Achievement Standard 91170

Demonstrate understanding of waves

PHYSICS

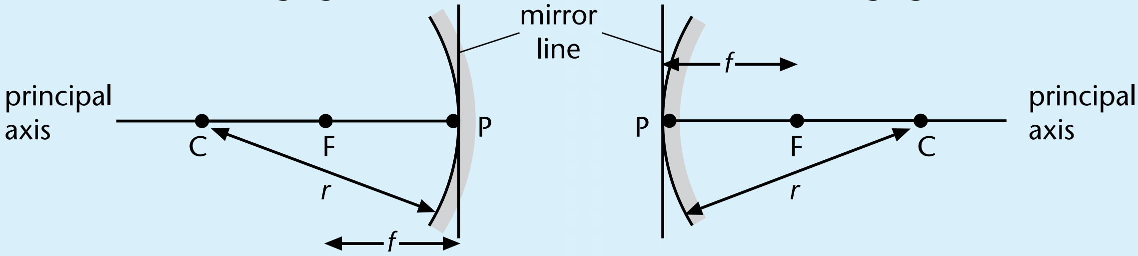
2.3

Externally assessed 4 credits

Reflection – curved surfaces

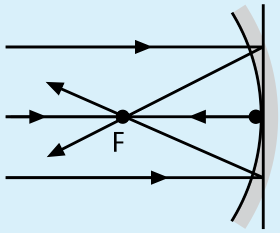
Reflection of light

Concave (converging) mirror **Convex (diverging) mirror**

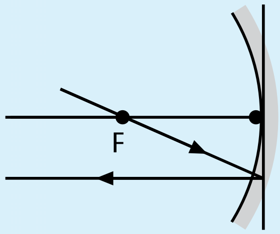


C = centre of curvature P = pole F = focal point (focus) f = focal length r = radius of curvature ($r = 2f$)

Drawing ray diagrams – concave mirror rules

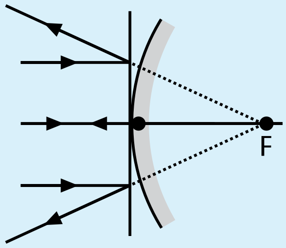


A ray parallel to the principal axis reflects through the focus.

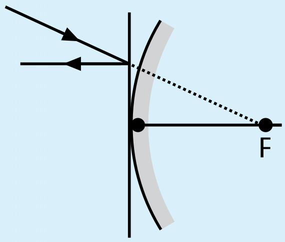


A ray that passes through the focus reflects off parallel to the principal axis.

Drawing ray diagrams – convex mirror rules



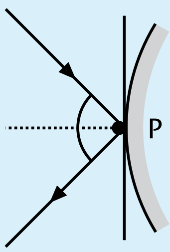
A ray parallel to the principal axis reflects off as if it comes from the focus.



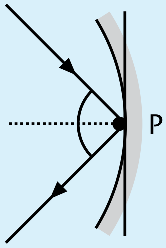
A ray aimed at the focus reflects off parallel to the principal axis.

Equal angle rule

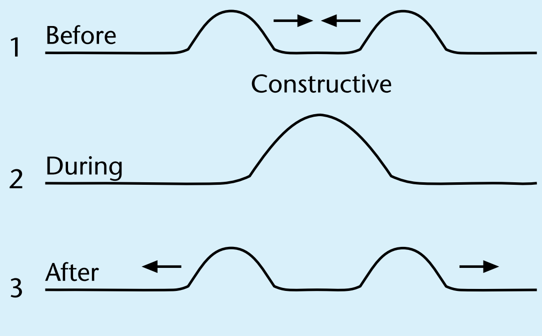
This is a particularly useful rule as it can be used for both types of mirror.

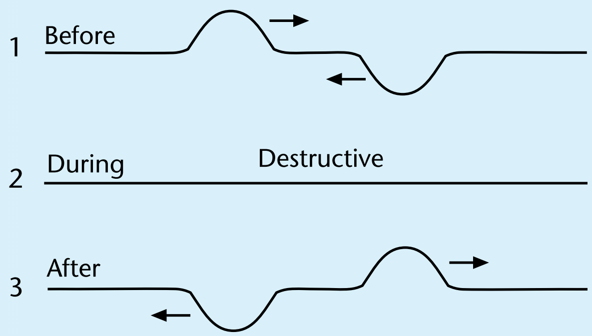


A ray aimed at the pole of the mirror at some angle reflects off at the same angle.



Using these rules, a ray diagram can be drawn to predict the nature (i.e. is it virtual, real, enlarged, upright, etc.?) and the size of an image.

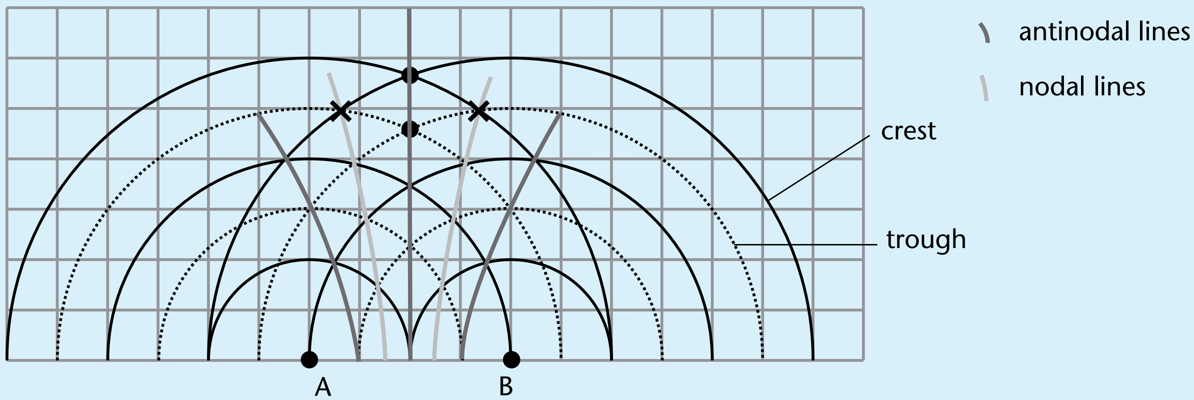




Constructive interference results if the two waves are added together to form a maximum amplitude.

Destructive interference results if the two waves are added together to form a wave of zero amplitude.

Superposition can be dramatically illustrated in a tank of water, as shown below:

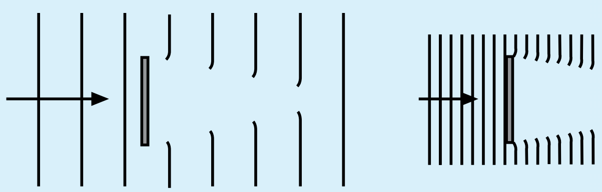


If circular waves come from A and B simultaneously there will be places where constructive interference (marked with ●) and destructive interference (marked with an ✕) take place.

Diffraction

The bending of waves around a barrier or through a gap is called **diffraction**. The smaller the wavelength, the lesser the diffraction. For the diffraction to be most noticeable, the wavelength needs to be about the size of the gap or obstacle.

Diffraction around obstacles



Diffraction through gaps

2.3

Question Five: Radio waves and light

Henry listens to music on his radio while driving. There are two radio stations that he usually tunes to:

- Radio Station A, which broadcasts on its FM network using a radio wave of 93.4 MHz (93.4×10^6 Hz)
- Radio Station B, which broadcasts on its AM network using a radiowave of 856 kHz.

a. Calculate the wavelength of the radio wave used by Radio Station A.

Year 2010
Ans. p. 113

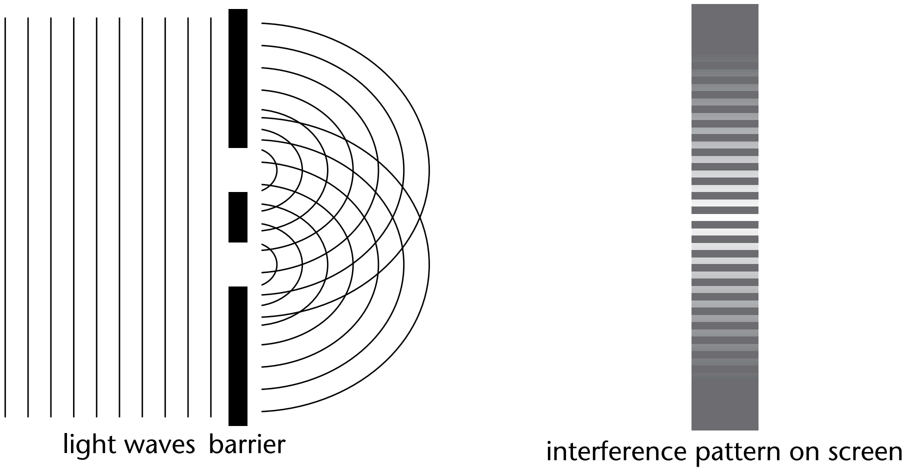
b. While driving on hilly terrain, Henry notices that he can only tune into one of these two radio stations.

Explain why he can hear music from only one of these two radio stations.

In your answer, identify which radio station he can hear, giving reasons for your answer.

You may use calculations / diagrams to justify your reasoning.

Ashley shines a red laser through two slits. He obtains a pattern on a screen as shown.



c. Describe what would happen to the pattern if the screen was brought closer to the barrier.

d. Explain why every alternate band is a dark band.

Achievement Standard 91171

Demonstrate understanding of mechanics

PHYSICS

2.4

Externally assessed 6 credits

Motion

A **scalar** quantity is a physical quantity that has only *size* (called **magnitude**). Direction is irrelevant. Temperature, mass, time, distance, speed, voltage and energy are examples of scalar quantities.

A **vector** quantity is a physical quantity that involves both *size* and *direction*. Force, displacement, velocity and momentum are examples of vector quantities.

A vector is drawn as a straight, arrowed line. The arrow points in the direction of the vector. The length of the line represents the vector's *magnitude*.

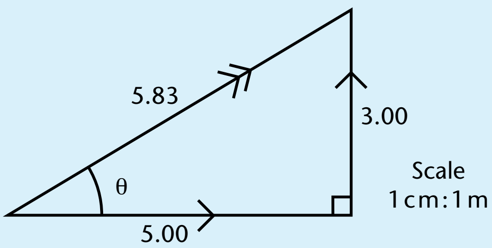
Vector addition

Vectors are added 'head to tail' using a scale diagram.

Example

Q. Calculate the displacement if you travel 5.00 m to the right and then 3.00 m up.

A. Displacement is 5.83 m at an angle of $\theta = 31°$ anticlockwise from right.



Vector subtraction

The same 'head-to-tail' method is used for vector subtraction, except the **reverse vector** is added (the vector with the *same magnitude* but the *opposite direction* of the original vector).

Example

Q. The final velocity is $5.00\ \text{m s}^{-1}$ to the right, the initial velocity is $3.00\ \text{m s}^{-1}$ up. Calculate the change in velocity.

A. Change in a quantity (Δ) = final amount – initial amount.

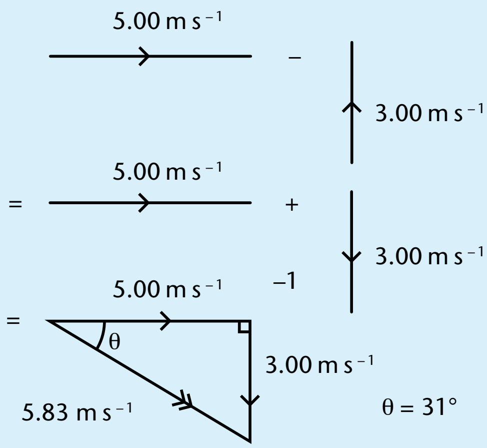
Note: When finding the change in vector quantities, the subtraction becomes a vector subtraction and usually involves drawing a vector diagram (as shown on the right).

Using Pythagoras and trigonometry:

magnitude = $\sqrt{5.00^2 + 3.00^2} = 5.83$

direction, $\theta = \tan^{-1}\dfrac{3.00}{5.00} = 31°$, clockwise from right

Change in velocity =



Year 2008 Ans. p. 114

Question Three: The rolling ball

While Louise is running at 6.0 m s^{-1} to the right, a ball rolls at 4.0 m s^{-1} to the left. Calculate the speed of the ball **relative to Louise**.

Question Four: The aircraft

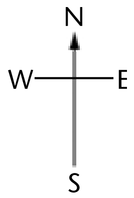
An aircraft has a constant horizontal airspeed of 100 m s^{-1}.

The pilot wants to fly directly east, but there is a wind blowing **from the north** with a speed of 40 m s^{-1}.

Year 2007 Ans. p. 114

a. Draw a **labelled** vector diagram showing the direction in which the pilot must **point** the aircraft.

Use the diagram to calculate the angle between the aircraft and north (the bearing).



b. While the aircraft is landing, its speed reduces from 80.0 m s^{-1} to 25.0 m s^{-1} in 8.0 seconds.

Calculate the **size** and **direction** of the acceleration. Express your answer to the correct number of **significant figures**.

Achievement Standard 91172

Demonstrate understanding of atomic and nuclear physics

PHYSICS

2.5

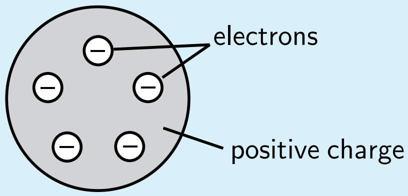
Internally assessed 3 credits

Essential exam notes

Models of the atom

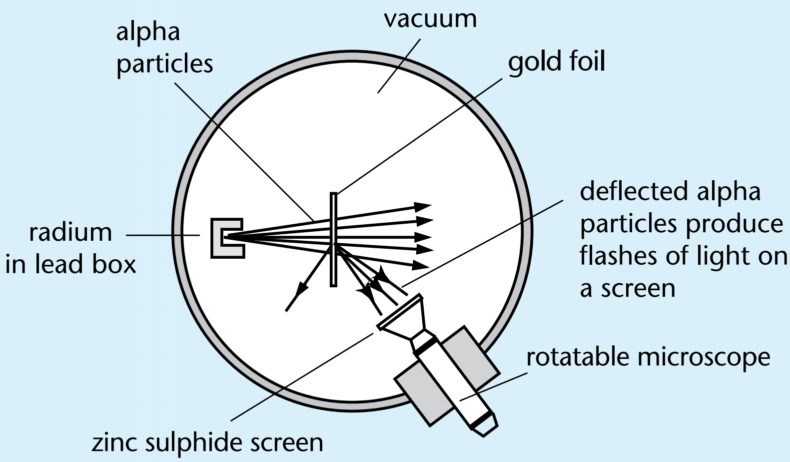
Historical approach

In the latter part of the 19th century, JJ (Joseph) Thomson, a British physicist, showed that negatively charged particles (**electrons**) can be removed easily from many types of atom. He concluded that electrons are a common constituent of all atoms. Since the atom as a whole is electrically neutral, the atom must also have positive charge – Thomson believed this positive charge was evenly distributed throughout the atom. His model is often referred to as the **plum-pudding model**.



Thomson's 'plum-pudding' model

About 15 years later, a New Zealand physicist, Ernest Rutherford, attempted to prove this model correct by experimenting with **alpha particles** fired at thin gold foil. He found that although most alpha particles deviated by only a small extent, a significant number were scattered through large angles, thus disproving Thomson's model of evenly distributed mass throughout the atom.



Rutherford's gold-foil experiment

Rutherford concluded:

- The atom was mainly empty space.
- The atom contained a tiny positive core (made up of **protons**).
- Electrons orbited the **nucleus**.

To visualise the relative size of the nucleus, imagine an atom to be blown up to the size of a house – the outermost electrons would be moving round the walls of the house, but the nucleus would have a diameter of less than one millimetre.

Questions
Models of the atom

Ans. p. 119

Question One: Models of the atom

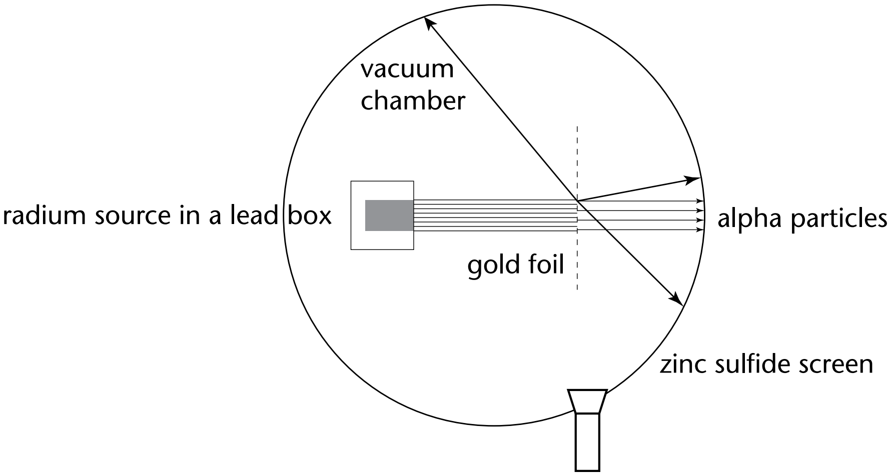
At different times scientists have proposed various descriptions or models of the atom to match experimental evidence available.

a. The model that Thomson proposed was called the plum-pudding model.

Describe this model.

b. Geiger and Marsden performed a series of experiments under the direction of Ernest Rutherford which led to a new model of the atom.

A model of the gold-foil experiment is shown below.



For each of the conclusions given below, state which observation from the experiment provides evidence that:

i. most of the mass of the atom is concentrated in a tiny region which Rutherford called the nucleus

ii. the nucleus is positively charged.

Achievement Standard 91173

Demonstrate understanding of electricity and electromagnetism

PHYSICS

2.6

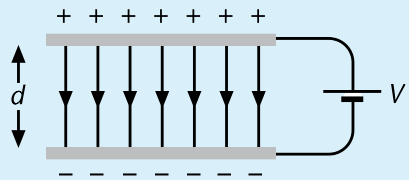
Externally assessed 6 credits

Static electricity

Uniform electric field

An **electric field** is a region where a charged object experiences a force. An electric field can exist in a vacuum or in a substance. Electric fields are drawn using lines, with arrows representing the direction of the field. **Field lines** always run from positive to negative.

A **uniform electric field** is a field where the electric field lines are parallel and evenly spaced. An example of this is a pair of oppositely charged parallel metal plates, as shown.



Uniform electric field

Electric field strength

The size of the electric field depends on the voltage and the separation. The following formula allows the electric field strength to be calculated:

$$E = \frac{V}{d}$$

where V is the voltage, in volts V and d is the separation, in metres m and E is the electric field strength, in V m^{-1}

Force on a charge in an electric field

A small charge of magnitude q is placed in an electric field of strength E. The size of the electric force experienced by the charge is given by the formula:

$$F = Eq$$

where F is the force, in newtons N; and q is the charge, in coulombs C; and E is the electric field strength, in N C^{-1}

Example

Q. Calculate the force on an electron in an electric field of strength 15 N C^{-1}.

A. The charge on an electron is -1.6×10^{-19} C.

The force equals $15 \times 1.6 \times 10^{-19} = 2.4 \times 10^{-18}$ N in the direction towards the positive charge producing the field. (Remember unlike charges attract.)

Electric potential energy

Work is done when an object is moved by a force through a distance (like lifting an object in a gravitational field). In the same way, if a charge q is moved against an electrical field, work is done. This work will then be stored as **electric potential energy**.

The size of the electric potential energy is given by the formula:

$$\Delta E_p = Eqd$$

where ΔE_p is the electric potential energy, in joules J; and E and q are as defined above; and d is the distance the charge has moved, in metres m

NCEA practice

Questions
Static electricity

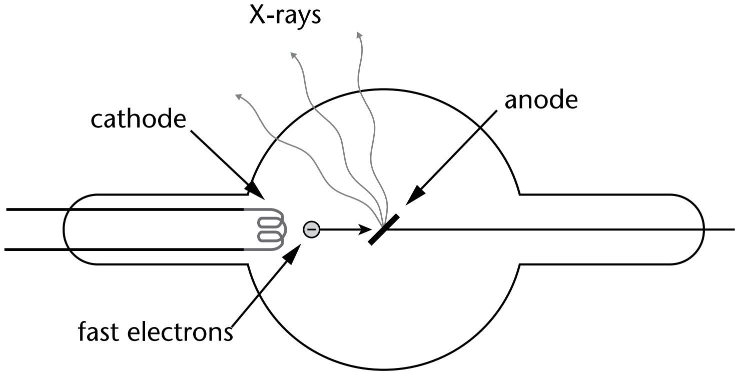
Year 2013
Ans. p. 121

Question One: Hospital X-ray tube

Tavita is working on the design of an X-ray tube for hospitals. The diagram below shows the main parts of the X-ray tube. Electrons are emitted by a filament in the cathode. A high voltage between the cathode (negative electrode) and anode (positive electrode) causes the electrons to accelerate until they crash into the anode.

Mass of an electron = 9.1×10^{-31} kg

Charge on an electron = 1.6×10^{-19} C



a. The electrons start from rest and reach a speed of 3.0 × 107 m s^{-1}.

By considering the energies involved, calculate the size of the voltage between the cathode and the anode.

b. Tavita decides to reduce the distance from the cathode to the anode by half.

Explain fully what will happen to:

i. the size of the force acting on an electron

ii. the kinetic energy gained by an electron.

2.6

Answers and explanations

Achievement Standard 91170 (Physics 2.3): Demonstrate understanding of waves

2.3 Reflection – curved surfaces

Question One: Moana's spotlight

p.3

a. Focal point. (A)

b. i. Centre of curvature. (A)

ii. As the angle of incidence is zero, the angle of reflection is also zero.

The law of reflection states that 'the angle of incidence = the angle of reflection'. (M)

c. The focal length is 25 cm and height of the image = 2 times the height of the object.

$\frac{d_i}{d_o} = \frac{h_i}{h_o}$ … and since the height of the image = 2 times the height of the object:

$d_i = 2 \times d_o$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

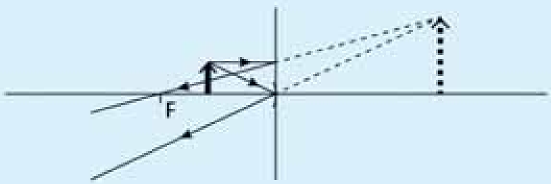
$\frac{1}{25} = \frac{1}{d_o} + \frac{1}{2d_o} = \frac{3}{2d_o}$ Substituting into the mirror formula.

$d_o = 38$ cm (E)

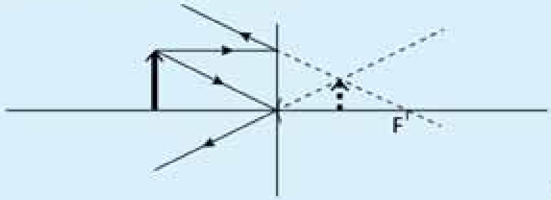
d. Mirror 1 is concave. Since the image is enlarged.

Mirror 2 is convex. It is an upright and diminished image.

The ray diagram for Mirror 1 is:



The ray diagram for Mirror 2 is:

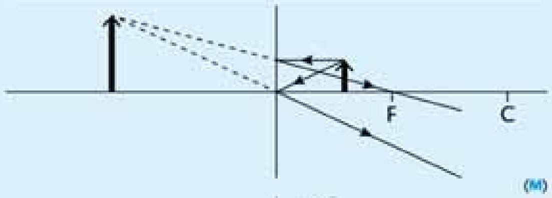


(E)

Question Two: Curved mirrors and lenses

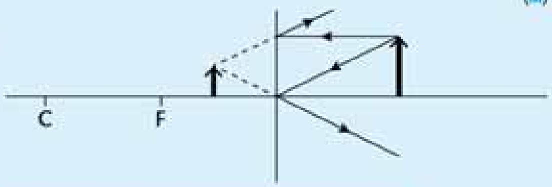
p.5

a. i. Object positioned between mirror and the focal point, rays drawn correctly obtain an enlarged virtual image.



(M)

ii.



Rays drawn correctly obtain a diminished, upright, virtual image. (A)

b. Images are always upright and appear behind the mirror. (M)

c. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

Rearranging for d_i gives:

$d_i = (-\frac{1}{6.0} - \frac{1}{4.5})^{-1} = -2.57$

$h_i = h_o \times \frac{d_i}{d_o}$

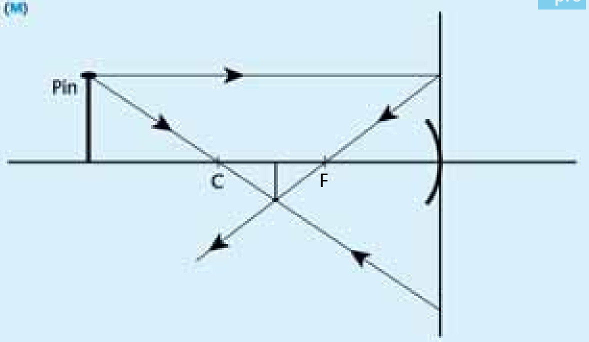
Using the definition of magnification:

$h_i = 2 \times \frac{2.57}{4.5} = 1.14$ cm (E)

Question Three: Pins, mirrors and lenses

p.6

a. (M)



b. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{3.6} = \frac{1}{12.5} + \frac{1}{d_i}$

$d_i = 5.056$ cm

$$\frac{d_i}{d_o} = \frac{h_i}{h_o}$$
$h_i = 1.62$ cm

By first finding the image distance, the height of the image can be found. (E)

c. When the pin is very close to the concave mirror, a virtual image is formed. The rays of light upon reflection in the mirror diverge and appear to meet at a point behind the mirror. This means that the image cannot be formed on a screen and is formed behind the mirror. (E)

2.3 Refraction

Question One: Frankie goes to the optician

p. 9

a. 20° The angle is measured with respect to the normal. (A)

b. Rays coming from a close object will not be parallel. They will be diverging, and so will require more bending to bring them to the same focus point. This will mean a fatter and therefore more curved lens. (M)

c. The amount of bending depends on the relative refractive indices of the lens and its surrounding medium.

Air has a lower refractive index than the liquid. This will mean that if the lens is surrounded by air, it will bend more than if the lens is surrounded by the liquid.

Snell's law.

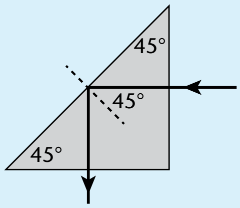
Since more bending will occur with air surrounding the lens, this will mean that the focal length of the lens is reduced. (E)

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

$1.5 \sin c = 1 \sin 90°$ At the critical angle the angle of refraction is 90 degrees.

$c = \sin^{-1}\frac{1}{1.5} = 42°$

Since the critical angle is less than the incidence angle, total internal reflection occurs.



(E)

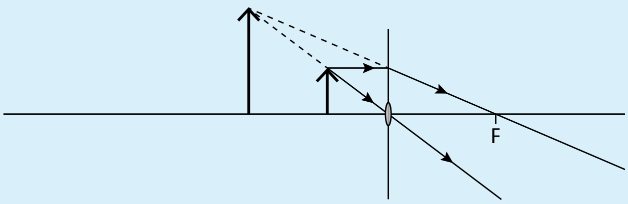
Question Two: The candle

p. 11

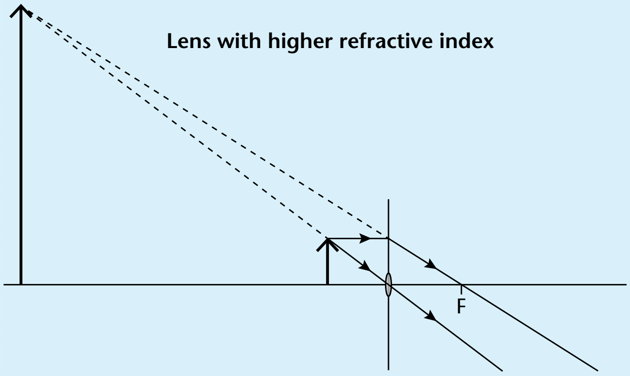
In the ray diagram, the higher refractive index lens has a smaller focal length – resulting in a larger image.

Since rays passing through the higher refractive index lens bend more, they will appear to meet further away from the lens and hence a larger image will be formed.

Lens with lower refractive index



Lens with higher refractive index

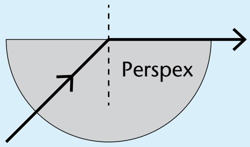


(E)

Question Three: Refraction

p. 12

a.



The angle between the incident ray and the normal is the critical angle. (A)

b. The angle of incidence has to be greater than the critical angle. The ray must go from a medium of higher refractive index to one of lower refractive index. (M)

c. $n_1 \sin \theta_c = n_2 \sin \theta_2$ Using Snell's law.

$n_1 \sin 42° = 1.0 \sin 90°$

$n_1 = 1.5$ (M)

d. $\theta_{air} = 90 - 56 = 34°$ The angle must be measured relative to the normal.

$n_{air} \sin \theta_{air} = n_{glass} \sin \theta_{glass}$ Using Snell's law to find the refracted angle in the glass.

$1.0 \sin 34° = 1.5 \sin \theta_{glass}$

$\theta_{glass} = 21.8°$

$\text{distance in glass} = \frac{8.0}{\cos 21.8°}$ The distance can be found by trigonometry.

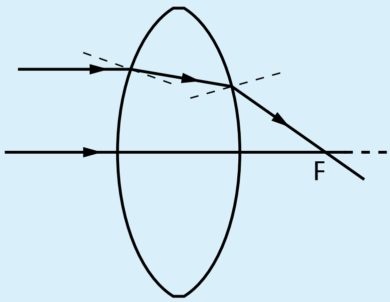
$= 8.6$ cm (E)

Question Four: Refraction and lenses

p. 13

a. i. convex / converging (A)

ii.



Normals must be at right angles to the two surfaces and the light bends toward the normal when it goes into the glass and away from the normal when it leaves the glass. (M)

iii. If the refractive index was greater, the light would bend more when it goes into the lens and when it comes out.

The light would cross the principal axis closer to the lens, therefore reducing the focal length. (E)

Answers

Resource Sheet

Physics 91170 (2.3): Demonstrate understanding of waves

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ or $s_i\, s_o = f^2$ $\quad m = \frac{d_i}{d_o} = \frac{h_i}{h_o}$ or $m = \frac{f}{s_o} = \frac{s_i}{f}$ $\quad n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\frac{n_1}{n_2} = \frac{v_2}{v_1} = \frac{\lambda_2}{\lambda_1}$ $\quad v = f\lambda$ $\quad f = \frac{1}{T}$ $\quad v = \frac{d}{t}$

Physics 91171 (2.4): Demonstrate understanding of mechanics

$v = \frac{\Delta d}{\Delta t}$ $\quad a = \frac{\Delta v}{\Delta t}$ $\quad v_f = v_i + at$ $\quad d = v_i t + \frac{1}{2}at^2$ $\quad p = mv$

$d = \frac{v_i + v_f}{2}t$ $\quad v_f^2 = v_i^2 + 2ad$ $\quad \Delta p = F\Delta t$ $\quad E_p = \frac{1}{2}kx^2$ $\quad E_k = \frac{1}{2}mv^2$

$\Delta E_p = mg\Delta h$ $\quad F = -kx$ $\quad F = ma$ $\quad a_c = \frac{v^2}{r}$ $\quad F_c = \frac{mv^2}{r}$

$W = Fd$ $\quad P = \frac{W}{t}$ $\quad \tau = Fd$ $\quad C = 2\pi r$

Physics 91173 (2.6): Demonstrate understanding of electricity and electromagnetism

$E = \frac{V}{d}$ $\quad F = Eq$ $\quad \Delta E_p = Eqd$ $\quad E_k = \frac{1}{2}mv^2$ $\quad F = BIL$ $\quad F = Bqv$

$I = \frac{q}{t}$ $\quad V = \frac{\Delta E}{q}$ $\quad V = IR$ $\quad P = IV$ $\quad V = BvL$

$P = \frac{\Delta E}{t}$ $\quad R_T = R_1 + R_2 + \ldots$ $\quad \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$