Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2024

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)
	Tick_n	Correct element (n marks)
	Horizontal wavy line	To be noticed
	Vertical wavy line	Additional page
n	Partial	Partially correct element (n marks)
-1	−1	−1
^	^	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 performed an experiment to investigate the laws of equilibrium. He suspended a metre stick from two Newton spring balances and hung weights from the metre stick until it was balanced and level.
Before setting up the experiment, the student took two measurements. He measured the weight of the metre stick to be 3 N. He found its centre of gravity at the 50 cm mark.
His results are shown in the table below.

(*i*) How did the student measure the weight of the metre stick?
using a Newton balance / using a mass balance (and multiplying by g) **[6]**

[accept partial answer for 3]

(*ii*) Describe how he found the centre of gravity of the metre stick.
balance on a pivot **[6]**

[accept partial answer for 3]

(*iii*) Copy the diagram of the metre stick below into your answerbook. Two of the forces have been included, complete the diagram to show all upward and downward forces and their positions.

upward force of 4 N at 70 cm
downward force of 5 N at 26 cm
downward force of 2 N at 60 cm **[3×2]**

The first law of equilibrium states that the sum of the upward forces equals the sum of the downward forces.

(*iv*) Use the data to show that the first law of equilibrium is verified in this experiment.
upward forces = 6 + 4 = 10 N
downward forces = 5 + 2 + 3 = 10 N **[6]**

[accept partial answer for 3]

The second law of equilibrium states that the sum of the clockwise moments equals the sum of the anticlockwise moments. (Remember: Moment = Force × Distance)

(*v*) Use the data to calculate the clockwise moments on the metre stick about the 0 cm mark.
(5 × 26) + (3 × 50) + (2 × 60) = 400 N cm **[6]**

[accept partial answer for 3]

(*vi*) Use the data to calculate the anticlockwise moments on the metre stick about the 0 cm mark.
(6 × 20) + (4 × 70) = 400 N cm **[6]**

[accept partial answer for 3]

(*vii*) Use your calculations to show that the second law of equilibrium is verified in this experiment.
(the sum of) clockwise moments are equal to anticlockwise moments **[4]**

[accept partial answer for 2]

2. A student carried out an experiment to measure *f*, the focal length of a converging lens.

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

converging lens

object

screen

correct arrangement **[4+4+2+2]**

[–1 if no label is present on diagram]

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

both distances indicated correctly **[4+2]**

[accept partial answer for 3]

The student ensured that the object was placed outside the focal length of the lens.

(*iii*) Explain why the student had to place the object outside the focal length of the lens.

to get an image on the screen / to get a real image **[6]**

[accept partial answer for 3]

(*iv*) How did the student know that the correct image distance had been found?

focussed image **[6]**

[accept partial answer for 3]

The following results were recorded.

u (cm)	18	25	30
v (cm)	90	38	30

(*v*) Using the formulae and tables booklet, write the lens formula used to calculate *f*.

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ **[4]**

[accept partial answer for 2]

(*vi*) Use the formula and the data in the table to calculate f

calculation of *f* **[6]**

[accept partial answer for 3]

3. A student carried out an experiment to measure *c*, the specific heat capacity of water. She added heat energy ΔE to water in a copper calorimeter.

The following results were recorded.

Mass of empty copper calorimeter	= 0.106 kg
Mass of calorimeter and cold water	= 0.262 kg
Initial temperature of cold water and calorimeter	= 18 °C
Final temperature of water and calorimeter	= 23 °C
Heat energy added	= 3467 J

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

calorimeter, water, source of heat (e.g. hot copper, heating coil), thermometer, mass balance, joulemeter, detail e.g. lagging, lid, stirrer, etc. **[any 4: *4+2+2+2*]**

[–1 if no label present on diagram]

(*ii*) How did the student supply the heat energy to increase the temperature of the water and the calorimeter?

any heat source **[6]**

[accept partial answer for 3]

(*iii*) Calculate **A**, the mass of the water.

0.262 – 0.106 = 0.156 kg **[6]**

[accept partial answer for 3]

(*iv*) Calculate **B**, the increase in temperature of the calorimeter and cold water.

23 – 18 = 5 ℃ **[6]**

[*accept partial answer for 3]*

(*v*) Use your answers for **A** and **B** to complete the following calculations to find *c.*

substitution for A **[4]**

substitution for B **[4]**

c = 4179.98 J kg^{-1} K^{-1} **[4]**

4. A student carried out an experiment to investigate how the fundamental frequency f of a stretched string changes with length l. The student set a length of string vibrating and adjusted the length until resonance occurred. The tension of the string was kept constant throughout the experiment.

(*i*) How did the student set the string vibrating?

using a tuning fork / using a frequency generator / pluck the string **[*6*]**

[accept partial answer for 3]

(*ii*) Describe what length l of string the student should measure.

distance between the bridges **[6]**

[accept partial answer for 3]

(*iii*) Explain why the tension of the string was kept constant.

frequency depends on tension [state or imply] / fair test **[6]**

[accept partial answer for 3]

(*iv*) What is the function of the paper rider?

indicates that resonance has occurred [state or imply] **[6]**

[accept partial answer for 3]

The student recorded the following results.

f (Hz)	256	320	341	427	480	512
l (m)	0.214	0.171	0.160	0.127	0.114	0.107
$1/l$ (cm^{-1})	4.67	5.85				

(*v*) Copy and complete the table above into your answerbook by calculating the value of $\frac{1}{l}$ to 2 decimal places.

$1/l$ (cm^{-1})	4.67	5.85	**6.25**	**7.87**	**8.77**	**9.35**

[4×1]

(*vi*) Use the data to plot a graph of f against $\frac{1}{l}$.

labelled axis **[3]**

points plotted **[6×1]**

line of best fit **[3]**

5. A student performed 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
ohmmeter
thermometer
arrangement **[4+4+2+2]**

[–1 if no label present on diagram]

(*ii*) How did the student vary the temperature of the metallic conductor?

any appropriate heat source **[6]**

[accept partial answer for 3]

(*iii*) State one safety precaution that the student should have taken.

any safety precaution **[4]**

[accept partial answer for 2]

The student recorded the following data:

T (°C)	10	20	30	40	50	60
R (Ω)	5.2	5.9	6.5	7.2	7.9	8.5

(*iv*) Use the data to plot a graph to show the relationship between *T* and *R*.

labelled axis **[3]**

points plotted **[6×1]**

line of best fit **[3]**

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

resistance increases with temperature **[3]**

The student used the apparatus to estimate the temperature of an unknown liquid. The resistance was measured as 5.5 Ω.

(*vi*) Use your graph to estimate the temperature of the unknown liquid.

14.4 ℃ **[3]**

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

(*a*) State the principle of conservation of momentum.

(in a closed system, the total) momentum before (interaction) = (the total) momentum after / $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ **[7]**

[accept partial answer for 4 e.g. p=mv]

(*b*) What is the difference between a scalar quantity and a vector quantity?

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

[accept partial answer for 4]

(*c*) Explain Archimedes' principle.

The diagram may help you answer.

upthrust = weight of the fluid displaced / upthrust 5 – 3 = 2 N, weight of fluid = 2 N **[7]**

[accept partial answer for 4]

(*d*) Describe an experiment to compare the rates of conduction of heat through solids.

apparatus

method

observation **[3+2+2]**

(*e*) State one difference between light waves and sound waves.

e.g. light waves do not need a medium to travel through / sound waves need a medium to travel through, etc. **[7]**

[accept partial answer for 4]

(*f*) The Doppler effect is used in a radar system to detect the speed of cars. What is the Doppler effect? A diagram may help your answer.

(apparent) change in frequency due to the movement of the source/observer **[7]**

[accept partial answer for 4]

(*g*) The solar constant (solar irradiance) is a measure of how much radiation from the Sun falls on each square metre of the Earth's surface in one second. It has a value of 1.36 kW m^{-2}. Calculate the amount of energy falling per second on a 72 m^2 garden.

1360 × 72 = 97920 W **[7]**

[accept partial answer for 4]

(*h*) What is meant by capacitance?

$\boldsymbol{C = \frac{Q}{V}}$ **[7]**

[accept partial answer for 4]

(*i*) State a safety precaution that should be taken when working with radioactive materials.

e.g. use appropriate shielding for the type of radiation, distance yourself appropriately from source of radiation, wear protective clothing, etc. **[7]**

[accept partial answer for 4]

(*j*) The critical angle of diamond is 24.4°. Calculate *n*, the refractive index of the diamond.

n = 2.42 **[7]**

[accept partial answer for 4]

(*k*) Name one part of the eye. Explain its function.

named part of the eye

function **[4+3]**

(*l*) Draw the magnetic field of a bar magnet.

shape

direction **[4+3]**

7. Oleksii Novikov from the Ukraine broke the world record in 2020 in the deadlift. He achieved the world record by lifting 537.5 kg from the ground to a height of 46 cm.

(*i*) Explain the difference between mass and weight.

e.g. mass is measure in kg / weight is measure in N, etc. **[6]**

[accept partial answer for 3]

(*ii*) Calculate the weight of a 537.5 kg mass.

***F* = 537.5 × 9.8 = 5267.5 N** **[6]**

[accept partial answer for 3, e.g.* F = *ma]

(*iii*) Calculate the work done in lifting a mass of 537.5 kg from the ground to the required height of 46 cm.

***W* = 5267.5 × 0.46 = 2423.05 J** **[6]**

[accept partial answer for 3, e.g. W = Fs]

To successfully complete the deadlift, a lifter has to bring the bar to a height of 46 cm, lock out their knees and wait for the referee to signal that the bar can be lowered to the ground.

(*iv*) Draw a diagram of the forces acting on the bar when it is at a height of 46 cm.

arrow up

arrow down

same length **[4+4+1]**

In 2020, Novikov won the World's Strongest Man competition. One of the events in this competition is a bus pull. The bus has a mass of 19 000 kg.

(*v*) Momentum is important when moving the bus. What is meant by momentum?

mass × velocity / *mv* **[6]**

[accept partial answer for 3]

(*vi*) Calculate the momentum of the bus at a speed of 0.6 m s^{-1}. Include units in your answer.

19000 × 0.6 = 11 400 **[4]**

[accept partial answer for 2]

kg ms^{-1} **[2]**

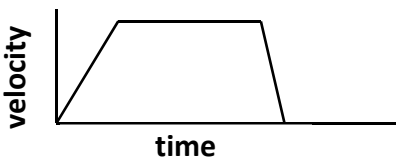
It took one man 52 s to complete the course. It took him 5 s to get the bus to a top speed of 0.6 m s^{-1}. The bus maintained that speed for 46 s and then it took 1 s for the bus to come to a stop.

(*vii*) Suggest a reason that the bus rolled to a stop.

friction **[5]**

[accept partial answer for 3]

(*viii*) Draw a velocity-time graph for the motion of the bus during the 52 s.



labelled axis **[3]**
acceleration shown **[3]**
constant velocity shown **[3]**
deceleration shown **[3]**

8. Light is reflected from different surfaces.

The picture shows light being reflected from a plane mirror. An image is formed.

(*i*) Explain what is meant by an image.

intersection of rays **[6]**

[accept partial answer for 3]

(*ii*) State one property of the image produced by a plane mirror.

e.g. same size, lateral inversion, etc. **[6]**

[accept partial answer for 3]

(*iii*) State one use of a plane mirror.

e.g. to see yourself, etc. **[3]**

One of the laws of reflection of light states that the angle of incidence equals the angle of reflection.

(*iv*) Describe an experiment to show this law of reflection.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

Light is also reflected from curved mirrors.

(*v*) In your answerbook, copy and complete the ray diagram below to show how a magnified image is formed in a concave mirror.

first incident ray **[3]**

first reflected ray **[3]**

second reflected ray **[3]**

image formed **[2]**

The picture on the right shows images in a concave mirror.

(*vi*) Explain why the image of person A in the picture is upright but the image of person B is upside down

person A is upright because they are inside the focal point of the mirror /

person B is inverted because they are outside the focal point of the mirror **[6]**

[accept partial answer for 3]

An object is placed 20 cm in front of a concave mirror and the image is formed 40 cm in front of the mirror.

(*vii*) Calculate the magnification *m* of this image.

$\boldsymbol{m = \frac{40}{20} = 2}$ **cm** **[6]**

[accept partial answer for 3]

(*viii*) If the object is 5 cm high, calculate the height of the image.

5 × 2 = 10 cm **[6]**

[accept partial answer for 3]

9. Solids, liquids and gases change state when they are heated or cooled. A heat pump is a device consisting of a closed system of circulating liquid called a refrigerant which absorbs and releases latent heat as it changes state. The graph shows the temperature and state of the liquid as heat is added.

(*i*) What is meant by latent heat?

heat energy needed to change state **[6]**

[accept partial answer for 3]

(*ii*) Explain why the graph flattens out at A.

changing state / no temperature change **[6]**

[accept partial answer for 3]

(*iii*) The specific latent heat of vaporisation of the refrigerant is 141 100 J kg^{-1}. Calculate the heat energy needed to change 0.3 kg of refrigerant from liquid to gas.

ΔE **= 0.3 × 141 100 = 42 330 J** **[6]**

[accept partial answer for 3 e.g. $\Delta E = ml$***]***

(*iv*) What happens to the temperature inside the fridge when the liquid changes state to become a gas?

it decreases **[6]**

The heat pump also turns the gas back into a liquid.

(*v*) According to the graph, what temperature does this happen at?

65 ℃ **[3]**

(*vi*) What is the process called when a gas changes into a liquid?

condensation **[6]**

[accept partial answer for 3]

(*vii*) Draw a labelled diagram of a heat pump.

closed system **[3]**

circulating fluid **[3]**

compressor/expansion valve **[3]**

[–1 if no label present on diagram]

The temperature of the refrigerant can be measured using a thermometer.

(*viii*) A thermometer uses a particular thermometric property to measure temperature. What is meant by a thermometric property?

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

[accept partial answer for 3]

(*ix*) What is the thermometric property of an alcohol-in-glass thermometer?

length **[4]**

[accept partial answer for 2]

(*x*) State one everyday use of a thermometer.

e.g. body temperature, cooking, etc. **[4]**

[accept partial answer for 2]

10. When a person sings, their vocal chords vibrate. This vibration can cause a wine glass to shatter if resonance occurs.

(*i*) What is meant by resonance?

transfer of energy between bodies at the same frequency **[6]**

[accept partial answer for 3]

(*ii*) Describe a laboratory experiment to demonstrate resonance.

apparatus **[4]**

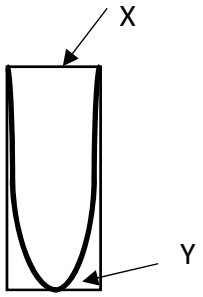
method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

A clarinet is an instrument that can be thought of as a pipe closed at one end.

(*iii*) The diagram on the right shows the fundamental frequency in a pipe closed at one end. Name the parts of the wave labelled X and Y.



X = antinode **[3]**

Y = node **[3]**

[accept partial answer for 3]

(*iv*) Draw a diagram, in your answerbook, to show the next harmonic for a sound wave in the same pipe.

node at closed end and two antinodes **[6]**

[accept partial answer for 3]

(*v*) The speed of sound in air *c* is 336 m s^{-1} and frequency *f* of the wave is 320 Hz. Calculate the wavelength λ of the sound wave.

$\boldsymbol{\lambda = \frac{336}{320}}$ **=1.05 m** **[6]**

[accept partial answer for 3 e.g. c =fλ]

(*vi*) If the distance from **X** to **Y** is taken as $\frac{\lambda}{4}$. Calculate the length of the pipe.

$\boldsymbol{l = \frac{1.05}{4} = 0.2625}$ **m** **[3]**

If a musician increases the loudness of the note she plays, she has increased the amplitude of the sound wave.

(*vii*) What property of the wave needs to change to affect the pitch of the note played by the clarinet?

frequency **[6]**

[accept partial answer for 3]

A flute is an instrument that can be thought of as a pipe that is open at both ends.

(*viii*) Draw a labelled diagram to show the fundamental frequency for a sound wave in a pipe open at both ends.

antinode at both ends with one node at the centre **[6]**

[accept partial answer for 3]

(*ix*) A sound wave vibrates at its fundamental frequency in a pipe of length 60 cm which is open at both ends. Calculate the wavelength of the sound wave.

$\boldsymbol{\lambda}$ **= 1.2 m** **[5]**

[accept partial answer for 3]

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

(*i*) Give an example of an electrical conductor

any named conductor **[5]**

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

ammeter/galvanometer **[6]**

[accept partial answer for 3]

(*iii*) The diagram on the right shows the parts of an electrical plug. Name the wires labelled A and B.

A = earth wire **[3]**

B = live wire **[3]**

[accept partial answer for 3]

A fuse is used as a safety precaution.

(*iv*) Describe how a fuse works.

melts/breaks if current is too high **[6]**

[accept partial answer for 3]

A miniature circuit breaker (MCB) is another device used for safety.

(*v*) What is the advantage of using a MCB instead of a fuse in a domestic circuit?

e.g. more sensitive to current than a fuse, can be reset rather than replaced, etc. **[6]**

[accept partial answer for 3]

(*vi*) Name another safety feature used in domestic cicruits.

e.g. earthing, bonding, RCD, etc. **[3]**

(*vii*) The circuit on the right is used to demonstrate Ohm's law.

(a) Which of the devices, **X** or **Y** is a voltmeter?

Explain your answer.

X as it is wired in parallel **[6]**

[accept partial answer for 3]

(b) The electrical component **Z** is a variable resistor. Explain why a variable resistor is used in the circuit when demonstrating Ohm's law.

to adjust the voltage/current in the circuit **[3]**

Previous results from the experiment have shown the resistance of the coil of wire is 2.5 Ω.

(*viii*) Verfy that the resistance is 2.5 Ω by calculating the resistance when the voltage is 2 V and the current is 0.8 A.

$\boldsymbol{R = \frac{2}{0.8} = 2.5\ \Omega}$ **[6]**

[accept partial answer for 3 e.g. V=IR]

(*ix*) The resistance of the coil of wire as 2.5 Ω and the resistance of device **X** is 20 000 Ω. Calculate the total reistance of this parallel combination.

$\boldsymbol{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}}$ **[3]**

$\boldsymbol{\frac{1}{R_T} = \frac{1}{2.5} + \frac{1}{20\,000}}$ **[3]**

$\boldsymbol{R_T = 2.5\ \Omega}$ **[3]**

[accept partial answer for 3 e.g. $R_T=R_1+R_2$]

12. The picture on the right is a nuclear fission reactor in Kamataka, a state in India.

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

the splitting of a nucleus **[6]**

[accept partial answer for 3]

The control rods and the moderator play a very important role in the production of energy by nuclear fission.

(*ii*) Explain the function of

(a) the control rods

absorbs neutrons

(b) the moderator

slows down neutrons **[6+3]**

[accept partial answer for 3]

(*iii*) The fission reactor must also have a shield. What material could be used to make the shield?

e.g. lead, etc. **[3]**

The fuels typically used in a nuclear fission reactor are plutonium and uranium.

(*iv*) What are isotopes?

atoms of the same element with different number of neutrons **[6]**

[accept partial answer for 3]

Pu-239 is an isotope of plutonium. It has a half-life of 24 110 years.

(*v*) What fraction of the isotope will remain after 72 330 years?

$\frac{1}{8}$ **[6]**

[accept partial answer for 3]

(*vi*) When Pu-239 decays, it emits alpha particles α_2^4. What is the daughter nucleus **X** in the nuclear equation below when an atom of Pu_{94}^{239} emits α_2^4?

$\boldsymbol{U_{92}^{235}}$ **[3 × 2]**

Nuclear fusion is another type of nuclear reaction.

(*vii*) Draw a diagram of an atom and indicate where the neutrons are located.

diagram of atom indicating neutrons in the nucleus **[6]**

[accept partial answer for 3]

(*viii*) Name another sub-atomic particle.

e.g. proton, electron, etc. **[6]**

[accept partial answer for 3]

Nuclear fusion is another type of nuclear reaction.

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

joining of two nuclei **[4]**

[accept partial answer for 2]

(*x*) Give one advantage of a nuclear fusion reactor over a nuclear fission reactor.

e.g. less radioactive waste, etc. **[4]**

[accept partial answer for 2]

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

Every year astronauts go to the International Space Station (ISS). They have to live and work in microgravity for months. The ISS orbits at an altitude of 322 km. It completes one revolution of the Earth every 90 minutes. At this altitude, acceleration due to gravity is about 90% of what it is on the Earth's surface

A big problem with this environment is loss of bone mass. Bones grow and change to adapt to your body's needs. In microgravity, the breaking down of bones happens faster than the rebuilding. This is because bones adapt to this new environment where they don't have to carry the body's weight due to the reduced gravity. Astronauts may be more likely to fracture their bones later in life. Because of this issue, astronauts spend a lot of their time in space doing exercise.

The leg and arm bones of 17 astronauts before and after spaceflight were examined. A computed tomography (CT) scanner was used which provided high resolution 3D images. The bones were examined for thickness, strength and density. The goal was to understand the role of exercising before and during spaceflight.

Adapted from: www.ScienceJournalForKids.org

(*a*) How high above the Earth is the ISS?

322 km **[7]**

(*b*) How many full orbits of the Earth does the ISS make in 24 hours?

16 full orbits **[7]**

[accept partial answer for 4]

(*c*) Describe how acceleration due to gravity changes as the distance from the centre of the Earth increases.

it decreases **[7]**

(*d*) A CT scanner uses x-rays to produce images of the inside of the body. What are x-rays?

high energy waves / electromagnetic radiation **[7]**

[accept partial answer for 4]

(*e*) Draw a labelled diagram of the x-ray tube.

heating filament
cathode and anode target / high voltage
shielding / glass tube **[3+2+2]**

[–1 if no label is present on diagram]

(*f*) The bone density of an astronaut was 1.39 g cm^{-3} before leaving Earth. The total volume of her bones is 7140 cm^3. Calculate the total mass of her bones at that time.

m = 1.39 × 7140 = 9924.6 g **[7]**

[accept partial answer for 4 e.g. $\rho = \frac{m}{V}$]

(*g*) The temperature outside the ISS is 116 K. Convert this temperature to Celsius (℃).

116 – 273.15 = –157.15 ℃ **[7]**

[accept partial answer for 4]

(*h*) Why do astronauts spend a lot of their time doing exercise while on the ISS?

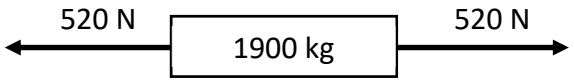
to reduce loss in bone mass / due to spending time in microgravity **[7]**

[accept partial answer for 4]

14. Answer any **two** of the following parts (*a*), (*b*), (*c*), (*d*).

(*a*) Newton's three laws of motion describe the relationship between the motion of an object and the forces acting on it.

A 1900 kg car is moving at 20 m s^{-1} to the right on a horizontal road. It has balanced forces acting on it in opposite directions as shown.



(*i*) Calculate the net horizontal force acting on the car**.**

520 – 520 = 0 N **[4]**

[accept partial answer for 2]

(*ii*) What is the acceleration of the car?

0 m s^{-2} **[2]**

(*iii*) What is the velocity of the car 12 s later?

20 m s^{-1} **[2]**

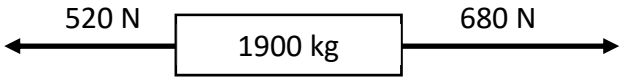
(*iv*) State Newton's first law of motion.

a body remains at rest (or moving at a constant velocity) unless an (unbalanced external) force acts on it **[5]**

[accept partial answer for 3]

Newton's second law of motion states that the rate of change of momentum of an object is proportional to the net force applied to it.

The same car is still moving at 20 m s^{-1} to the right but it now has unbalanced forces acting on it as shown.



(*v*) Calculate the net horizontal force acting on the car.

680 – 520 = 160 N (right) **[5]**

[accept partial answer for 3]

(*vi*) Calculate is the acceleration of the car.

$\boldsymbol{a = \frac{160}{1900} = 0.084}$ **m s^{-2}** **[5]**

[accept partial answer for 3 e.g. F=ma]

(*vii*) Calculate the velocity of the car after 12 s when the unbalanced forces are acting on the car.

***v* = 20 + (0.084)(12) = 21 m s^{-1}** **[5]**

[accept partial answer for 3 e.g. v=u+at]

(*b*) A thermistor is a type of resistor made of semiconductor material whose resistance is dependent on temperature.

(*i*) Name an instrument used to measure resistance

ohmmeter **[6]**

[accept partial answer for 3]

(*ii*) Sketch a graph to show the relationship between resistance and temperature for a thermistor.

labelled axis **[3]**

correct shape **[3]**

(*iii*) A thermistor is a semiconductor. What is meant by a semiconductor?

material with resistivity between an insulator and a conductor **[6]**

[accept partial answer for 3]

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

(*iv*) (a) Draw a circuit diagram to show a semiconductor diode connected in series with a filament bulb.

symbol for battery/cell, symbol for bulb, symbol for semiconductor diode **[3×2]**

connected in series **[2]**

(b) Indicate if the bulb is lighting or not.

answer consistent with circuit drawn in (a) **[2]**

(*c*) A laser light is shone at right angles to a diffraction grating as shown in the diagram on the right. Diffraction occurs at the grating producing an interference pattern which can be seen on the screen.

(*i*) What is meant by diffraction?

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

[accept partial answer for 3]

(*ii*) Constructive and destructive interference occurs to produce the interference pattern. Distinguish between constructive and destructive interference.

e.g. constructive interference: bright spots / destructive interference: dark spots, etc. **[6]**

[accept partial answer for 3]

The diffraction grating has a grating constant *d* of 2.5×10^{-6} m. The first order diffracted image (n=1) is at an angle of 14.6° from the straight through position

(*iii*) Using the formula $n\lambda = d\sin\theta$, calculate the wavelength λ of the laser light.

$\boldsymbol{\lambda = (2.5\times10^{-6})(\sin 14.6^\circ) = 6.3\times10^{-7}\,m}$ **[6]**

[accept partial answer for 3]

If white light is passed through the diffraction grating, dispersion occurs.

(*iv*) Name the 3 primary colours of light.

red, green, blue **[3×2]**

(*v*) Name a pair of complementary colours of light.

red and cyan / green and magenta / blue and yellow **[2+2]**

(*d*) Objects with opposite charges attract each other and objects with the same charge repel each other.

(*i*) Describe how an object can become charged by contact.

(when two materials are brought into contact) electrons can transfer from one to the other **[6)**

[accept partial answer for 3]

(*ii*) Describe an experiment to show that opposite charges attract and like charges repel.

apparatus **[4]**

method **[4]**

observation **[4]**

[accept partial answers for 2 in each case]

An object becomes charged when it gains or loses electrons.

(*iii*) What type of charge does an electron have?

negative **[3]**

(*iv*) Has a positively charged object gained or lost electrons?

lost electrons **[3]**

A student performed an experiment to investigate how charge is distributed on a pear-shaped conductor.

(*v*) Draw a diagram to show how charge is distributed on a pear-shaped conductor.

charges accumulated at the pointed end **[4]**

[accept partial answer for 2]