Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2026

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)
	Horizontal wavy line	To be noticed
	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 measure the value for the acceleration due to gravity g.

She drew the following diagram to show the apparatus that she used.

(*i*) Copy the diagram above into your answerbook and mark the displacement s that the student measured.

distance indicated from bottom of ball **[3]**
to trapdoor **[3]**
***s* labelled** **[3]**

(*ii*) On your diagram, add in the piece of apparatus used to measure the displacement s.

metre stick **[3]**

(*iii*) Suggest a reason why the trapdoor is connected to the timer.

to stop the timer **[3]**

The following data were recorded.

s (cm)	65	70	75	80	85	90
t (s)	0.36	0.38	0.39	0.40	0.41	0.43

(*iv*) Copy and complete the table below into your answerbook by calculating the missing values for $2s$ in metres.

s (cm)	65	70	75	80	85	90
$2s$ (m)	1.3	1.4	**1.5**	**1.6**	**1.7**	**1.8**

[4 x 1]

(*v*) Copy and complete the table below into your answerbook by calculating the missing values for t^2.

t (s)	0.36	0.38	0.39	0.40	0.41	0.43
t^2 (s^2)	**0.1296**	**0.1444**	**0.1521**	**0.16**	0.168	0.185

[4 x 1]

(*vi*) Use the data to draw a graph of $2s$ (y–axis) against t^2 (x–axis).

labelled axis **[3]**
points plotted **[6]**
line of best fit **[3]**

(*vii*) Calculate the slope of the graph to get a value for g.

g = 9.63 m s^{-2} **[5]**
[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 25 cm.
She measured the image distance *v* to be 48 cm.

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

object **[3]**
mirror **[3]**
screen **[3]**
arrangement **[3]**
[–1 if no label is present on diagram]

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

u **indicated between object and mirror** **[3]**
v **indicated between mirror and screen** **[3]**
[accept partial answer for 3]

(*iii*) Describe the steps used to determine *v*.

move screen/ move mirror
until sharpest image is formed
measure *v* / measure using a metre stick **[any two 6 + 3]**

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

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ **[3]**

(*b*) Calculate *f*.

$\frac{1}{25} + \frac{1}{48} = \frac{73}{1200}$ **[3]**

f = 16.4 cm **[3]**

(*v*) Describe one precaution that the student could have taken to improve the experiment.

e.g. repeat **[4]**
[accept partial answer for 2]

3. In an experiment to investigate the relationship between frequency *f* and length *l* for a stretched string, a student set a length of string vibrating and adjusted the length until resonance occurred. He measured *l* and noted the corresponding *f*. He repeated this for different values of *f*.

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

sonometer, string, bridges, tension key, paper rider, tuning fork **[any 3 x 3]**

[–1 if no label is present on diagram]

(*ii*) On your diagram, indicate the length *l* the student measured.

correct length indicated **[3]**

(*iii*) Describe the steps that the student used to determine *l* for a particular value of *f*.

tuning fork of known frequency (constant tension)

vary length until paper rider falls off **[6 + 3]**

The student recorded the following results.

f (Hz)	256	288	320	341	384	426
l (cm)	50	44	40	37	33	30
$\frac{1}{l}$ (cm^{-1})	0.020	0.023	**0.025**	**0.027**	**0.030**	**0.033**

(*iv*) Copy and complete the table above into your answerbook by calculating the missing values for $\frac{1}{l}$ to 3 decimal places. **[4 x 1]**

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

labelled axis **[3]**

points plotted **[6]**

line of best fit **[3]**

(*vi*) State the relationship between *f* and *l*.

f* is inversely proportional to *l **[3]**

4. A student carried out an experiment to measure l the specific latent heat of fusion of ice. She added ice to warm water in a copper calorimeter. When the ice had fully melted, she recorded the measurements below. She then calculated l.

mass of calorimeter + warm water (kg)	0.450
mass of calorimeter + water + melted ice (kg)	0.474
initial temperature of the calorimeter and warm water (°C)	27
final temperature of calorimeter, water and melted ice (°C)	20
energy lost by calorimeter and water and given to the ice (J)	9585

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

calorimeter **[3]**

water **[3]**

ice **[3]**

detail e.g. thermometer, mass balance, etc **[3]**

[–1 if no label is present on diagram]

When the ice was added to the warm water, all the ice melted.

(*ii*) The initial temperature of the ice was 0 °C.
Calculate the change in temperature of the melted ice, $\Delta\theta$.

20 – 0 = 20 °C **[3]**

(*iii*) Calculate the mass *m* of the ice added.

0.474 – 0.450 = 0.024 kg **[3]**

(*iv*) (*a*) Calculate the energy needed to change the temperature of the melted ice from 0 °C to 20 °C.

$\boldsymbol{Q = mc\Delta\theta = 2006.4\ \mathrm{J}}$ **[6]**

[accept partial answer for 3]

(*b*) Calculate l, the specific latent heat of fusion of the ice.

$\mathbf{9585 = (0.024)(\mathit{l}) + 2006.4}$

$\boldsymbol{l = 315\,775\ \mathrm{J\ kg^{-1}}}$ **[6]**

[accept partial answer for 3]

(*v*) Suggest a reason why the student used warm water at the start of the experiment.

so that the energy gained = energy lost / ice melts quicker **[6]**

[accept partial answer for 3]

(*vi*) State one precaution the student should take to improve the accuracy of the experiment.

insulate the calorimeter, etc. **[4]**

[accept partial answer for 2]

specific heat capacity, $c = 4180\ \mathrm{J\ kg^{-1}\ K^{-1}}$

5. A student carried out an experiment to investigate how the resistance *R* of a metallic conductor changes with temperature *T*.

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

conductor **[3]**
ohmmeter **[3]**
thermometer **[3]**
arrangement **[3]**

[–1 if no label is present on diagram]

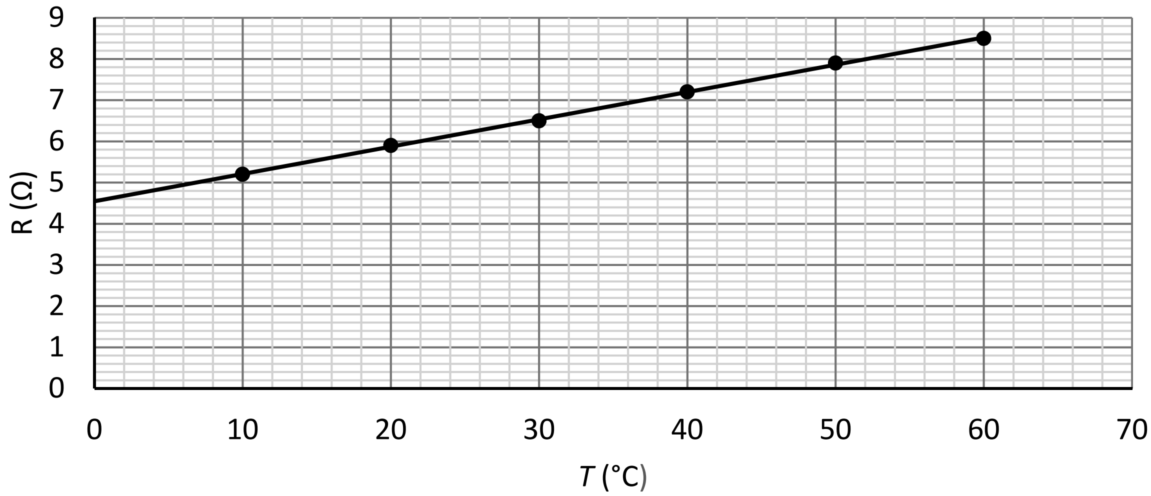
(*ii*) Name the piece of apparatus used to measure the resistance.
ohmmeter **[6]**

[accept partial answer for 3]

(*iii*) Describe how the student varied the temperature of the metallic conductor.
any appropriate heat source **[6]**

[accept partial answer for 3]

The student used their recorded data to plot the following graph.



(*iv*) Describe the relationship between *T* and *R*.

R* increases linearly with increasing *T **[4]**

[accept partial answer for 2]

(*v*) Use the graph to find the resistance of the metallic conductor when it was placed into melting ice.

4.5 Ω **[6]**

[accept partial answer for 3]

The student used the apparatus to estimate the temperature of an unknown liquid.
The resistance was measured as 7.6 Ω.

(*vi*) Use the graph to estimate the temperature of the unknown liquid.
46 °C **[6]**

[accept partial answer for 3]

6. (*a*) State the difference between a vector and a scalar quantity.

a scalar quantity has magnitude only / a vector quantity has magnitude and direction **[7]**

[accept partial answer for 4]

(*b*) Copy and complete the following sentences.

An object moving at constant velocity will continue moving at constant velocity unless a net ___________ acts on it.

The force on an object is ___________ to the rate of change of the object's momentum.

force

proportional **[4 + 3]**

[accept partial answer for 4]

(*c*) Calculate the work done in giving an 11 kg mass potential energy by raising it through a height of 0.5 m.

acceleration due to gravity g = 9.8 m s^{-2}

53.9 J **[7]**

[accept partial answer for 4]

(*d*) Choose, from the following list of apparatus, an instrument used to measure

(*i*) energy transferred,

(*ii*) force.

Write your answer in your answerbook.

barometer **joulemeter** **newton balance** **voltmeter**

(*i*) **joulemeter**

(*ii*) **newton balance** **[4 + 3]**

[accept partial answer for 4]

(*e*) State Boyle's law.

the pressure is inversely proportional to the volume (for a fixed mass of gas at constant temperature} **[7]**

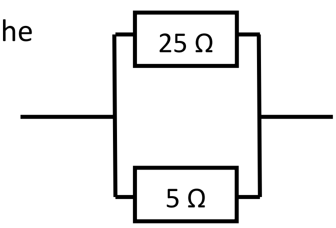
[accept partial answer for 4]

(*f*) Draw the magnetic field around a bar magnet.

correct shape

correct direction **[4 + 3]**

(*g*) Two resistors are connected in parallel as in the diagram on the right. Calculate the total resistance in the circuit.



$$\frac{\mathbf{1}}{\mathbf{25}}+\frac{\mathbf{1}}{\mathbf{5}}=\frac{\mathbf{6}}{\mathbf{25}}$$

R = 4.17 Ω

[7]

[accept partial answer for 4]

(*h*) State the three primary colours of light.

red, green, blue **[3 + 2 + 2]**

(*i*) Infrared radiation is electromagnetic radiation with a wavelength longer than visible red light. Describe how infrared radiation can be detected.

thermometer **[7]**

[accept partial answer for 4]

(*j*) Explain the difference between an electrical insulator and an electrical conductor.

electrical insulator does not allow current to flow through it / an electrical conductor does allow current to flow through it **[7]**

[accept partial answer for 4]

(*k*) Explain what is meant by doping a semiconductor.

adding impurities / improving the conductivity of the material **[7]**

[accept partial answer for 4]

(*l*) Explain what is meant by the photoelectric effect.

emission of electrons from the surface of a metal when light {of a suitable frequency} shines on it **[7]**

[accept partial answer for 4]

7. Apollo 11 launched from Kennedy Space Station in Florida on 16th July, 1969.

(*i*) State Newton's 3rd law of motion.

every action has an equal and opposite reaction **[6]**

[accept partial answer for 3]

(*ii*) Use Newton's 3rd law to explain why the rocket was able to lift off from the Earth.

the rocket engine exerts a downward force **[3]**

an equal and opposite upward force acts on the rocket **[3]**

[accept partial answer for 3]

Apollo 11 started from rest (u = 0 m s^{-1}). Its engine exerted a force that increased its velocity.

(*iii*) Explain what is meant by a force.

(force) causes acceleration **[6]**

[accept partial answer for 3]

(*iv*) State the unit of force.

newton **[6]**

[accept partial answer for 3]

(*v*) Assume that it reached a velocity v of 7800 m s^{-1} in a time t of 600 s. Calculate the average acceleration a during this phase of the flight.

$v = u + at$ **[3]**

a **= 13 m s^{-2}** **[3]**

[accept partial answer for 3]

(*vi*) Assume that the rocket's average mass m is 45 702 kg. Calculate the average net force F on the rocket during this phase of the flight.

$F = ma$ **[3]**

F **= 594 126 N** **[3]**

[accept partial answer for 3]

After this, the rocket went into orbit around the Earth. During this next phase, Apollo 11 was moving at a constant speed of 7800 m s^{-1}.

(*vii*) Is Apollo 11 moving at a constant velocity while in orbit? Explain your answer.

no **[3]**

moving in a circle **[3]**

[accept partial answer for 3]

Apollo 11 landed on the Moon on 20th July, 1969. Neil Armstrong became the first person to step on the Moon.

(*viii*) Neil Armstrong, while wearing his spacesuit, had a mass of 163 kg on Earth. Given that the acceleration due to gravity on the Moon is 1.6 m s^{-2}, calculate his weight on the Moon

$W = mg$ **[3]**

W **= 260.8 N** **[3]**

[accept partial answer for 3]

(*ix*) What was his mass on the Moon?

163 kg **[3]**

(*x*) Buzz Aldrin, the second person on the Moon left a footprint. That footprint has remained on the Moon as the Moon has no atmosphere. Explain why there is no atmosphere on the Moon.

force of gravity is too low **[5]**

[accept partial answer for 3]

8. Polystyrene boards can be used to insulate the wall cavity of a house. This improves the U-value of the house.

(*i*) Explain what is meant by U-value.

the rate of transfer of heat through a material **[6]**

[accept partial answer for 3]

Insulation helps to keep the temperature inside the house at a comfortable level. A thermometer inside the house can be used to monitor this temperature.

(*ii*) The temperature inside a house is maintained at 20 °C. Calculate this temperature in kelvin.

293(.15) K **[6]**

[accept partial answer for 3]

(*iii*) All thermometers are based on a thermometric property. Explain what is meant by a thermometric property.

property that changes (measurably) with temperature **[6]**

[accept partial answer for 3]

(*iv*) State an example of a thermometric property.

e.g. length, etc. **[6]**

[accept partial answer for 3]

When heat is added to the inner wall, its temperature slowly increases.

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

heat is a form of energy / temperature is a measure of hotness **[6]**

[accept partial answer for 3]

(*vi*) The mass *m* of a block used to construct the inner wall in a house is 23 kg. Energy ΔE of 41 400 J is needed to raise the temperature of the block by 2 °C.
Calculate the specific heat capacity *c* of the block.

$\Delta E = mc\Delta\theta$ **[3]**

substitution **[3]**

c = 900 J kg^{-1} K^{-1} **[3]**

The external surface of the house is heated by the Sun. Heat is transferred from the Sun by radiation.

(*vii*) Radiation is one type of heat transfer. Name another way in which heat can be transferred.

conduction / convection **[5]**

[accept partial answer for 3]

(*viii*) Describe an experiment to show how heat can be transferred.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

9. Spearfishing is one of the oldest human hunting practices. Even without formal science, early spear fishers realised fish weren't where they "appeared" to be in the water. Hunters adapted and learned to adjust their aim. This is one of humanity's earliest applications of refraction.

(*i*) Explain what is meant by refraction.

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

[accept partial answer for 3]

(*ii*) Describe an experiment to show that light undergoes refraction.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

(*iii*) A fish is at a depth of 2 m below the surface of the water. The refractive index of the water is 1.33.
Calculate the apparent depth of the fish.

apparent depth = 1.5 m **[6]**

[accept partial answer for 3]

(*iv*) Does the hunter need to aim above or below where the fish appears to be?

below **[3]**

Refraction is also used in underwater photography. The phenomenon in the photograph on the right is called Snell's window. It happens due to the critical angle and total internal reflection.

(*v*) Explain what is meant by the critical angle.
A diagram may help your answer.

angle of incidence (in the denser medium causing) **[3]**

angle of refraction of 90° **[3]**

[accept partial answer for 3]

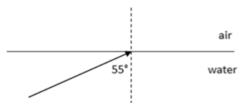
(*vi*) A diver notes that the critical angle *C* of water is 49°. Calculate the refractive index of the water *n* to 3 decimal places.

$\boldsymbol{n = \frac{1}{\sin C}}$ **[3]**

***n* = 1.325** **[3]**

[accept partial answer for 3]

(*vii*) Copy and complete the diagram below to show the path of the light.
The light is travelling in the water.



light reflected in water (at the same angle) **[6]**

A fibre optic cable is a thin flexible fibre with a glass core that can transmit light from one end to the other by total internal reflection.

(*viii*) (*a*) Draw a labelled diagram to show how a ray of light is transmitted through a fibre optic cable by total internal reflection.

ray of light in material **[3]**

multiple internal reflections **[3]**

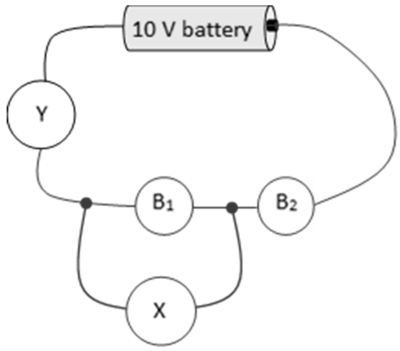
[–1 if no label is present on diagram]

(*b*) State one other use of fibre optic cables.

endoscopy, broadband, Christmas decorations, etc. **[5]**

[accept partial answer for 3]

10. A student drew the electrical circuits shown below to show bulbs B_1 and B_2 connected in series and then connected in parallel. B_1 and B_2 are identical bulbs.



(*i*) Explain what is meant by electric current.

flow of charge **[6]**

[accept partial answer for 3]

(*ii*) (*a*) Instrument X is used to measure voltage. Name the instrument.

voltmeter

(*b*) Instrument Y is used to measure current. Name the instrument.

ammeter **[6 + 3]**

[accept partial answer for 3]

(*iii*) The voltage across B_1 is 5 V. What is the voltage across B_2? Explain your answer.

5 V **[3]**

total voltage is 10 V **[3]**

[accept partial answer for 3]

(*iv*) The current through B_1 is 0.5 A. The voltage across it is 5 V. Calculate the resistance of B_1.

V = IR **[3]**

10 Ω **[3]**

[accept partial answer for 3]

(*v*) Write one of the following statements ***(1)***, ***(2)*** or ***(3)*** in your answerbook to describe how the bulbs light in the circuit when the battery is connected.

(3) B_1 and B_2 light at the same time **[3]**

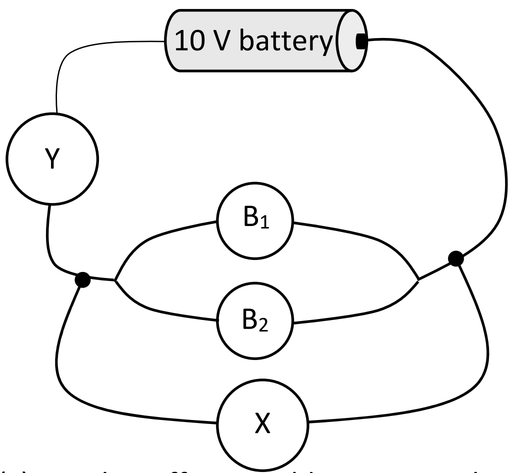
(*vi*) Use electrical circuit symbols to redraw the series circuit above.

Note: You may refer to the electrical circuit symbols on pages 72 to 78 of the *Formulae and Tables* booklet when answering this question.

correct symbols **[4 x 1]**

correct arrangement **[4]**

In the circuit above the bulbs are connected in series but they can also be connected in parallel (as shown below).



(*vii*) State one advantage of connecting bulbs in parallel.

e.g. if bulbs break, the others will keep lighting, etc. **[6]**

[accept partial answer for 3]

(*viii*) Compare the voltage across B_1 with the voltage across B_2 in the new circuit.

the same **[3]**

(*ix*) Instrument Y now reads 2 A. Calculate the current now flowing through B_1.

1 A **[6]**

[accept partial answer for 3]

(*x*) What effect would increasing the voltage of the battery have on the current flowing through each of the bulbs in this parallel circuit?

current increases **[3]**

11. Police use radar guns to measure the speed of moving vehicles by detecting changes in the frequency of reflected microwaves. This is an application of the Doppler effect.

(*i*) Explain what is meant by the Doppler effect.

(apparent) change in frequency due to the movement of the source/observer **[6]**

[accept partial answer for 3]

Reflection is a wave phenomenon.

(*ii*) State one of the laws of reflection.

angle of incidence equals angle of reflection / incident ray, reflected ray and normal all lie on same plane **[6]**

[accept partial answer for 3]

(*iii*) Describe an experiment to show that a wave can undergo reflection.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

Refraction is another wave phenomenon.

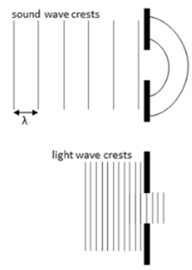
(*iv*) Light strikes a glass block at an angle of incidence of 40°. It is refracted at an angle of 25°. Calculate the refractive index *n* of the glass block**.**

$\boldsymbol{n = \frac{\sin i}{\sin r}}$ **[3]**

***n* = 1.52** **[3]**

[accept partial answer for 3]

Waves can also undergo diffraction, interference and polarisation.
Diffraction is the sideways spreading of a wave as it passes through a gap.



(*v*) The diagrams on the right show a sound wave and a light wave as they pass through a doorway. Explain why the sound wave diffracts as it passes through the door but the light wave does not.

wavelength of sound is similar to the width of the gap / wavelength of a light wave is not similar to the width of the gap **[6]**

[accept partial answer for 3]

(*vi*) Describe an experiment to show that light undergoes diffraction and interference.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

(*vii*) Two coherent waves meet out of phase. Do they undergo constructive or destructive interference?

destructive interference **[4]**

(*viii*) Explain why light waves can be polarised but sound waves cannot.

light waves are transverse waves / sound waves are longitudinal waves **[4]**

[accept partial answer for 2]

12. According to J. J. Thomson's plum pudding model, atoms were like buns: a soft, positive "dough" with negative electrons dotted around like raisins.
Ernest Rutherford wasn't convinced of this. He decided to test this idea in the laboratory. His team fired tiny particles, called alpha particles (helium nuclei), at an extremely thin sheet of gold foil.

(*i*) State two properties of an electron.
e.g. negative charge, small mass, etc. **[4 + 4]**
[accept partial answer for 4]

Rutherford's gold foil experiment changed scientific views on the structure of the atom.

(*ii*) Draw a labelled diagram of an atom showing the position of the protons, neutrons and electrons.
diagram of nucleus containing protons and neutrons with electrons orbiting **[6]**
[accept partial answer for 3]

Gold was used in this experiment. Gold appears on the periodic table as $^{197}_{79}\text{Au}$.
79 is the atomic number and 197 is the mass number.

(*iii*) Explain what is meant by the atomic number of an element.
atomic number is the number of protons in an atom **[6]**
[accept partial answer for 3]

(*iv*) Calculate the number of neutrons that are in an atom of $^{197}_{79}\text{Au}$.
197−79 = 118 neutrons **[6]**
[accept partial answer for 3]

In Thomson's earlier work, he used a piece of apparatus called a cathode ray tube. A cathode ray is a beam of electrons.

(*v*) How are the electrons produced in a cathode ray tube?
thermionic emission **[6]**
[accept partial answer for 3]

The electrons are accelerated to very high speeds in the tube.

(*vi*) How are the electrons accelerated in the tube?
high voltage **[6]**
[accept partial answer for 3]

(*vii*) Describe how the direction of a beam of electrons can be controlled in a cathode ray tube.
electric field / magnetic field **[6]**
[accept partial answer for 3]

In a cathode ray tube, a zinc sulphide screen can be used to convert the electrons' kinetic energy into light energy.

(*viii*) Given that an electron in a cathode ray tube has a mass *m* of 9.1×10^{-31} kg and moves with a velocity *v* of 3×10^{6} m s^{-1}, calculate the kinetic energy of the electron travelling in the cathode ray tube.
$\boldsymbol{E_k = \frac{1}{2}mv^2}$ **[3]**
$\mathbf{4.095 \times 10^{-18}}$ **J** **[3]**
[accept partial answer for 3]

(*ix*) State one use for a cathode ray tube.
e.g. old TV monitor, ECG, etc. **[6]**
[accept partial answer for 3]

13. Every kind of sound is produced by vibrations. The sound source may be a violin, a car horn or a barking dog. Whatever it is, some part of it is vibrating while it is producing sound. The vibrations from the source disturb the air in such a way that sound waves are produced. These waves travel through a substance in all directions, by passing the vibrations from molecule to molecule. If the waves happen to reach someone's ear, they set up vibrations that are perceived as sound.

Detecting sound depends on three things. There must be a vibrating source to set up sound waves, a medium to carry the waves, and a receiver to detect them. Sound waves cannot travel through a vacuum.

There is an age-old question concerning the definition of sound. If a tree falls in a forest far from any sound detector (such as a human ear or a microphone), does the tree's crash make any noise?

Adapted from https://kids.britannica.com/students/article/sound/277144

(*i*) Explain how sound is produced.

sound is produced by vibrations **[7]**

[accept partial answer for 4]

(*ii*) Sound needs a medium to carry the waves.

(*a*) Explain what is meant by a medium.

a substance through which a wave travels

(*b*) Identify if sound is a mechanical wave or an electromagnetic wave.

mechanical **[4 + 3]**

(*iii*) Describe a laboratory experiment to show that sound cannot travel through a vacuum.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

(*iv*) Explain why sound travels faster in solids than in gases.

molecules are more tightly packed in a solid **[7]**

[accept partial answer for 4]

(*v*) Sources can vibrate at different frequencies. Explain what is meant by the frequency of a wave.

number of waves passing a point each second **[7]**

[accept partial answer for 4]

(*vi*) The speed of sound in air c is 340 m s^{-1}. A sound wave has a wavelength λ of 0.78 m. Calculate the frequency f of the wave.

$\boldsymbol{c = f\lambda}$ **[3]**

substitution **[3]**

$\boldsymbol{f}$ **= 435.9 Hz** **[3]**

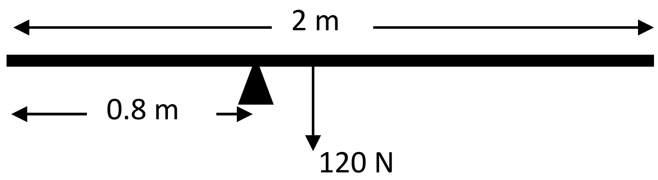
(*vii*) Another sound has a frequency of 200 Hz. Identify if changing the frequency affects the loudness, the pitch or the quality of the sound.

pitch **[7]**

[accept partial answer for 4]

14.

(*a*) A uniform beam with length 2 m has a weight of 120 N. It appears that the 120 N acts through the centre of gravity of the beam. It is placed horizontally on a pivot which is 0.8 m from the left end of the beam.



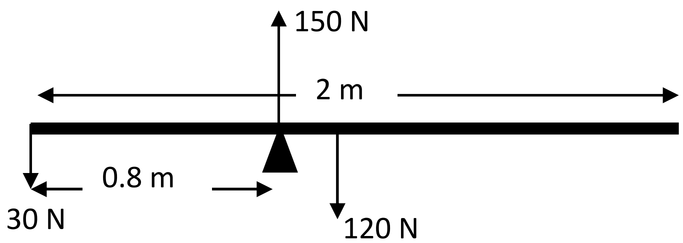
(*i*) Explain what is meant by the moment of a force.
the turning effect of a force about a pivot / force x perpendicular distance **[6]**
[accept partial answer for 3]

(*ii*) Calculate the distance between the pivot and the centre of gravity of the beam.
1 – 0.8 = 0.2 m **[4]**

[accept partial answer for 2]

(*iii*) Calculate the moment, about the pivot, due to the 120 N weight of the beam acting through its centre of gravity.
M* = *Fd **[3]**
24 N m **[3]**
[accept partial answer for 3]

Students hang a 30 N weight on the left-hand side of the beam, as shown below. The pivot exerts an upward force of 150 N. The beam is now stationary and in equilibrium.



(*iv*) State the two conditions necessary for equilibrium.
upward forces = downward forces **[3]**
clockwise moments = anticlockwise moments **[3]**
[accept partial answer for 3]

(*v*) Show by calculation that the beam is in equilibrium.
150 N = 30 N + 120 N **or** **(120)(0.2) N m = (30)(0.8) N m** **[6]**
[accept partial answer for 3]

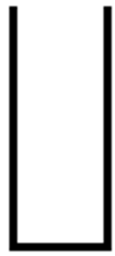
(*b*) A group of students investigate how different musical instruments produce sound. A clarinet can be treated as a pipe that is closed at one end. Different harmonics can be set up in a pipe closed at one end.

(*i*) Explain what is meant by harmonics.

frequencies which are multiples of the fundamental **[6]**

[accept partial answer for 3]

(*ii*) (*a*) Copy and complete the diagram on the right to show the fundamental frequency in a pipe closed at one end, showing any nodes or antinodes in the diagram.



node at closed end / antinode at open end **[5]**

correct shape **[3]**

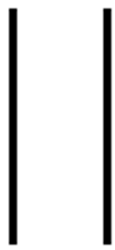
(*b*) Label a node and an antinode on your diagram.

correct labels **[4]**

[accept partial answer for 2]

A flute can be treated as a pipe that is open at both ends.

(*iii*) Copy and complete the diagram on the right to show the fundamental frequency in a pipe open at both ends, showing any nodes or antinodes in the diagram.



antinode at each end **[3]**

correct shape **[3]**

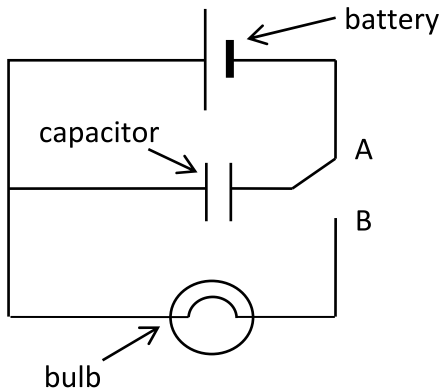
A guitar string is vibrating at its fundamental frequency.

(*iv*) The length of the string is 0.6 m. Calculate the wavelength of the wave.

1.2 m **[4]**

[accept partial answer for 2]

(*c*) A student investigates how capacitors store and release charge using a simple circuit.



(*i*) Explain what is meant by capacitance.

charge per unit volt / $\frac{Q}{V}$ **[6]**

[accept partial answer for 3]

When the switch is at A, the capacitor charges. When a capacitor is charged, one plate is positively charged and the other is negatively charged. An electric field is set up between the plates.

(*ii*) Copy and complete the diagram below to show the shape of the electric field between two parallel plates.

parallel lines **[3]**
from + to – **[3]**

(*iii*) Describe an experiment to show the electric field between two parallel plates.

apparatus **[4]**
method **[4]**
observation **[4]**

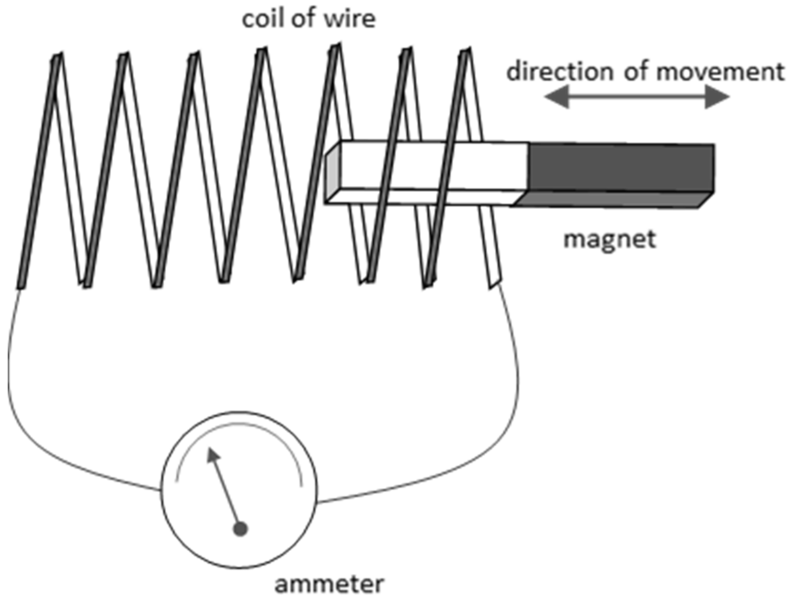
[accept partial answers for 2 in each case]

(*iv*) Describe what happens when the switch is moved to B.

bulb flashes **[4]**

[accept partial answer for 2]

(*d*) Electromagnetic induction is used to generate electricity. The diagram below shows a laboratory experiment to demonstrate electromagnetic induction.



(*i*) Describe what happens on the ammeter as

(*a*) the magnet is moved into the coil,

the ammeter needle deflects in one direction **[3]**

(*b*) the magnet is moved out of the coil.

the ammeter needle deflects in the opposite direction **[3]**

The size of the induced emf can be calculated using the formula $\Phi = BA$.

(*ii*) Calculate the magnetic flux Φ through a coil with an area A of 0.3 m^2 when placed at right angles to a magnetic flux density B of 2 T.

0.6 Wb **[6]**

[accept partial answer for 3]

(*iii*) Describe what happens on the ammeter if

(a) the magnet is moved in and out of the coil more quickly,

the ammeter shows a greater deflection **[3]**

(*b*) a similar sized copper rod is moved in and out of the coil.

the ammeter shows no deflection **[3]**

(*iv*) This experiment is usually done with a galvanometer instead of an ammeter.

(*a*) Suggest a reason why a galvanometer may be used instead of an ammeter.

more sensitive / can detect very small currents

(*b*) Draw the circuit symbol for a galvanometer.

correct circuit symbol **[6 + 4]**

[accept partial answer for 4]