in a standing wave.



Calculate the wavelength of the wave.

16. A student sets up a stationary sound wave using the following apparatus.



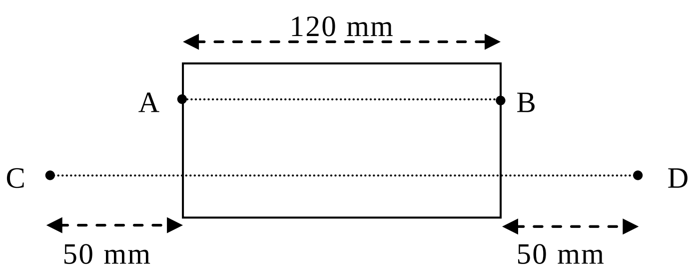
The microphone is used to find the position of the nodes when the reflected wave interferes with the incident wave.
The student notes the following results:

frequency of sound = 700 ± 50 Hz
distance between two adjacent nodes = 25 ± 2 cm

(a) Using this data calculate:
 (i) the speed of sound
 (ii) the absolute uncertainty in the calculated value for the speed of sound.
(b) How could the student reduce the absolute uncertainty in the calculated value for the speed of sound?

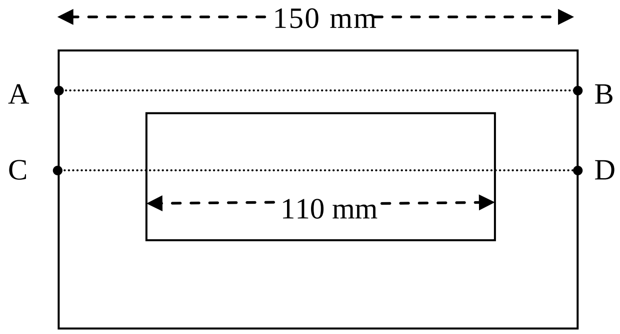
Interference

1. A glass block of refractive index 1.5 is surrounded by air. Rays of light pass from A to B and from C to D as shown.



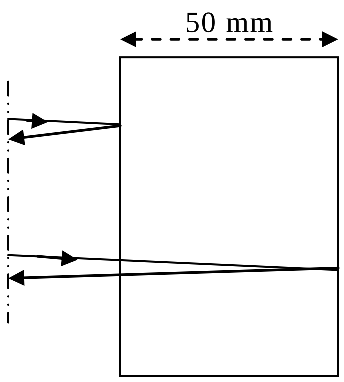
(a) State the geometric path length AB.
(b) Calculate the optical path length AB.
(c) What is the geometric path length CD?
(d) Calculate the optical path length CD.

2. A hollow air-filled glass block is 150 mm long. The refractive index of the glass is 1.5 and rays of light pass from A to B and from C to D as shown.



Calculate:
(a) the optical path length AB
(b) the optical path length CD
(c) the optical path difference between rays AB and CD.

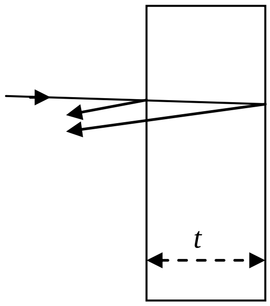
3. A perspex block reflects two rays of light from different surfaces as shown:



The perspex block has a refractive index of 1.47 and a thickness of 50 mm.
Assume both rays have near normal incidence.

(a) Calculate the optical path difference between the rays.
(b) State the phase change undergone by each ray on reflection.

4. A ray of light strikes a thin film of transparent material at near-normal incidence.
The material has refractive index n and thickness t.



The two reflected rays can interfere constructively or destructively.

(a) Show that the condition for destructive interference between the reflected rays is $2nt = m\lambda$ where the symbols have their usual meanings.

(b) Show that the condition for constructive interference between the reflected rays is $2nt = (m + ½)\lambda$ where m = 0, 1, 2...

5. A soap film of refractive index 1.3 is illuminated by light of wavelength 650 nm. The light is incident normally on the soap film.

(a) Calculate the minimum thickness of soap film required to give no reflection.

(b) White light is now used to illuminate this minimum thickness of soap film. What is the colour of the reflected light? Explain your answer.

6. Light of wavelength 560 nm is incident normally on a thin film of material surrounded by air. The refractive index of the material is 1.5.

(a) Calculate the minimum thickness of the thin film required to give zero reflection of this wavelength.

(b) Calculate the minimum thickness of the thin film required to give maximum reflection of this wavelength.

7. A glass lens of refractive index 1.6 is coated with a thin transparent film of refractive index 1.38. The coated lens gives zero reflection of light of wavelength 590 nm.
Calculate the minimum thickness of the film to give zero reflection of this wavelength.

8. A camera lens has a thin film of material of refractive index 1.36 applied to its surface.
   The thin film is designed to give zero reflection of light of wavelength 690 nm.

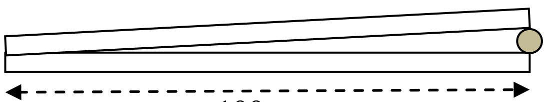
   (a) Calculate the minimum thickness of film required.
   (b) Calculate the next lowest thickness of film required to give zero reflection of this wavelength.

9. A glass lens is coated with a thin transparent film of thickness 110 nm and refractive index 1.38.
   What wavelength of light will pass into this coated lens with 100% transmission?

10. An air wedge is formed by two glass slides of length 100 mm in contact at one end.
    The other ends of the slides are separated by a piece of paper 30 μm thick.

Light of wavelength 650 nm is reflected vertically from the air wedge. Calculate the fringe separation of the interference pattern produced by the air wedge.

11. An air wedge is formed by two glass plates in contact at one end and separated by a length of wire at the other end, as shown.

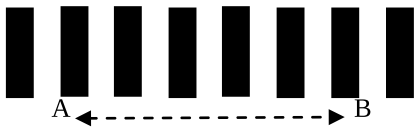


Light of wavelength 690 nm is reflected vertically from the wedge, resulting in an interference pattern. The average fringe separation is 1.2 mm.

(a) Calculate the diameter of the wire.
(b) The temperature of the wire increases. What effect will this have on the fringe separation? Explain your answer.

12. An air wedge is formed by two glass slides in contact at one end and separated by a sheet of paper at the other end.

A student observes the following interference pattern from monochromatic light reflected vertically from the air wedge:

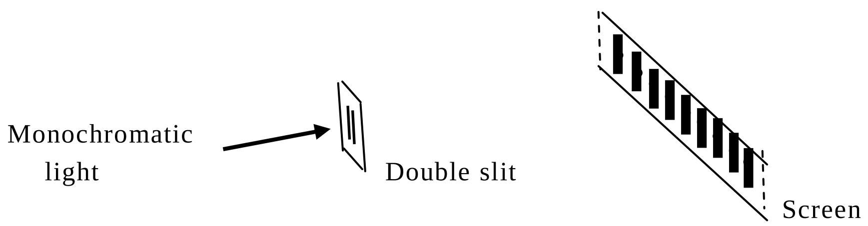


The student notes the following measurements/data.

distance AB	=	6.0 ± 0.5 mm
length of glass slides	=	100 ± 0.2 mm
wavelength of light used	=	589 ± 1 mm

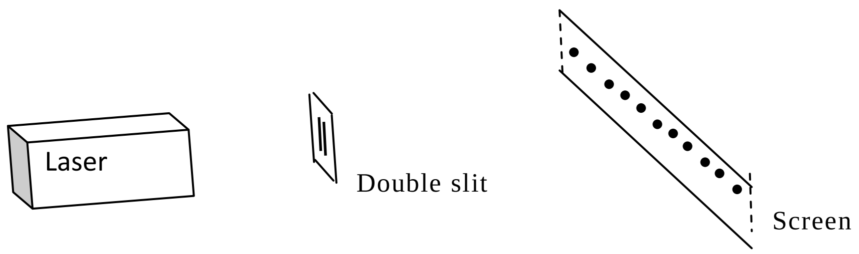
(a) Calculate the thickness of the paper.
(b) Calculate the absolute uncertainty in the thickness of the paper.
(c) The student suggests in an evaluation that measuring the length of the glass slides more accurately would reduce the uncertainty in the thickness of the paper.
  (i) Explain why this statement is not correct.
  (ii) How could the uncertainty in the thickness of the paper be reduced?

13. Two parallel slits are separated by a distance of 5.0×10^{-4} m and are illuminated by monochromatic light. An interference pattern is observed on a screen placed 7.2 m beyond the double slit.



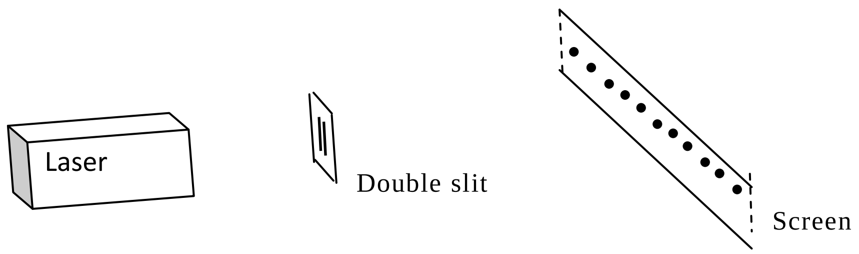
The bright fringes on the screen are separated by a distance of 8.0 mm. Calculate the wavelength of the light.

14. Light of wavelength 695 nm from a laser is shone onto a double slit with a separation of 2.0×10^{-4} m.



Calculate the separation of the bright fringes on a screen placed 0.92 m beyond the double slit.

15. A Young's slits experiment is set up to measure the wavelength of light from a laser.



The measurements taken are:

distance between adjacent fringes	=	7.0 ± 1.0 mm
separation of double slits	=	0.20 ± 0.01 mm
distance from double slit to screen	=	2.40 ± 0.01 m

Calculate:

(a) the wavelength of the laser light
(b) the absolute uncertainty in the wavelength.

16. Two parallel slits have a separation of 0.24 ± 0.01 mm. Monochromatic light illuminates the slits and an interference pattern is observed on a screen placed 3.80 ± 0.01 m beyond the double slits.
The separation between adjacent fringes is 9.5 ± 0.1 mm.

(a) Calculate the wavelength of the light used, including its absolute uncertainty.
(b) A student suggests that measuring the fringe separation more accurately will reduce the absolute uncertainty in the wavelength. Explain whether this is true or not.

17. A Young's slits experiment uses yellow monochromatic light to produce interference fringes on a screen.
State and explain the effect of the following changes on the spacing between adjacent interference fringes on the screen:

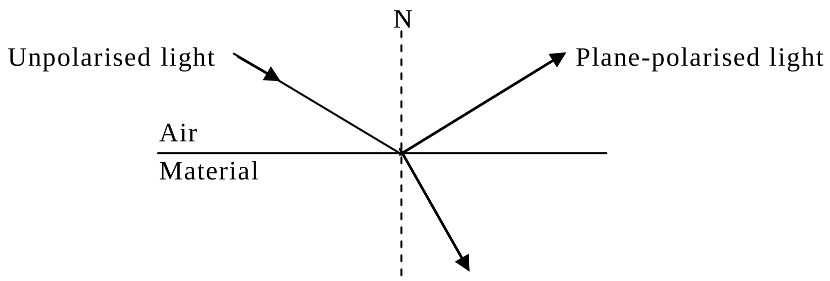
(a) moving the screen closer to the slits
(b) reducing the separation of the slits
(c) replacing the yellow light with red monochromatic light
(d) replacing the yellow light with blue monochromatic light
(e) doubling the slits to screen distance *and* doubling the slit separation.

Polarisation

1. The refractive index of water is 1.33 for a particular wavelength of light. Calculate the polarising angle of water for this wavelength.

2. Brewster's angle for a liquid is 52.0° for a particular wavelength of light. Calculate the refractive index of the liquid for this wavelength.

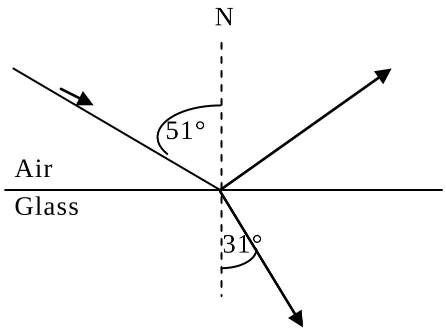
3. An unpolarised light ray in air reflects and refracts on contact with a transparent material of refractive index 1.38.



The reflected light is plane polarised.
Sketch the diagram and write in the values of all the angles.

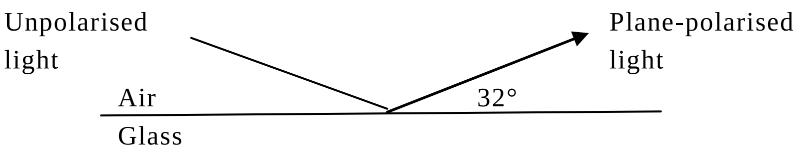
4. The critical angle of a certain glass is 40.5° for a particular wavelength of light.
Calculate the polarising angle for this wavelength in the glass.

5. An unpolarised light ray refracts into glass and is also partially reflected as shown.



Is the reflected light plane polarised? You must justify your answer.

6. A ray of light reflects off a type of glass in air as shown.



Calculate the refractive index of the glass.

Numerical answers

Quantum theory

1. $\pm 1.1 \times 10^{-23}$ kg m s^{-1}

2. $\pm$ 5.7$\times 10^{-9}$ m

3. $\pm 5.3 \times 10^{-26}$ J

4. $\pm 1.3 \times 10^{-26}$ kg m s^{-1}

5. (a) 1.8×10^{-10} m
   (b) 6.1×10^{-14} m
   (c) 2.0×10^{-38} m

6. The electron has the larger de Broglie wavelength by 1800 times.

7. (a) 4.7×10^{-13} m
   (b) 1.4×10^{-21} kg m s^{-1}

8. (a) 8.4×10^{6} m s^{-1}
   (b) 8.7×10^{-11} m
   (c) Particle behaviour

9. 2.5×10^{-11} m (2.46×10^{-11} m)

10. 940 V

11. 2.4×10^{-11} m (24 pm)

12. (a) (i) 1.06×10^{-34} kg m^2 s^{-1} (1.056×10^{-34} kg m^2 s^{-1})
   (ii) 3.2×10^{-34} kg m^2 s^{-1}
   (b) Show $2\pi r = n\lambda$
   (c) (i) 6.6×10^{-10} m
   (ii) 1.3×10^{-9} m

Particles from space

1. 5.0×10^{-13} N

2. 3.8×10^{-15} N

3. A neutron has zero charge: $q = 0$

4. (a) 6.1×10^{-16} N out from page
   (b) Zero force, as velocity is parallel to magnetic field.

5. 4.5×10^{6} m s^{-1}

6. 1.6×10^{-19} C

7. 9.1 T

8. (a) 2.1×10^{-13} N
   (b) This force is a central force at right angles to the direction of motion.
   (c) 2.9×10^{-4} m

9. 0.54 m

10. (a) 45 mm
    (b) 2.9×10^{-16} N

11. (a) 2.6×10^{7} m s^{-1}
    (b) 1.1×10^{-7} s
    (c) 2.2×10^{-12} J

12. 1.9×10^{6} m s^{-1}

13. 0.61 T

14. 9.56×10^{7} C kg^{-1}; proton, q/m for proton = 9.56×10^{7} C kg^{-1}

15. (a) $v \cos\theta$
    (b) $v \sin\theta$
    (c) $v \cos\theta$ stays unchanged ,as it is parallel to the magnetic field

16. (a) 2.3×10^{6} m s^{-1}
    (b) 6.4×10^{6} m s^{-1}
    (c) 2.36×10^{-13} N
    (d) 1.6×10^{-4} m

(e) 1.6×10^{-10} s
(f) 3.7×10^{-4} m

17. (a) 4.4×10^{5} m s^{-1}
(b) 3.7×10^{5} m s^{-1}
(c) 2.8×10^{-14} N
(d) 8.2×10^{-3} m
(e) 1.4×10^{-7} s
(f) 6.2×10^{-2} m

18. (a) 1.2×10^{-4} m
(b) 5.3×10^{-4} m

Simple harmonic motion

1. (a) 40 mm
(b) (i) 2 Hz
(ii) 0.5 s
(c) (i) 40 mm
(ii) 40 mm
(iii) 12 mm (calculator must be in radian mode)

2. (a) 0.44 mm
(b) 4.5 Hz
(c) 0.22 s
(d) 0.017 s (calculator must be in radian mode)

3. (a) 0.025 s
(b) $y = 0.05 \sin 251t$
(c) (i) Zero
(ii) $\pm 3.2 \times 10^{3}$ m s^{-2}
(d) (i) ± 12.6 m s^{-1}
(ii) Zero displacement

4. (a) Zero; ±26 N
(b) 1.3 m s^{-1}; zero
(c) 1.1 m s^{-1}; 20 m s^{-2}

5. (a) (i) -1.26×10^{-2} m
(ii) –0.11 N
(b) 0.5 s

6. (a) 513 Hz
   (b) 2.1×10^{4} m s^{-2}
   (c) Observing frequency unchanged as vibration dies away.

7. (a) 9.9×10^{-3} J at centre
   (b) Zero at extremities
   (c) 9.9×10^{-3} J at extremities
   (d) Zero at centre
   (e) (i) $E_p = 3.9 \times 10^{-4}$ J; $E_k = 9.5 \times 10^{-3}$ J
       (ii) $E_p = 2.46 \times 10^{-3}$ J; $E_k = 7.4 \times 10^{-3}$ J
   (f) 9.9×10^{-3} J

8. (a) (i) 7.6 m s^{-2}
       (ii) No, as $7.6 < 9.8$
   (b) (i) 10.1 m s^{-2}
       (ii) Yes, as ruler acceleration is greater than 9.8 so ruler accelerates away from the mass.

9. 2.5×10^{-3} m

10. (b) 0.38 J

Waves

1. (a) 30 mm
   (b) 10 Hz
   (c) 0.1 s
   (d) 5 mm
   (e) 50 mm s^{-1}

2. (a) 0.60 m
   (b) 75 Hz
   (c) 1.3×10^{-2} s
   (d) 5 m
   (e) 375 m s^{-1}

3. (a) 3.2 Hz
   (b) 4.2 m
   (c) 13 m s^{-1} (13.4 m s^{-1})

4. $y = 0.30 \sin 2\pi(20t - 2x)$

5. $y = 1.5 \sin(250t - 21x)$

6. $y = 2.5 \sin(25t - 0.70x)$

7. $y_R = 0.40 \sin 2\pi(220t + 15x)$

8. (a) $y_2 = 0.24 \sin(21t + 1.8x)$
   (b) Same speed as $v = f\lambda$ and f halves and λ doubles.

9. $y_2 = 1.2 \sin(17t + 3.2x)$

11. (a) 1.8 rad
    (b) 2.9 rad
    (c) 4.7 rad
    (d) 3.9 rad
    (e) 8.6 rad

12. (a) 0.12 m
    (b) 2.0×10^{-2} m

13. 0.75 rad

14. 24 cm

15. 70 mm

16. (a) (i) 350 m s^{-1}
        (ii) ±40 m s^{-1} (± 37 m s^{-1} rounded to 1 significant figure)
    (b) Measure distance between five nodes (uncertainty still ±2 cm). This reduces the percentage uncertainty in distance and wavelength.

Interference

1. (a) 120 mm
   (b) 180 mm
   (c) 220 mm
   (d) 280 mm

2. (a) 225 mm
   (b) 170 mm
   (c) 55 mm

3. (a) 147 mm
   (b) Upper ray has phase change of π on reflection.
   Lower ray has no phase change on reflection.

5. (a) 2.5×10^{-7} m
   (b) Blue/violet. Little red light reflected so more blue reflected or maximum reflection when $m = 1.5$ gives 433 nm reflected strongly.

6. (a) 1.9×10^{-7} m
   (b) 9.3×10^{-8} m

7. 1.07×10^{-7} m

8. (a) 1.27×10^{-7} m
   (b) 3.81×10^{-7} m

9. 6.07×10^{-7} m (607 nm)

10. 1.1 mm

11. (a) 2.9×10^{-5} m
    (b) Fringe separation smaller as diameter of wire increases due to expansion.

    (d increases) and Δx is proportional to $\frac{1}{d}$.

12. (a) 2.5×10^{-5} m
    (b) $\pm 2 \times 10^{-6}$ m
    (c) (i) The percentage uncertainty in L is less than a third of the dominant uncertainty so can be ignored, therefore there is no improvement in uncertainty in d by making L more accurate.
        (ii) Reduce uncertainty in Δx by measuring the width of 10 consecutive fringes rather than five consecutive fringes. If absolute uncertainty is still ±0.5 mm then the percentage uncertainty in Δx will be halved from 8% to 4%. The calculated uncertainty in d will therefore be reduced.

13. 5.6×10^{-7} m (556 nm)

14. 3.2 mm

15. (a) 580 nm
    (b) ±90 nm

16. (a) $6.0 \times 10^{-7} \pm 3 \times 10^{-8}$ m

(b) Not true as percentage uncertainty in Δx is less than a third of the percentage uncertainty in d, so percentage uncertainty in Δx is ignored. Any reduction in percentage uncertainty in Δx will also be ignored.

17. (a) Fringes closer together as $\Delta x \propto D$.

(b) Fringes further apart as $\Delta x \propto \frac{1}{d}$.

(c) Fringes further apart as $\lambda_{red} > \lambda_{yellow}$ and $\Delta x \propto \lambda$.

(d) Fringes closer together as $\lambda_{blue} < \lambda_{yellow}$ and $\Delta x \propto \lambda$.

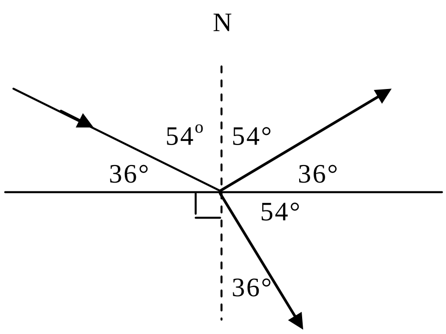
(e) No change in fringe spacing as $\Delta x = \frac{\lambda D}{d}$ so numerator doubles and denominator doubles, cancelling the overall effect on Δx.

Polarisation

1. 53.1°

2. 1.28

3.



4. 57°

5. No. Show n = 1.51 so i_p = 56° not 51°, or angle between reflected and refracted rays is 98° and not 90°.

6. 1.6