Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2023

Marking Scheme

Physics

Ordinary Level

Note to teachers and students on the use of published marking schemes

Marking schemes published by the State Examinations Commission are not intended to be standalone documents. They are an essential resource for examiners who receive training in the correct interpretation and application of the scheme. This training involves, among other things, marking samples of student work and discussing the marks awarded, so as to clarify the correct application of the scheme. The work of examiners is subsequently monitored by Advising Examiners to ensure consistent and accurate application of the marking scheme. This process is overseen by the Chief Examiner, usually assisted by a Chief Advising Examiner. The Chief Examiner is the final authority regarding whether or not the marking scheme has been correctly applied to any piece of candidate work.

Marking schemes are working documents. While a draft marking scheme is prepared in advance of the examination, the scheme is not finalised until examiners have applied it to candidates' work and the feedback from all examiners has been collated and considered in light of the full range of responses of candidates, the overall level of difficulty of the examination and the need to maintain consistency in standards from year to year. This published document contains the finalised scheme, as it was applied to all candidates' work.

In the case of marking schemes that include model solutions or answers, it should be noted that these are not intended to be exhaustive. Variations and alternatives may also be acceptable. Examiners must consider all answers on their merits, and will have consulted with their Advising Examiners when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes should be avoided. While the underlying assessment principles remain the same, the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. The Chief Examiner in any given year has the responsibility to determine how best to ensure the fair and accurate assessment of candidates' work and to ensure consistency in the standard of the assessment from year to year. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination are subject to change from one year to the next without notice.

In considering this marking scheme the following points should be noted.

1. In many instances only key words are given – words that must appear in the correct context in the candidate's answer in order to merit the assigned marks.

2. Words, expressions or statements separated by a solidus, /, are alternatives which are equally acceptable.

3. Answers that are separated by a double solidus, //, are answers which are mutually exclusive. A partial answer from one side of the // may not be taken in conjunction with a partial answer from the other side.

4. The descriptions, methods and definitions in the scheme are not exhaustive and alternative valid answers are acceptable.

5. The detail required in any answer is determined by the context and manner in which the question is asked, and also by the number of marks assigned to the answer in the examination paper. Therefore, in any instance, it may vary from year to year.

6. Each time an arithmetical slip occurs in a calculation, one mark is deducted.

7. A zero should only be recorded when the candidate has attempted the question item but does not merit marks. If a candidate does not attempt a question item examiners should record NR.

8. Examiners are expected to annotate parts of the responses as directed at the marking conference. (See below.)

Symbol	Name	Use
✗	Cross	Incorrect element
✓	Tick	Correct element (0 marks)
✓ n	Tick_n	Correct element (n marks)
$\boxed{\sim\sim\sim}$	Horizontal wavy line	To be noticed
$\boxed{\wr}$	Vertical wavy line	Additional page
$\boxed{n}$	Partial	Partially correct element (n marks)
$\boxed{-1}$	−1	−1
$\boxed{\wedge}$	^	Missing element

9. Bonus marks at the rate of 10% of the marks obtained will be given to a candidate who answers entirely through Irish and who obtains 75% or less of the total mark available (i.e. 300 marks or less). In calculating the bonus to be applied decimals are always rounded down, not up ¬ e.g., 4.5 becomes 4; 4.9 becomes 4, etc. See below for when a candidate is awarded more than 300 marks.

Marcanna Breise as ucht freagairt trí Ghaeilge

Léiríonn an tábla thíos an méid marcanna breise ba chóir a bhronnadh ar iarrthóirí a ghnóthaíonn níos mó ná 75% d'iomlán na marcanna.

N.B. Ba chóir marcanna de réir an ghnáthráta a bhronnadh ar iarrthóirí nach ngnóthaíonn níos mó ná 75% d'iomlán na marcanna don scrúdú. Ba chóir freisin an marc bónais sin **a shlánú síos**.

Tábla 400 @ 10%
Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 400 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 300 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
301 - 303	29
304 - 306	28
307 - 310	27
311 - 313	26
314 - 316	25
317 - 320	24
321 - 323	23
324 - 326	22
327 - 330	21
331 - 333	20
334 - 336	19
337 - 340	18
341 - 343	17
344 - 346	16
347 - 350	15

Bunmharc	Marc Bónais
351 - 353	14
354 - 356	13
357 - 360	12
361 - 363	11
364 - 366	10
367 - 370	9
371 - 373	8
374 - 376	7
377 - 380	6
381 - 383	5
384 - 386	4
387 - 390	3
391 - 393	2
394 - 396	1
397 - 400	0

1. A student carried out an experiment to show that the acceleration *a* of an object is proportional to the force *F* applied.

The student recorded the following results.

F (N)	0.2	0.4	0.6	0.8	1.0	1.2
a (m s^{-2})	0.72	1.39	2.11	2.76	3.47	4.22

(*i*) Draw a labelled diagram of the apparatus used in this experiment.

runway **[3]**

trolley **[3]**

means of applying/measuring force **[3]**

means of measuring distance/velocity/time **[3]**

[–1 if no label present on diagram]

(*ii*) What measurements did the student take to calculate acceleration?

first distance/velocity, second distance/velocity, time (*any two*) **[2 × 3]**

(*iii*) State one precaution the student took to ensure an accurate result.

e.g. avoid error of parallax, smooth runway **[4]**

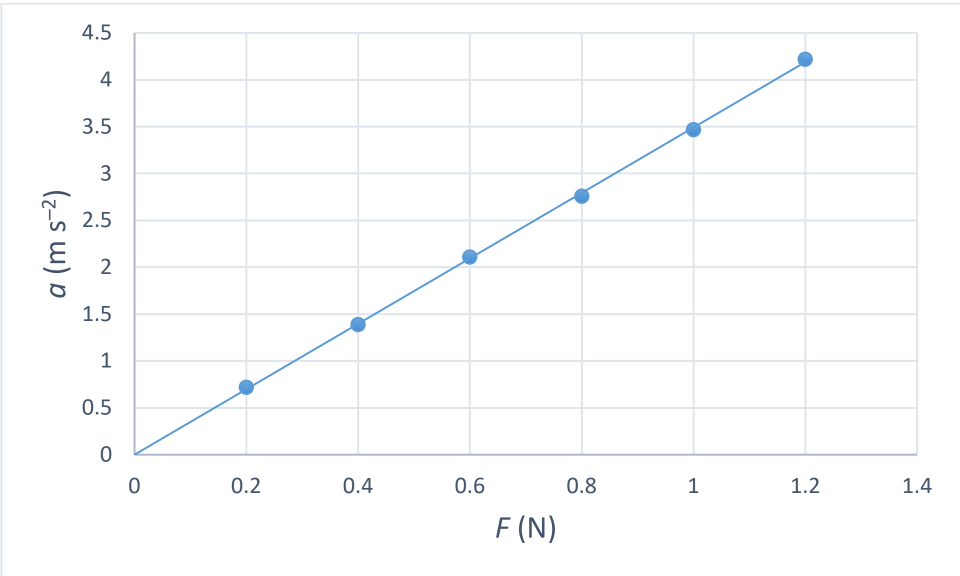
[accept partial answer for 2]

(*iv*) Use the data in the table to draw a graph on graph paper of *F* against *a*.

labelled axis **[3]**

points plotted **[6 × 1]**

line of best fit **[3]**



(*v*) Explain how your graph shows that acceleration is proportional to force.

straight line (through the origin) **[6]**

[accept partial answer for 3]

2. A student carried out an experiment to measure the focal length *f* of a concave mirror.
She measured the object distance *u* to be 20 cm and the image distance *v* to be 61 cm.

(*i*) Draw a labelled diagram of the apparatus used in this experiment.

object, mirror, screen **[6 + 3 + 3]**

[–1 if no label present on diagram]

(*ii*) On your diagram, indicate the object distance *u* and the image distance *v*.

***u* shown** **[3]**

***v* shown** **[3]**

[accept partial answer for 3]

(*iii*) Describe how the student found the position of the image.

move screen/mirror/object / sharpest image is formed **[6]**

[accept partial answer for 3]

(*iv*) State the formula used to calculate the focal length *f*.

$1/u + 1/v = 1/f$ **[6]**

[accept partial answer for 3]

(*v*) Calculate *f*.

$f = 15.1$ cm **[6]**

[accept partial answer for 3]

(*vi*) Describe how the student could have improved the experiment.

e.g. repeat and average **[4]**

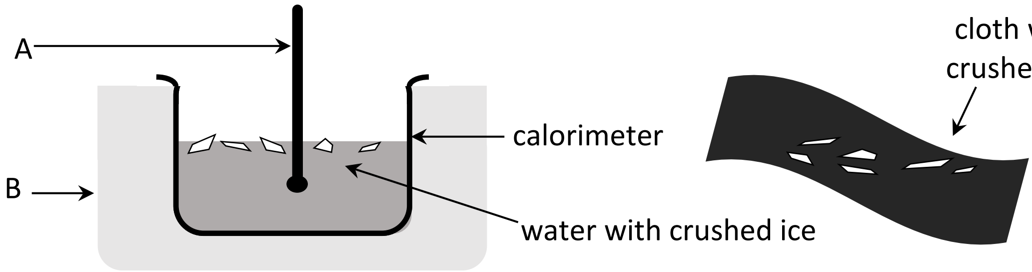
[accept partial answer for 2]

3. A student carried out an experiment to measure the specific latent heat of fusion of ice. He added ice at 0 °C to water in a copper calorimeter.

The following results were recorded.

Mass of empty copper calorimeter	= 0.083 kg
Mass of calorimeter + water	= 0.181 kg
Mass of ice	= 0.008 kg
Initial temperature of calorimeter + water	= 23 °C
Final temperature of calorimeter + water + melted ice	= 16 °C

Below is a diagram of the apparatus used in this experiment.



(*i*) Name the piece of equipment labelled A.

thermometer **[3]**

(*ii*) Name the piece of equipment labelled B.

lagging/insulation **[3]**

(*iii*) Why did the student crush the ice before adding it to the calorimeter?

melts faster / increase surface area / all at the same temperature/0 °C **[4]**

[accept partial answer for 2]

(*iv*) What was the cloth used for in this experiment?

to dry the ice **[4]**

[accept partial answer for 2]

(*v*) Calculate the fall in temperature of the calorimeter and water.

23 – 16 = 7 °C **[4]**

[accept partial answer for 2]

(*vi*) Calculate the mass of the water.

0.181 – 0.083 = 0.098 kg **[4]**

[accept partial answer for 2]

(*vii*) Using the formula $mc\Delta\theta$ and your answers to (*v*) and (*vi*), calculate *E*, the heat lost by the water and the calorimeter.

(0.098 × 4180 × 7) **[3]**

(0.083 × 390 × 7) **[3]**

= 3094.07 J **[3]**

[accept partial answer for 3]

(*viii*) Calculate the rise in temperature of the ice.

16 °C **[3]**

(*ix*) Calculate the value for l, the specific latent heat of fusion of ice.

0.008l + (0.008 × 4180 ×16) = 3094.07 so l = 319880 J kg^{-1} **[6]**

[accept partial answer for 3]

4. A student carried out an experiment to determine the speed of sound in air. The student set a tuning fork vibrating and measured the length l of a column of air when the air was vibrating at its fundamental frequency f. The experiment was repeated for different frequencies.

The student recorded the following results.

f (Hz)	256	288	320	341	384	480
l (m)	0.33	0.29	0.27	0.25	0.22	0.18

(*i*) Draw a labelled diagram of the apparatus used in this experiment.

tube, tuning fork, means of changing length, metre stick (*any three*) **[6 + 3 + 3]**

[–1 if no label present on diagram]

(*ii*) Indicate on your diagram the length that the student measured.

valid length shown **[3]**

(*iii*) How did the student find the frequency values?

from tuning fork **[6]**

[accept partial answer for 3]

(*iv*) The student knew that the column of air was vibrating at its fundamental frequency because resonance had occurred.

How did the student know that resonance had occurred?

loud sound **[6]**

[accept partial answer for 3]

(*v*) For each value of l in the table above, calculate the value of $\frac{1}{l}$ to 2 decimal places.

l (m)	**0.33**	**0.29**	**0.27**	**0.25**	**0.22**	**0.18**
$1/l$ (m^{-1})	**3.03**	**3.45**	**3.70**	**4.00**	**4.55**	**5.56**

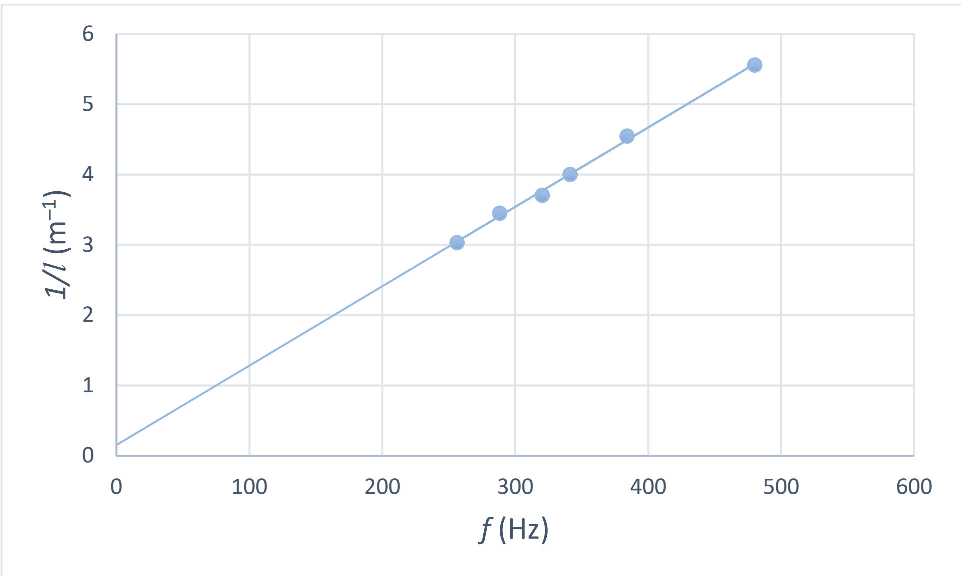
[6 × 1]

(*vi*) Draw a graph on graph paper of f against $\frac{1}{l}$.

labelled axis **[2]**

points plotted **[3]**

line of best fit **[2]**



5. In an experiment to determine the resistivity of a nichrome wire, a student measured the resistance R and the length l of the wire. She repeated this for different lengths of wire. She also measured the diameter d of the wire.

The student recorded the following results.

l (cm)	20	30	40	50	60	70
R (Ω)	0.08	0.12	0.17	0.21	0.25	0.29
d (mm)	2					

(*i*) Name the apparatus used in this experiment to measure (*a*) the length of the wire (*b*) the resistance of the wire and (*c*) the diameter of the wire.

a **metre stick** **[3]**

b **ohmmeter** **[3]**

c **micrometer** **[3]**

(*ii*) How did the student check that the wire had the same diameter throughout its length?

checked the diameter at various points **[6]**

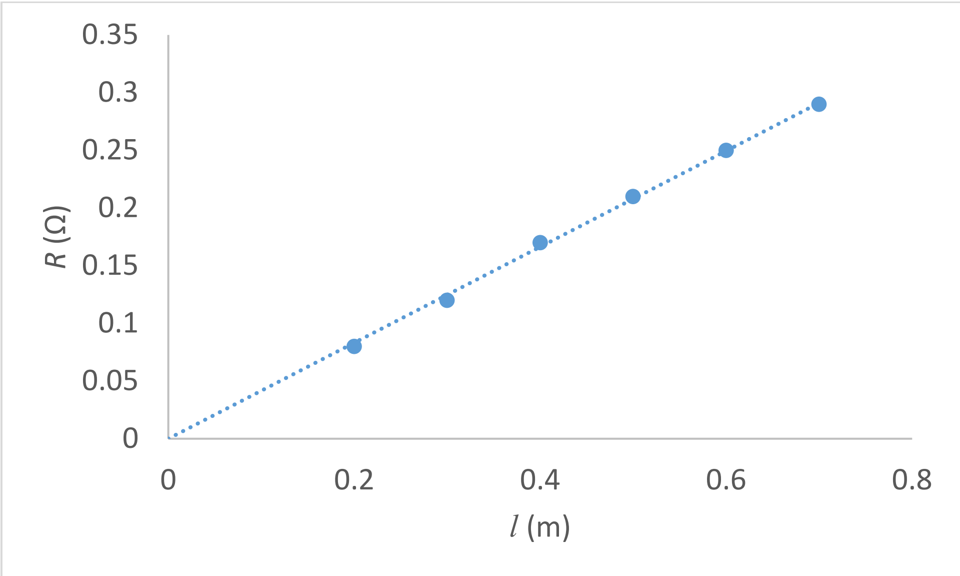
[accept partial answer for 3]

(*iii*) Use the data in the table to draw a graph on graph paper of length l against resistance R.

labelled axis **[4]**

points plotted **[6 × 1]**

line of best fit **[3]**



(*iv*) State the relationship between l and R.

proportional **[6]**

[accept partial answer for 3]

(*v*) State the formula used to calculate ρ, the resistivity of the wire.

$\boldsymbol{\rho = RA/l}$ **[6]**

[accept partial answer for 3]

6. Answer any **eight** of the following parts (*a*), (*b*), (*c*), etc.

(*a*) What is meant by the moment of a force?

force × distance (to fulcrum) / the turning effect of the force **[7]**

[accept partial answer for 4]

(*b*) A car accelerates from a speed of 17 m s^{-1} to a speed of 28 m s^{-1} in a time of 8 s. Calculate the acceleration of the car.

(28 – 17)/8 = 1.375 m s^{-2} **[7]**

[accept partial answer for 4]

(*c*) Convert 30 °C into kelvin (K).

30 + 273 = 303 K **[7]**

[accept partial answer for 4]

(*d*) Which of the following is the unit of work?

joule ~~watt~~ ~~farad~~ ~~metre~~

[7]

(*e*) Name an instrument used to measure voltage.

voltmeter **[7]**

[accept partial answer for 4]

(*f*) An object has a height of 2 cm. Its image in a mirror has a height of 5 cm. Calculate the object's magnification.

5 ÷ 2 = 2.5 **[7]**

[accept partial answer for 4]

(*g*) Explain the difference between heat and temperature.

heat is a form of energy / temperature is a measure of hotness **[7]**

[accept partial answer for 4]

(*h*) What are complementary colours of light?

a primary and a secondary colour / colours that combine to give white light **[7]**

[accept partial answer for 4]

(*i*) Describe how infrared radiation can be detected.

heating effect, etc. **[7]**

[accept partial answer for 4]

(*j*) What is meant by capacitance?

ratio of charge to voltage **[7]**

[accept partial answer for 4]

(*k*) Describe how white light can be separated into its constituent colours.

prism / diffraction grating / etc. **[7]**

[accept partial answer for 4]

(*l*) State what each letter in Einstein's famous equation $E = mc^2$ stands for.

E **= energy,** ***m*** **= mass,** ***c*** **= speed of light** **[3 + 2 + 2]**

7. A *big drop* is an amusement ride where a carriage with passengers is lifted to the top of a large vertical tower and then released to fall down the tower before it brakes and comes to rest.

(*i*) As the carriage travels to the top, the carriage is gaining potential energy. What is meant by potential energy?

energy due to position in a force field **[6]**

[accept partial answer for 3]

(*ii*) Draw a diagram of the forces acting on the carriage as it travels up the tower at a constant velocity.

arrow down **[3]**

equal arrow up **[3]**

[–1 if arrows are clearly not equal]

(*iii*) The carriage is dropped from a height of 37 m above the braking zone. The mass of the carriage is 6200 kg. Calculate the potential energy the carriage had before it was dropped.

mgh **[3]**

6200 × 9.8 × 37 **[3]**

= 2248120 J **[3]**

[accept partial answer for 3]

(*iv*) What is the main energy conversion that takes place as the carriage falls?

potential energy to kinetic energy **[6]**

[accept partial answer for 3]

(*v*) Calculate the velocity of the carriage when it has fallen 37 m.

$E_k = \frac{1}{2}mv^2$ // $v^2 = u^2 + 2as$ **[3]**

substitution **[3]**

v **= 26.9 m** s^{-1} **[3]**

[accept partial answer for 3]

(*vi*) Calculate the time it takes the carriage to fall 37 m.

26.9 ÷ 9.8 = 2.75 s **[6]**

[accept partial answer for 3]

(*vii*) Draw a diagram of the forces acting on the carriage as it falls.

arrow down **[6]**

[accept partial answer for 3]

(*viii*) Draw a velocity-time graph for the motion of the carriage from when it was dropped to when it comes to rest.

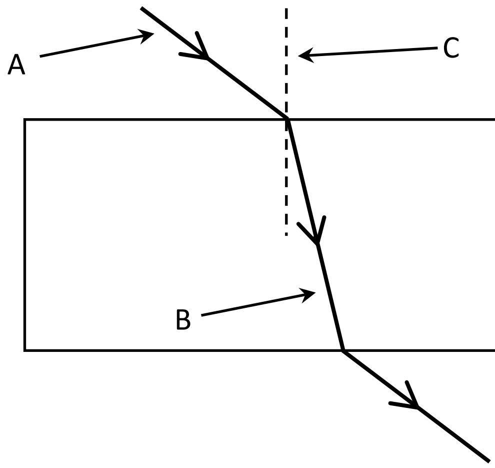
axis labelled **[2]**

acceleration shown **[3]**

deceleration shown **[3]**

[–1 if incorrect acceleration shown]

8. The diagram below shows how a ray of light travels through a rectangular glass block.



(*i*) What is meant by refraction of light?

the bending of light (as it travels from one medium to another) **[6]**

[accept partial answer for 3]

(*ii*) Name A, B and C.

A incident ray **[3]**

B refracted ray **[3]**

C normal **[3]**

(*iii*) Copy the diagram into your answerbook and label the angle of incidence *i* and the angle of refraction *r*.

angles labelled **[2 × 3]**

[accept partial answer for 3]

(*iv*) The refractive index of the glass block is 1.5. Calculate the angle of refraction when the angle of incidence is 35°.

$n = \sin i/\sin r$ **[3]**

substitution **[3]**

$r = 22.5°$ **[3]**

[accept partial answer for 3]

Refraction also occurs when light travels through a lens.

(*v*) Draw a converging lens and draw a ray diagram to show how the lens forms a real image.

converging lens **[3]**

object, incident ray(s), image formed **[3 × 3]**

(*vi*) An object is placed 25 cm in front of a converging lens of focal length 15 cm. Calculate the position of the image formed.

$1/u + 1/v = 1/f$ **[3]**

substitution **[3]**

$v = 37.5$ cm **[3]**

[accept partial answer for 3]

(*vii*) Converging lenses can be used in glasses to correct a sight defect. Which sight defect is corrected using a converging lens?

long-sightedness / hypermetropia / hyperopia **[5]**

[accept partial answer for 3]

9. Brick is considered one of the best construction materials in the world for a number of reasons. One reason is that brick is a better insulator than many other building materials.

(*i*) Heat is transferred through a wall by conduction. Name two other ways in which heat can be transferred.

convection, radiation **[2 × 3]**

(*ii*) What is meant by the *U*-value of a material?

measure of the conducting/insulating property /

the rate of transfer of energy (through unit area of a material when there is a temperature difference of 1 K between the two sides) **[6]**

[accept partial answer for 3]

(*iii*) A wall has an area of 66 m^2 and a *U*-value of 0.31 W m^{-2} K^{-1}. The temperature difference between inside and outside the wall is 15 °C. Calculate how much heat energy is transmitted through the wall every second.

66 × 0.31 × 15 **[6]**

306.9 J **[3]**

[accept partial answer for 3]

Another reason for bricks being such a popular building material is that that they are durable and strong. A brick has length l = 20 cm, width w = 9 cm and height h = 6 cm, as shown in the diagram.

The brick has a mass of 2 kg.

(*iv*) Calculate the volume of the brick in cm^3.

20 × 9 × 6 = 1080 cm^3 **[6]**

[accept partial answer for 3]

(*v*) Calculate the density of the brick in g cm^{-3}.

conversion to grams; 2000 ÷ 1080 = 1.85 g cm^{-3} **[4 + 2]**

[accept partial answer for 3]

(*vi*) The bricks are stacked to build a wall. On which side, A, B or C, should a brick be stacked so that it exerts the least amount of pressure on the bricks below it? Explain your answer.

B **[4]**

greatest area **[4]**

Brick is a sustainable material. Factories that make bricks are moving away from non-renewable energy sources and are using alternative energy sources instead.

(*vii*) What is meant by non-renewable energy?

energy that is not replaced as it is used **[6]**

[accept partial answer for 3]

(*viii*) State an example of a renewable energy source.

e.g. solar **[3]**

Bricks alone are not enough to meet today's heat retention standards.

(*ix*) State two ways in which you can reduce heat loss from your home.

e.g. double-glazed windows, insulated attic **[2 × 3]**

10. The source of every sound is a vibration. Sound travels as a wave. As a sound wave moves it interacts with its environment in four ways, one of which is reflection.

(*i*) What is meant by reflection?

bouncing of a wave off a surface **[6]**

[accept partial answer for 3]

Sound also undergoes refraction as it moves from one medium to another.

(*ii*) What causes sound to refract as it moves from one medium to another?

change in speed / change in (optical) density **[6]**

[accept partial answer for 3]

When two sound waves meet they can undergo interference.

(*iii*) Describe a laboratory experiment to show that sound waves undergo interference.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

Sounds waves can undergo diffraction as they pass through a doorway or a window.
This is why we can hear around corners.

(*iv*) What is meant by diffraction?

spreading of a wave as it passes through a gap/around an object **[6]**

[accept partial answer for 3]

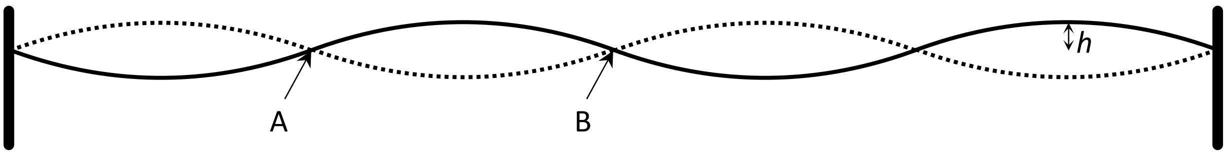
Light waves can undergo polarisation but sound waves cannot.

(*v*) Why do sound waves not undergo polarisation?

sound waves are longitudinal **[6]**

[accept partial answer for 3]

A standing wave is set up on a string as shown so that the distance between points A and B is 45 cm. The waves on the string are travelling with a speed of 400 m s^{-1}.



(*vi*) What name is given to points A and B?

nodes **[4]**

[accept partial answer for 2]

(*vii*) What name is given to height *h*?

amplitude **[4]**

[accept partial answer for 2]

(*viii*) Calculate the wavelength of the wave.

2 × 45 = 90 cm **[6]**

[accept partial answer for 3]

(*ix*) Calculate the frequency of the wave.

400 ÷ 0.9 = 444.4 Hz **[6]**

[accept partial answer for 3]

11. Electric current is the movement of charged particles through a conductor.

(*i*) What is an electrical conductor?

a material that allows current to flow **[3]**

(*ii*) Name an instrument used to measure electric current.

ammeter **[6]**

[accept partial answer for 3]

(*iii*) Draw a circuit diagram for the arrangement of apparatus shown in the diagram on the right.

symbol for battery/cell, symbol for bulb, connected in series **[3 × 3]**

(*iv*) Draw a circuit diagram to show two light bulbs connected in parallel across a battery.

second bulb **[3]**

in parallel **[3]**

Note: You may refer to the electrical circuit symbols on pages 72 to 78 of the *Formulae and Tables* booklet when answering parts (*iii*) and (*iv*).

(*v*) Two light bulbs connected in parallel have resistances of 5 Ω and 4 Ω. Calculate the total resistance of the two light bulbs.

$1/R_T = 1/R_1 + 1/R_2$ **[3]**

substitution **[3]**

$R_T = 2.22\ \Omega$ **[3]**

[accept partial answer for 3]

(*vi*) Calculate the total current flowing in this circuit if the battery had a voltage of 12 V.

$12 \div 2.22 = 5.4$ A **[6]**

[accept partial answer for 3]

The relationship between current and voltage for a filament bulb is shown in the graph below.

(*vii*) Explain the shape of the graph.

the resistance is greater at high current / due to the heating effect / as voltage increases, the current increases **[6]**

[accept partial answer for 3]

(*viii*) Sketch the graph of current against voltage for a metallic conductor held at constant temperature.

axis labelled **[3]**

correct shape **[3]**

(*ix*) The charged particles that carry current through a metallic conductor are electrons. Name the charged particles that carry current through an ionic solution such as copper sulfate solution?

ions **[5]**

[accept partial answer for 3]

12. An electron is a negatively charged subatomic particle.

(*i*) Name a positively charged subatomic particle.

proton **[3]**

(*ii*) Name a neutral subatomic particle.

neutron **[3]**

(*iii*) Draw a labelled diagram of an atom. Include in your diagram the names and locations of the subatomic particles of the atom.

location of proton(s)/neutron(s) **[3]**

electron **[3]**

location of electron(s) **[3]**

The picture on the right is of a cathode ray tube. A beam of electrons is produced in a cathode ray tube.

(*iv*) How are the electrons produced in a cathode ray tube?

thermionic emission **[6]**

[accept partial answer for 3]

(*v*) How can the beam of electrons be deflected in a cathode ray tube?

electric/magnetic field **[6]**

[accept partial answer for 3]

(*vi*) How is the beam of electrons detected in a cathode ray tube?

light on a screen **[6]**

[accept partial answer for 3]

The picture on the right is of an X-ray tube. A beam of high speed electrons is used to produce X-rays in an X-ray tube.

(*vii*) How are the electrons accelerated to high speeds in an X-ray tube?

(high) voltage **[6]**

[accept partial answer for 3]

(*viii*) Tungsten is often used as the target in an X-ray tube because it has a high melting point. Why does the target in an X-ray tube need to have a high melting point?

heat is produced **[6]**

[accept partial answer for 3]

(*ix*) X-rays are a type of electromagnetic radiation. They travel at a speed of 3×10^8 m s^{-1}. Calculate the wavelength of an X-ray that has a frequency of 5.5×10^{17} Hz.

$\mathbf{(3 \times 10^8) \div (5.5 \times 10^{17}) = 5.45 \times 10^{-10}}$ **m** **[6]**

[accept partial answer for 3]

(*x*) Name one other type of electromagnetic radiation.

e.g. gamma **[5]**

[accept partial answer for 3]

13. Read the following passage and answer the questions below.

It was recently announced that a team of researchers at the Joint European Torus tokamak reactor near Oxford generated the highest sustained energy pulse ever created using nuclear fusion, the joining of two atomic nuclei with the release of energy.

If researchers can harness nuclear fusion, the process that powers the Sun, it promises to provide a near-limitless source of clean energy. But so far no experiment has generated more energy than has been put in, due to the huge force of electrostatic repulsion between nuclei. These results do not change that, but they suggest that scientists should eventually be able to reach this goal.

To break the energy record, the scientists used a fuel made of equal parts tritium and deuterium. Tritium is a rare and radioactive isotope of hydrogen, meaning it has the same atomic number as normal hydrogen but a different mass number. When tritium undergoes nuclear fusion with the isotope deuterium, the reaction produces more energy than a reaction involving deuterium only.

In this experiment, 59 MJ of energy was produced during a fusion pulse that lasted 5 s. This pulse generated more than twice the power of the previous record for nuclear fusion.

Adapted from: www.nature.com

(*i*) What is meant by nuclear fusion?

joining of two nuclei **[7]**

[accept partial answer for 4]

(*ii*) Why is there a huge force of electrostatic repulsion between two nuclei that are brought close to each other?

they are both positively charged **[7]**

[accept partial answer for 4]

(*iii*) The scientists used isotopes of hydrogen in this experiment. What are isotopes?

atoms of the same atomic number but with different mass numbers **[7]**

[accept partial answer for 4]

(*iv*) The symbol for tritium is H_1^3.

(*a*) How many protons are in an atom of tritium? **1**

(*b*) How many neutrons are in an atom of tritium? **2** **[4 + 3]**

(*v*) Tritium decays by beta emission. What is the daughter nucleus when an atom of H_1^3 emits a beta particle?

$\mathbf{He_2^3}$ **[3 + 2 + 2]**

(*vi*) In this experiment, 59 MJ of energy was produced during 5 s.
Calculate the power generated.

59 ÷ 5 = 11.8 MW **[7]**

[accept partial answer for 4]

(*vii*) Nuclear power plants currently use nuclear fission, not nuclear fusion.
What is meant by nuclear fission?

the splitting of a nucleus **[7]**

[accept partial answer for 4]

(*viii*) Large amounts of money are being invested into nuclear fusion research.
Why is there such interest in replacing nuclear fission with nuclear fusion?

any valid reference to fuel/products/etc. **[7]**

[accept partial answer for 4]

14. (*a*) A train has a mass of 180 000 kg and is travelling at a speed of 4 m s^{-1}.

(*i*) Calculate the momentum of the train. Include units in your answer.

720 000 **[6]**

[accept partial answer for 3]

kg m s^{-1} **[3]**

The train then joins together with a carriage of mass 85 000 kg which is at rest.

(*ii*) What is the momentum of the carriage before the coupling?
Explain your answer.

0 **[3]**

because it has zero velocity **[3]**

(*iii*) Calculate the initial velocity of the train after it joins with the carriage.

720 000 ÷ 265 000 = 2.72 m s^{-1} **[6]**

[accept partial answer for 3]

The train then accelerates to a speed of 22 m s^{-1}. It maintains this speed for 8 minutes.

(*iv*) Calculate the distance travelled by the train over the 8 minutes.

22 × 8 × 60 = 10560 m **[7]**

[accept partial answer for 4]

(*b*) Light travels through an optical fibre using total internal reflection.

(*i*) Sketch the path of a ray of light through an optical fibre.

internal reflection shown in path of ray in fibre **[6]**

[accept partial answer for 3]

(*ii*) Describe a laboratory experiment to demonstrate total internal reflection.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

(*iii*) The critical angle of the glass in an optical fibre is 43.6°.
Calculate *n*, the refractive index of the glass.

1/sin 43.6° = 1.45 **[6]**

[accept partial answer for 3]

(*iv*) State one use of an optical fibre.

e.g. microsurgery **[4]**

[accept partial answer for 2]

(*c*) The diagram shows the electric field around two oppositely charged particles.

(*i*) Draw the electric field lines around two positively charged particles held close to each other.

shape **[3]**

direction **[3]**

The force between two electric charges is calculated using Coulomb's law.
Coulomb's law is an example of an inverse square law.

(*ii*) Describe what is meant by an inverse square law.

e.g. as one quantity doubles, the other quantity decreases by a factor of 4 **[6]**

[accept partial answer for 3]

Electric charge builds up on the dome of a Van de Graaff generator.

(*iii*) Describe a laboratory experiment that uses a Van de Graaff generator to show that charge resides on the outside of a hollow metal conductor.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

(*iv*) The picture on the right shows a student touching a Van de Graaff generator. Explain why her hair is standing up.

hair is charged (and like charges repel) **[4]**

[accept partial answer for 2]

(*d*) A current-carrying conductor has a magnetic field around it.

(*i*) What is a magnetic field?

region where magnetic forces can be felt **[6]**

[accept partial answer for 3]

(*ii*) Describe a laboratory experiment to plot the magnetic field around a current-carrying conductor.

apparatus **[6]**

method **[6]**

[accept partial answers for 3 in each case]

When a current-carrying conductor is placed in an external magnetic field, it experiences a force.

The magnitude of the force *F* is proportional to the magnitude of the magnetic flux density *B*. The force may be calculated using the formula $F = IlB$.

(*iii*) A straight piece of wire of length 1.8 m carrying a current of 3 A experiences a maximum force of 11 N when it is placed in a uniform magnetic field.
Calculate the magnetic flux density.

11 ÷ (3 × 1.8) = 2.04 T **[6]**

[accept partial answer for 3]

(*iv*) Magnetic flux density is an example of a vector quantity.
Name another example of a vector quantity.

e.g. force **[4]**