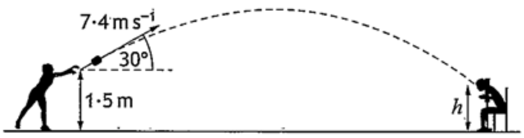
Candidate 1 evidence

SECTION 2 — 110 marks

Attempt ALL questions

1. During a school funfair, a student throws a wet sponge at a teacher. The sponge is thrown with an initial velocity of $7 \cdot 4\,m\,s^{-1}$ at an angle of $30°$ to the horizontal.

The sponge leaves the student's hand at a height of $1 \cdot 5\,m$ above the ground.



The sponge hits the teacher.

The effects of air resistance can be ignored.

(a) (i) Calculate:

(A) the horizontal component of the initial velocity of the sponge; **1**

Space for working and answer

$V_h = V\cos\theta$
$= 7.4\cos 30$
$= 6.4\,ms^{-1}$

(B) the vertical component of the initial velocity of the sponge. **1**

Space for working and answer

$V_v = V\sin\theta$
$= 7.4\sin 30$
$= 3.7\,ms^{-1}$

1. (a) (continued)

(ii) Calculate the time taken for the sponge to reach its maximum height. **3**

Space for working and answer

S U V A T
3·7 0 −9·8 ?

$v = u + at$
$u + at = v$
$at = v - u$
$t = \frac{v-u}{a} = \frac{0-3.7}{-9.8} = 0.4\text{s} \times 2 = 0.76\text{s}$

(iii) The sponge takes a further 0·45 s to travel from its maximum height until it hits the teacher.

Determine the height h above the ground at which the sponge hits the teacher. **4**

Space for working and answer

s u v a t
? 3.7 9.8 0.45

$s = ut + \frac{1}{2}at^2$
$= (3.7 \times 0.45) + (0.5 \times 9.8 \times 0.45^2)$
$= 5.47\text{m} - 1.5 = 3.97\text{m}$

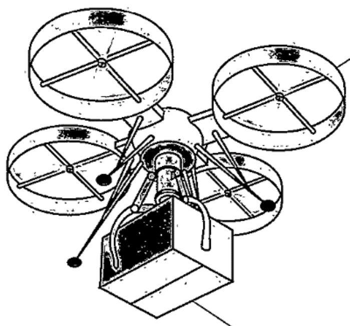
(b) The student throwing the sponge makes the following statement.

"If the sponge is thrown with a higher speed at the same angle from the same height then it would take a shorter time to hit the teacher in the same place."

Explain why the student's statement is incorrect. **2**

It is incorrect as the vertical velcity would increase so the sponge would go past the teacher.

2. An internet shopping company is planning to use drones to deliver packages.



(a) During a test the drone is hovering at a constant height above the ground.

The mass of the drone is 5·50 kg.

The mass of the package is 1·25 kg.

(i) Determine the upward force produced by the drone. 3

Space for working and answer

mass = 6.75kg

F = ma

= 6.75 × 9.8 = 66.15 N

2. (a) (continued)

(ii) The package is now lowered using a motor and a cable.

A battery supplies 12 V across the motor. The resistance of the motor is 9·6 Ω.

Calculate the power dissipated by the motor. **3**

Space for working and answer

$P = \frac{V^2}{R} = \frac{12^2}{9{\cdot}6} = \underline{15 W}$

(iii) While the package is being lowered the cable breaks.

The upward force produced by the drone remains constant.

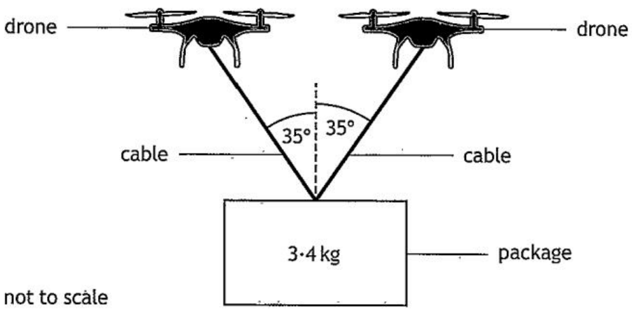
Describe the vertical motion of the drone immediately after the cable breaks. **2**

Justify your answer.

The drone will rise up as the ~~upward~~ ~~force~~ it will be lighter ~~as forces are unba~~

2. (continued)

(b) To carry a package with a greater mass two drones are used as shown.



The drones are hovering at a constant height above the ground.

The mass of the package suspended from the two drones is 3·4 kg.

Determine the tension in each cable. **4**

Space for working and answer

35 + 35 = 70

W = mg sinθ

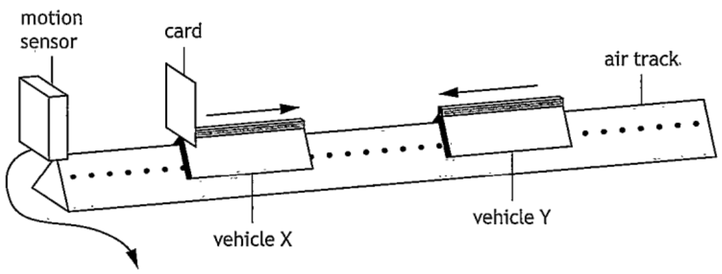
= 3·4 × 9·8 sin 70 = 31.3 of force to each

F = ma

= 3.4 × 9.8 = 33.32 N

31.3 / 2 = 15.66 N of tension in each cable

3. A student sets up an experiment to investigate a collision between two vehicles on a frictionless air track.

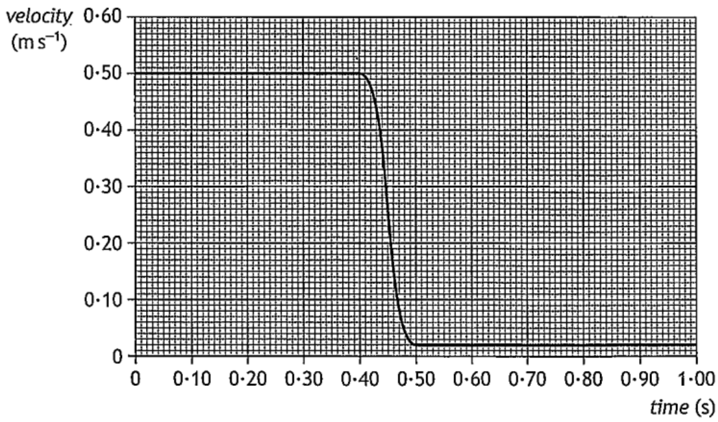


Vehicle X of mass 0·75 kg is travelling to the right along the track.

Vehicle Y of mass 0·50 kg is travelling to the left along the track with a speed of 0·30 m s^{-1}.

The vehicles collide and move off separately.

A computer displays a graph showing the velocity of vehicle X from just before the collision to just after the collision.



3. **(continued)**

(a) Show that the velocity of vehicle Y after the collision is $0{\cdot}42\ \text{m s}^{-1}$. **2**

Space for working and answer

$d = vt$

~~$v = d/t$~~

(b) Determine the impulse on vehicle Y during the collision. **3**

Space for working and answer

Impulse $= mv$

$= 0.5 \times 0.50 = 0.125\ \text{kgms}^{-1}$

MARKS

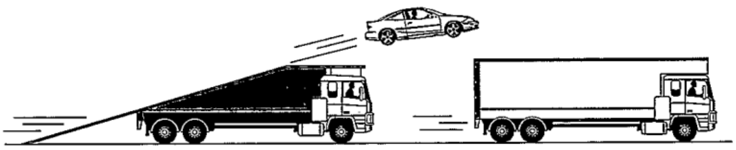
3. (continued)

(c) Explain how the student would determine whether the collision was elastic or inelastic. **2**

~~see~~ calculate if kinetic energy has been lost - ~~is~~ inelastic or conserved - elastic

4. A stunt is being carried out during the making of a film.

A car is to be driven up a ramp on a moving lorry by a stunt driver, who will attempt to land the car safely on the roof of a second moving lorry. The car is to stop on the roof of the second lorry while this lorry is still moving.



Using your knowledge of physics, comment on the challenges involved in carrying out the stunt successfully. 3

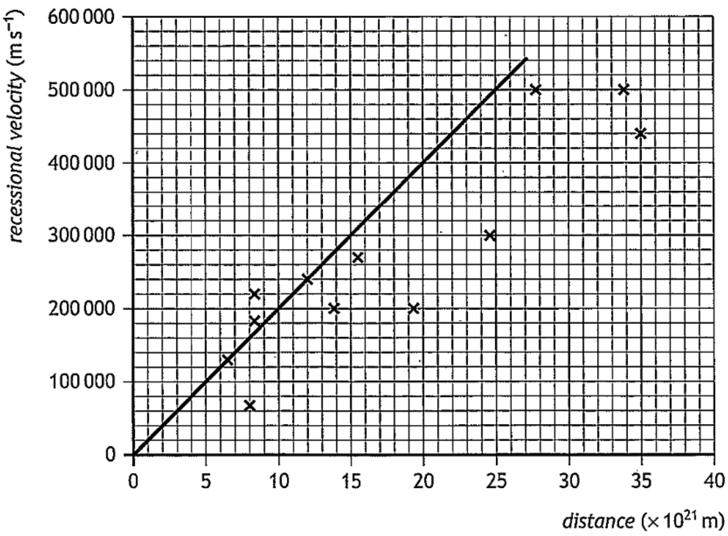
To carry out the stunt successfully the car would have to be faster than the second moving lorry to ensure it would make it and the second lorry would have to be travelling at a constant velocity. However the car has to make sure it has enough break force in order to stop on top of the lorry in time otherwise it will fall off the front of the lorry. The first lorry would also have to be travelling at a constant velocity relative to the 2nd lorry too.

5. Hubble's Law states that the universe is expanding. The expanding universe is one piece of evidence that supports the Big Bang theory.

(a) State one other piece of evidence that supports the Big Bang theory. **1**

Redshift

(b) A student plots some of the original data from the 1929 paper by Edwin Hubble and adds the line shown in order to determine a value for the Hubble constant H_0.



The student calculates the gradient of their line and obtains a value for the Hubble constant of $2{\cdot}0 \times 10^{-17}\,s^{-1}$.

The age of the universe can be calculated using the relationship

$$\text{age of universe} = \frac{1}{H_0}$$

5. (b) (continued)

(i) Calculate the age of the universe, in years, obtained when using the student's value for the Hubble constant. **2**

Space for working and answer

age of universe $= \frac{1}{H_0}$

$= \frac{1}{2.0 \times 10^{-17}} = 5 \times 10^{16}$ years

(ii) The current estimate for the age of the universe is $13 \cdot 8 \times 10^9$ years.

(A) State why the value obtained in (b)(i) is different from the current estimate for the age of the universe. **1**

Because technology has advanced since 1929 so it is a more accurate estimate now

(B) Suggest a change that the student could make to their graph to obtain a value closer to the current estimate for the age of the universe. **1**

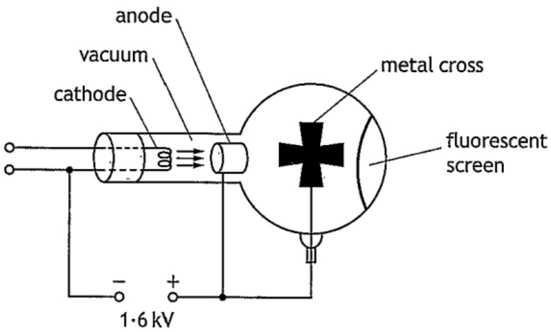
Plot all the original data not just some

(c) It has been discovered that the rate of expansion of the universe is increasing.

State what physicists think is responsible for this increase. **1**

Dark energy

6. An experiment is set up to demonstrate a simple particle accelerator.



(a) Electrons are accelerated from rest between the cathode and the anode by a potential difference of 1·6 kV.

(i) Show that the work done in accelerating an electron from rest is $2{\cdot}6 \times 10^{-16}$ J. **2**

Space for working and answer

$E_W = QV$

$= 1.60 \times 10^{-19} \times 1.6 \times 10^3$

$= 2.6 \times 10^{-16}$ J

(ii) Calculate the speed of the electron as it reaches the anode. **3**

Space for working and answer

$E_K = \frac{1}{2}mv^2$

$\frac{1}{2}mv^2 = E_K$

$mv^2 = 2E_K$

$v^2 = \frac{2E_K}{m}$

$v = \sqrt{\frac{2E_K}{m}} = \sqrt{\frac{(2 \times 2.6 \times 10^{-16})}{4.11 \times 10^{-31}}}$ = ~~8.8×10~~

2.4×10^{7} ms^{-1}

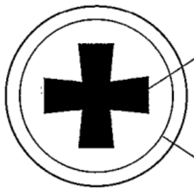
6. (continued)

(b) As the electrons travel through the vacuum towards the fluorescent screen they spread out.

In the path of the electrons there is a metal cross, which is connected to the positive terminal of the supply. The electrons that hit the cross are stopped by the metal.

Electrons that get past the metal cross hit a fluorescent screen at the far side of the tube.

When electrons hit the fluorescent screen, the screen glows.



The potential difference between the anode and the cathode is now increased to 2·2 kV. This changes what is observed on the screen.

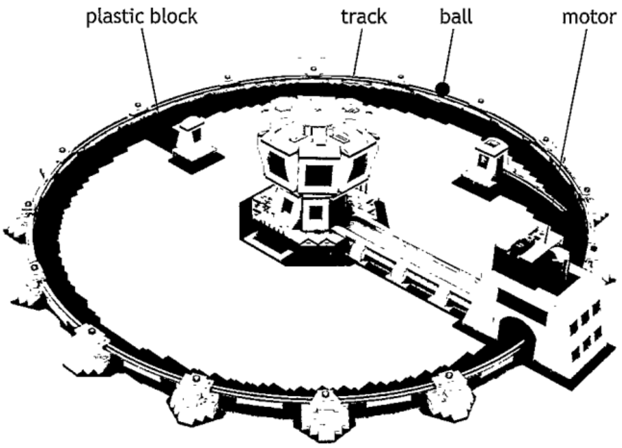
Suggest one change that is observed. **2**

You must justify your answer.

There would be less electrons hitting the screen as as potential difference increases current decrease so there would be less electrons

6. (continued)

(c) A student builds a model of a particle accelerator. The model accelerates a small ball on a circular track. A battery-operated motor accelerates the ball each time it passes the motor. To cause a collision a plastic block is pushed onto the track. The ball then hits the block.



Using your knowledge of physics comment on the model compared to a real particle accelerator, such as the large hadron collider at CERN. 3

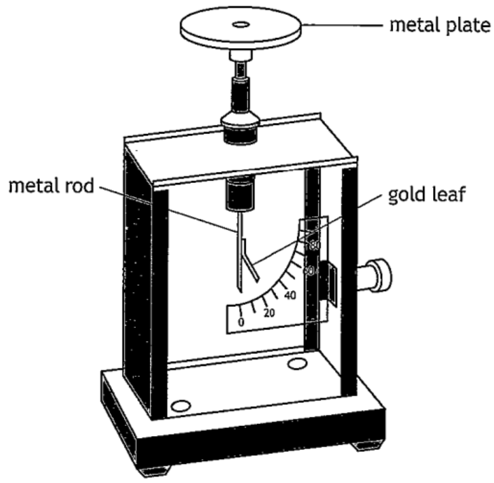
This model compared to the large hadron collider is similar as both pieces accelerate objects inside in order for them to collide with one another. ~~However in the model Both the ball & the particles inside the Hadron Collider will have a velocity~~ however the collider will have huge numbers of particles inside so the model should have more than

6. (c) (continued)

1 ball in order to be completely accurate

7. A student uses a gold-leaf electroscope to investigate the photoelectric effect. A deflection of the gold leaf on the electroscope shows that the metal plate is charged.

The student charges the metal plate on the electroscope and the gold leaf is deflected.



gold-leaf electroscope

(a) Ultraviolet light is shone onto the negatively charged metal plate. The gold-leaf electroscope does not discharge. This indicates that photoelectrons are not ejected from the surface of the metal.

Suggest one reason why photoelectrons are not ejected from the surface of the metal. 1

~~light~~ photoelectrons doesn't have enough energy to be ejected from the surface

7. (continued)

(b) The student adjusts the experiment so that the gold-leaf electroscope now discharges when ultraviolet light is shone onto the plate.

The work function for the metal plate is $6{\cdot}94 \times 10^{-19}$ J.

(i) State what is meant by a *work function of* $6{\cdot}94 \times 10^{-19}$ *J*. **1**

6.94×10^{-19} J is the minimum amount of energy needed to release a photoelectron

(ii) The irradiance of the ultraviolet light on the metal plate is reduced by increasing the distance between the gold-leaf electroscope and the ultraviolet light source.

State what effect, if any, this has on the maximum kinetic energy of the photoelectrons ejected from the surface of the metal. **2**

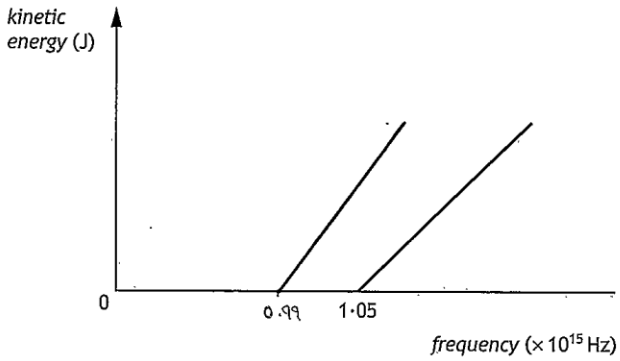
Justify your answer.

No effect as irradiance only affects no. of photoelectrons not the kinetic energy as ~~vel sa~~ velocity stays the same

7. (continued)

(c) The graph shows how the kinetic energy of the photoelectrons ejected from the metal plate varies as the frequency of the incident radiation increases.

The threshold frequency for the metal plate is $1{\cdot}05 \times 10^{15}$ Hz.



The metal plate is now replaced with a different metal plate made of aluminium.

The aluminium has a threshold frequency of $0{\cdot}99 \times 10^{15}$ Hz.

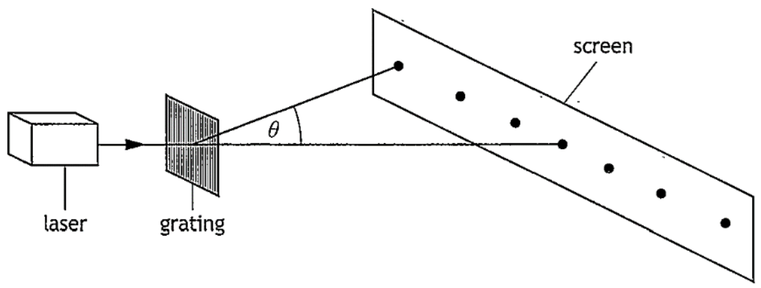
Add a line to the graph to show how the kinetic energy of the photoelectrons ejected from the aluminium plate varies as the frequency of the incident radiation increases. 2

(An additional graph, if required, can be found on *page 45*.)

(d) Explain why the photoelectric effect provides evidence for the particle nature of light. 1

Because light is released as photons

8. A student investigates interference of light by directing laser light of wavelength 630 nm onto a grating as shown.



(a) A pattern of bright spots is observed on a screen.

(i) Explain, in terms of waves, how bright spots are produced on the screen. 1

When waves meet in phase (constructive interference)

(ii) The grating has 250 lines per millimetre.

Calculate the angle θ between the central maximum and the third order maximum. 3

Space for working and answer

$d\sin\theta = m\lambda$

$250\times10^{-3}\times\sin\theta = 3\times630\times10^{-9}$

$\theta = \sin^{-1}\left(\frac{3\times630\times10^{-9}}{250\times10^{-3}}\right) = 4.3\times10^{-4}\,^{\circ}$

8. (a) (continued)

(iii) The grating is now replaced by one which has 600 lines per millimetre.

State the effect of this change on the pattern observed. **2**

Justify your answer.

Lines are closer together because sinθ has decreased

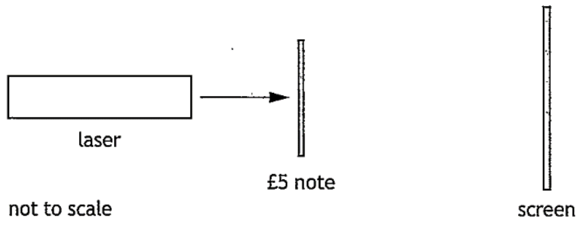
(iv) The interference pattern is produced by coherent light.

State what is meant by the term *coherent*. **1**

Light with same speed, phase relationship & wavelength

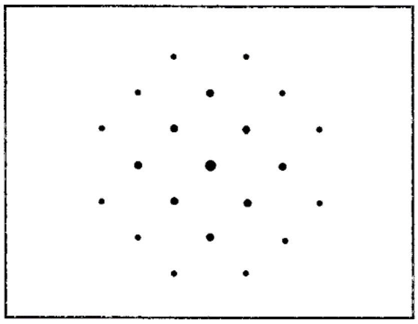
8. (continued)

(b) The student now shines light from the laser onto a £5 note.



When it is shone through the transparent section of the note the student observes a pattern of bright spots on the screen.

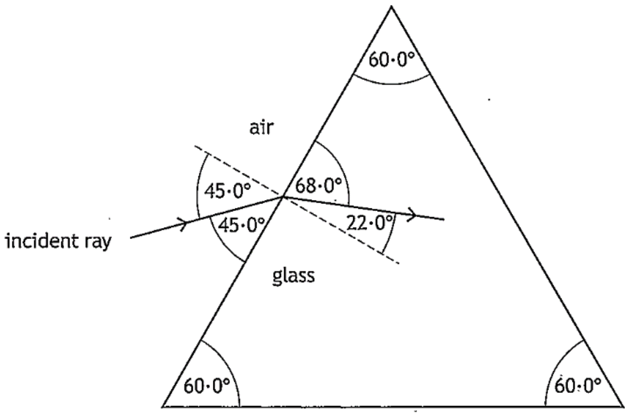
The diagram below shows the pattern that the student observes on the screen.



Suggest a reason for the difference in the pattern produced using the £5 note and the pattern produced using the grating. **1**

The grating is a line grating & the £5 note isn't so it can't make dots in a straight line

9. A ray of monochromatic light is incident on a glass prism as shown.



(a) Show that the refractive index of the glass for this ray of light is 1·89. **2**

Space for working and answer

$$n = \frac{\sin\theta_1}{\sin\theta_2} = \frac{\sin 45}{\sin 22} = 1.89$$

(b) (i) State what is meant by the term *critical angle*. **1**

The angle at which the light is reflected

9. (b) (continued)

(ii) Calculate the critical angle for this light in the prism. 3

Space for working and answer

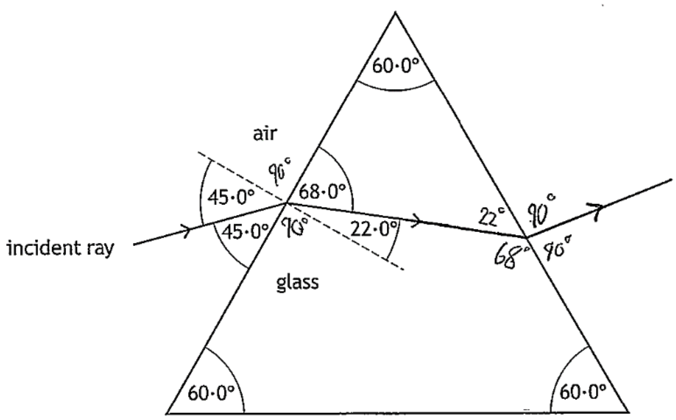
$\sin\theta_c = \frac{1}{n}$

$\sin\theta_c = \frac{1}{1.89}$

$\theta_c = \sin^{-1}\left(\frac{1}{1.89}\right) = \underline{\underline{31.9^\circ}}$

(iii) Complete the diagram below to show the path of the ray as it passes through the prism and emerges into the air.

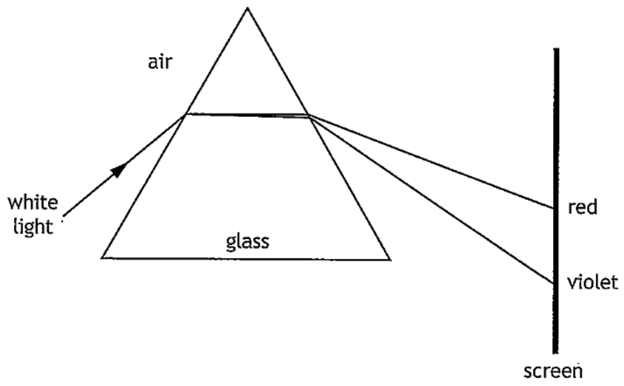
Mark on the diagram the values of all relevant angles. 4



(An additional diagram, if required, can be found on *page 45*.)

9. (continued)

(c) A ray of white light is shone through the prism and a spectrum is observed as shown.



The prism is now replaced with another prism made from a different type of glass with a lower refractive index.

Describe one difference in the spectrum produced by this prism compared to the spectrum produced by the first prism. 1

The ~~light~~ spectrum will be smaller in width

10. In a laboratory experiment, light from a hydrogen discharge lamp is used to produce a line emission spectrum. The line spectrum for hydrogen has four lines in the visible region as shown.

(a) The production of the line spectrum can be explained using the Bohr model of the atom.

State **two** features of the *Bohr model* of the atom. **2**

~~Visible is in levels which go from lowest ground level to highest ionisation level~~

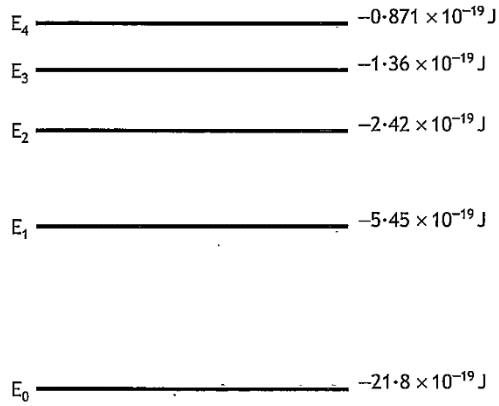
* Electrons are arranged in electron shells around the nucleus

* It shows the different energy levels

[Turn over

10. (continued)

(b) Some of the energy levels of the hydrogen atom are shown.



One of the spectral lines is due to electron transitions from E_3 to E_1.

Determine the frequency of the photon emitted when an electron makes this transition. **3**

Space for working and answer

$E_3 - E_1 = hf$

$(-1.36\times10^{-19}) - (-5.45\times10^{-19}) = 6.63\times10^{-34} f$

$f = \dfrac{4.09\times10^{-19}}{6.63\times10^{-34}} = \underline{6.17\times10^{14}\ \text{Hz}}$

10. (continued)

(c) In the laboratory, a line in the hydrogen spectrum is observed at a wavelength of 656 nm.

When the spectrum of light from a distant galaxy is viewed, this hydrogen line is now observed at a wavelength of 661 nm.

Determine the recessional velocity of the distant galaxy. 5

Space for working and answer

$$Z = \frac{\lambda o - \lambda r}{\lambda r} = \frac{(661 \times 10^{-9}) - (656 \times 10^{-9})}{(656 \times 10^{-9})}$$

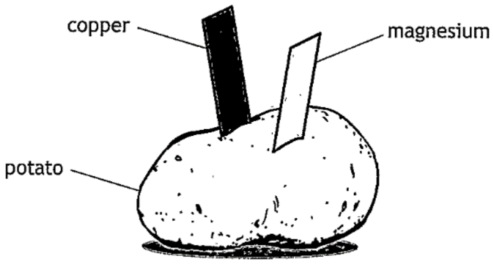
$$= 0.0076$$

$$Z = \frac{V}{C}$$

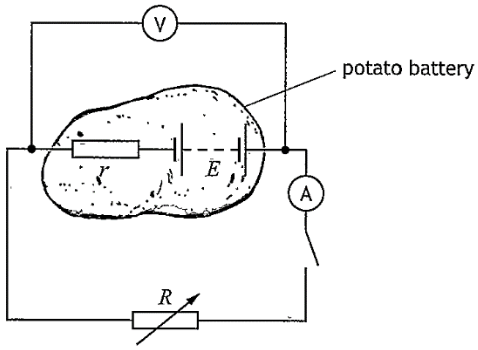
$$\frac{V}{C} = Z$$

$$V = Z \times C = 0.0076 \times 3 \times 10^{8} = 2.29 \times 10^{6}\ ms^{-1}$$

11. A student constructs a battery using a potato, a strip of copper and a strip of magnesium.



The student then sets up the following circuit with the potato battery connected to a variable resistor R, in order that the electromotive force (e.m.f.) and internal resistance of the battery may be determined.

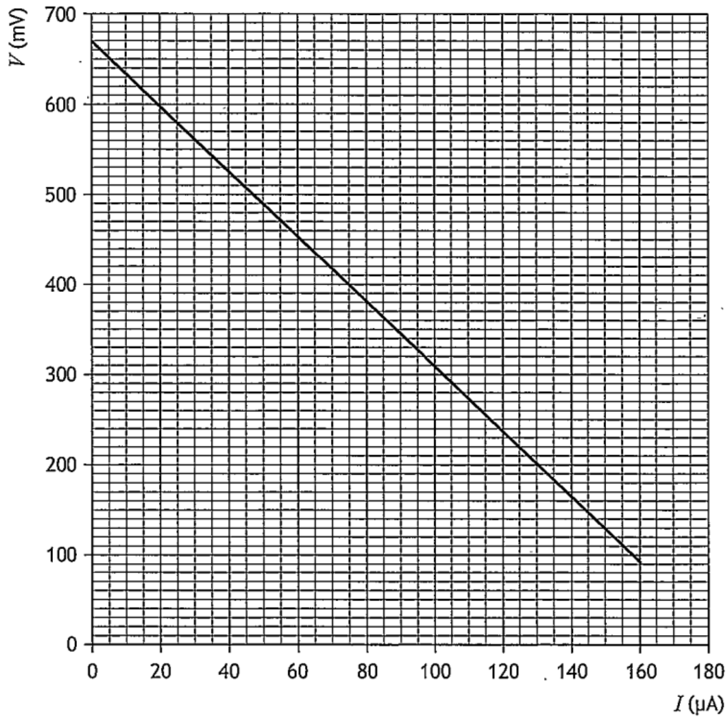


(a) State what is meant by the term *electromotive force* (*e.m.f.*). 1

The number of joules of energy supplied to each coloumb of charge passing through the circuit

11. (continued)

(b) The student uses readings of current I and terminal potential difference V from this circuit to produce the graph shown.



Determine the internal resistance of the potato battery. 3

Space for working and answer

x_1 0 x_2 160

y_1 670 y_2 90

Ir = gradient

$= \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{90 - 670}{160 - 0} = 3.6 \ \Omega$

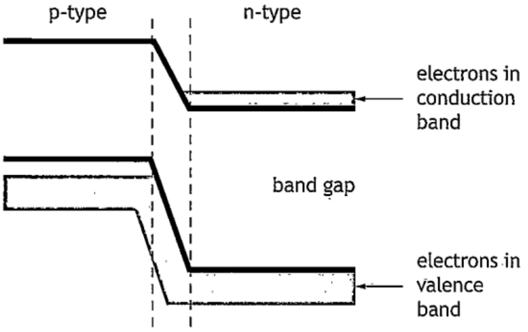
11. (continued)

(c) The student connects a red LED and a blue LED, in turn, to the battery.

The LEDs are forward biased when connected.

The student observes that the battery will operate the red LED but not the blue LED.

The diagram represents the band structure of the blue LED.



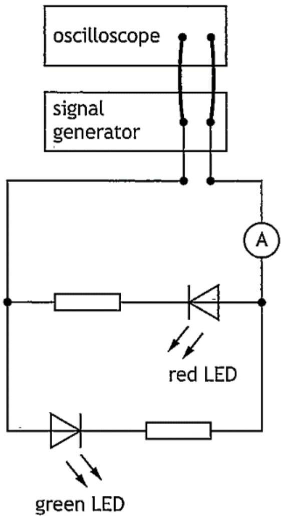
LEDs emit light when electrons fall from the conduction band into the valence band of the p-type semiconductor.

Explain, using **band theory**, why the blue LED will not operate with this battery. 1

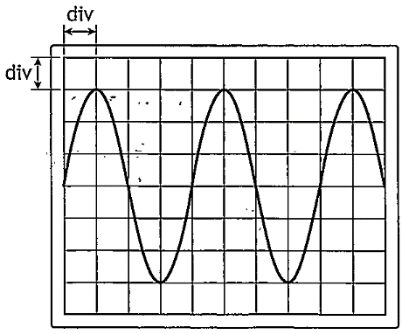
Blue light doesn't have a high enough wavelength to make and electron fall from conduction band to valence band to make the LED work

12. A student carries out a series of experiments to investigate alternating current.

(a) A signal generator is connected to an oscilloscope and a circuit as shown.



The output of the signal generator is displayed on the oscilloscope.



The Y-gain setting on the oscilloscope is 1·0 V/div.

The timebase setting on the oscilloscope is 0·5 s/div.

12. (a) (continued)

(i) Determine the peak voltage of the output of the signal generator. **1**

Space for working and answer

$V_p = 3 \times 1 = 3V$

(ii) Determine the frequency of the output of the signal generator. **3**

Space for working and answer

Frequency = 4 × 0.5 = 2

$T = \frac{1}{F}$ $f = \frac{1}{t}$ $= \frac{1}{2} = 0.5Hz$

(iii) The student observes that the red LED is only lit when the ammeter gives a positive reading and the green LED is only lit when the ammeter gives a negative reading.

Explain these observations. **2**

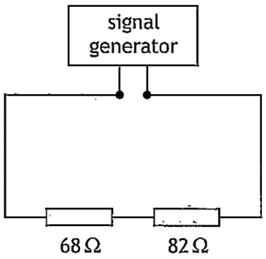
current only flows in one direction in a diode so red only works when positive flow + green when its a negative flow

12. (continued)

(b) The signal generator is now connected in a circuit as shown.

The settings on the signal generator are unchanged.

The signal generator has negligible internal resistance.



Determine the r.m.s. voltage across the 82 Ω resistor. **5**

Space for working and answer

$V_p = \sqrt{2} V_{rms}$

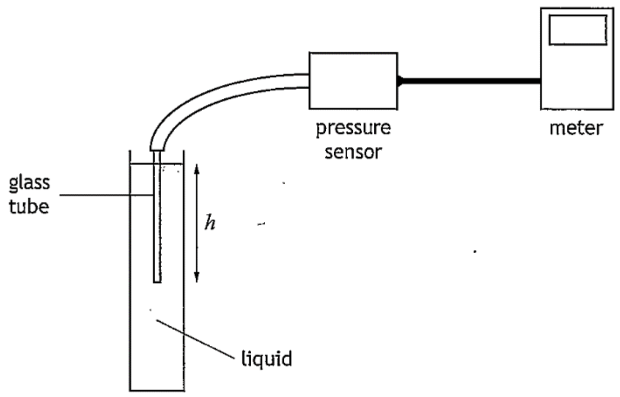
$V = IR$

$I = V/R = 3/82 = 0.036 \text{ A}$

$V = IR = 0.036 \times 82 = 2.96$

$V_{rms} = 3 - 2.96 = 0.04 \text{ V}$

13. A student sets up an experiment to investigate the pressure due to a liquid as shown.



The pressure due to a liquid is given by the relationship

$$p = \rho g h$$

where p is the pressure due to the liquid in pascals (Pa),
g is the gravitational field strength in N kg^{-1},
ρ is the density of the liquid in kg m^{-3},
and h is the depth in the liquid in m.

(a) The student initially carries out the investigation using water.

The density of water is $1{\cdot}00 \times 10^3$ kg m^{-3}.

Calculate the pressure due to the water at a depth of 0·35 m. 2

Space for working and answer

$P = pgh$

$= (1.00 \times 10^3) \times 9.8 \times 0.35$

$= \underline{3430 \text{ Pa}}$

13. (continued)

(b) The student repeats the experiment with a different liquid.

The pressure meter is set to zero before the glass tube is lowered into the liquid.

The student takes measurements of the pressure at various depths below the surface of the liquid.

The student records the following information.

Depth, h (m)	Pressure, p (kPa)
0·10	1·2
0·20	2·5
0·30	3·6
0·40	4·9
0·50	6·2

(i) Using the square-ruled paper on *page 43*, draw a graph of p against h. **3**

(Additional graph paper, if required, can be found on *page 44*.)

(ii) Calculate the gradient of your graph. **2**

Space for working and answer

x_1 0.10 x_2 0.50

y_1 1.2 y_2 6.2

Gradients

$= \frac{y_2 - y_1}{x_2 - x_1} = \frac{6.2 - 1.2}{0.50 - 0.10} = 9.9$

(iii) Determine the density of this liquid. **2**

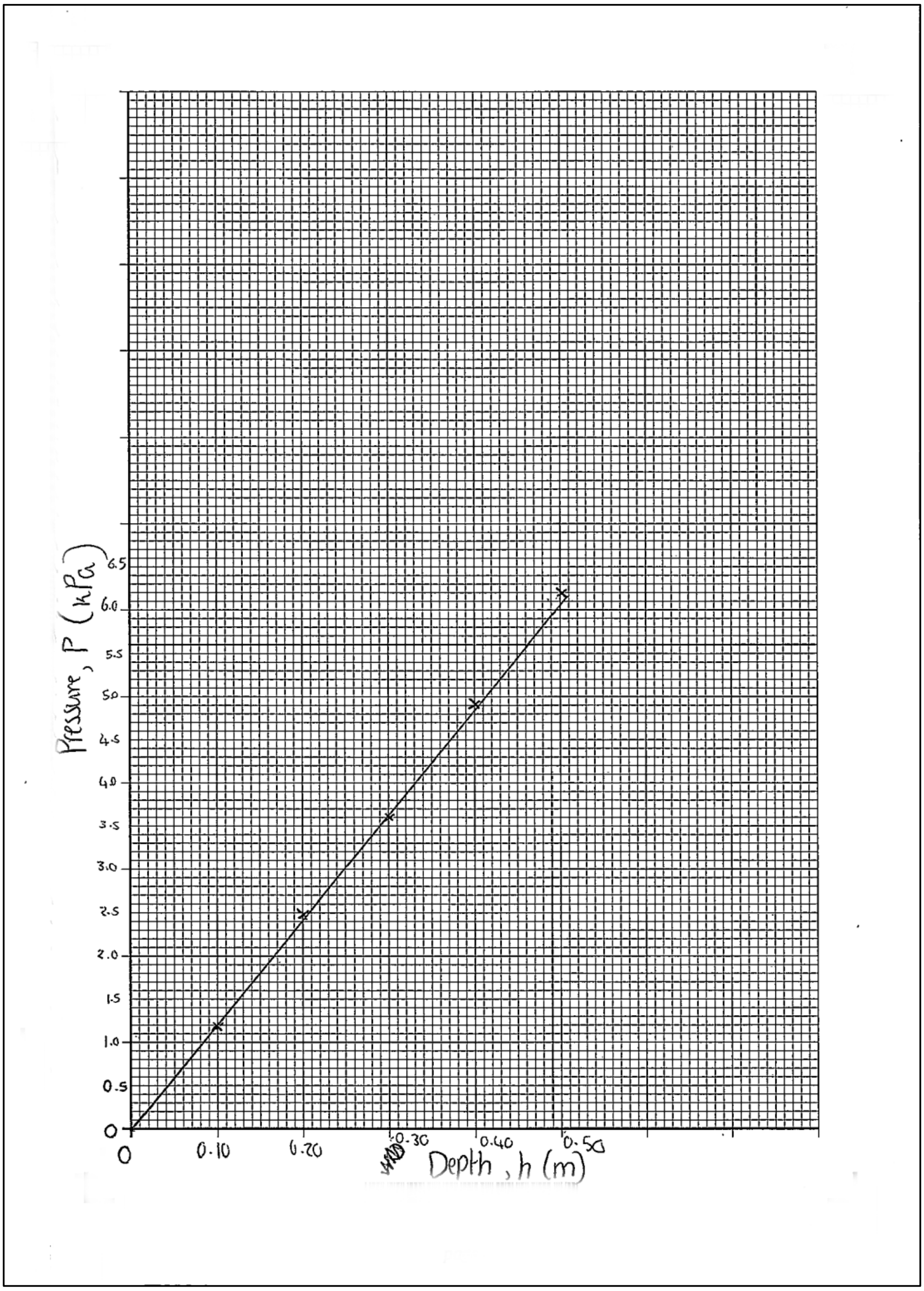
Space for working and answer

$P = \rho g h$

$\rho g h = P$

$\rho = \frac{P}{gh}$

Density $= \frac{P}{g \times h} = \frac{1.2}{9.8 \times 0.10} = 1.2 \times 10^{-2}$ Kgm^{-3}


Pressure, P (kPa)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
0
0.10
0.20
0.30
0.40
0.50
Depth, h (m)