Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2021

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. Words which are separated by a solidus and which are underlined must appear in the correct context by including the rest of the statement to merit the assigned mark.

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 but does not merit marks. If a candidate does not attempt a question (or part of) 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
$\boxed{-1}$	−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. 228 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 228 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 304 @ 10%
Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 304 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 228 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
229 - 230	22
231 - 234	21
235 - 237	20
238 - 240	19
241 - 244	18
245 - 247	17
248 - 250	16
251 - 254	15
255 - 257	14
258 - 260	13
261 - 264	12
265 - 267	11

Bunmharc	Marc Bónais
268 - 270	10
271 - 274	9
275 - 277	8
278 - 280	7
281 - 284	6
285 - 287	5
288 - 290	4
291 - 294	3
295 - 297	2
298 - 300	1
301 - 304	0

SECTION A (80 MARKS) Answer **two** questions from this section. Each question carries 40 marks.

Question 1 **40 marks**

A student carried out an experiment to measure the acceleration due to gravity *g*. An object was allowed to fall through a known distance *s* and the time *t* for the fall was measured.

(*i*) Draw a labelled diagram of the apparatus used in this experiment. **4 × 3**

labelled diagram to show:

falling object e.g. (metal) ball	3
starting mechanism e.g. release mechanism	3
stopping mechanism e.g. trapdoor	3
means of measuring time e.g. timing circuit/ (electronic) timer	3
partial answer	(3)

NOTE: no labels deduct 2
incorrect experiment, maximum mark 2 × 3
accept valid alternatives

(*ii*) How did the student measure the distance *s*? **6 or 3**

metre stick / ruler / measuring tape	6
partial answer e.g. from the bottom of the ball to the trapdoor	(3)

(*iii*) How did the student measure the time *t* for the object to fall? **5 or 3**

timer	5
partial e.g. from when ball starts falling to when it hits trapdoor	(3)

(*iv*) How did the student improve the accuracy of the time *t* that was used? **3**

take the smallest time for *t*, repeat, took average, place a paper between the ball and magnet, use large distance/*s*, used a more accurate timer / electronic timer, etc. 3

The student recorded the following results.

***s* (m)**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
***t* (s)**	**0.29**	**0.32**	**0.35**	**0.38**	**0.40**	**0.43**

The value for *g*, the acceleration due to gravity near the surface of the Earth, is 9.8 m s^{-2}.

(*v*) From the table, when the distance *s* is 0.4 m the time *t* is 0.29 s. Use this data and the formula *g* = $\frac{2s}{t^2}$ to calculate a value for *g*. **6 or 3**

$(g = \frac{2s}{t^2} = \frac{2(0.4)}{(0.29)^2} = \frac{0.8}{0.0841} =)$9.5 m s^{-2}	6
partial answer	(3)

(*vi*) Use the results to calculate two other values for *g* and calculate their average. **2 × 3**

9.76 m s^{-2}, 9.8 m s^{-2}, 9.69 m s^{-2}, 10 m s^{-2}, 9.73 m s^{-2}	any two	3
average of any two above		3

(*vii*) The maximum distance used is 0.9 m. Why does the student not use a greater distance? **2**

difficult to measure with metre stick, difficult to align the ball with the trapdoor, etc. 2

Question 2 **40 marks**

A student performed an experiment to verify Boyle's law by investigating how the volume *V* varied with pressure *p* of a fixed mass of gas.
The student recorded the following results.

***V* (cm^3)**	**19**	**17**	**15**	**13**	**11**	**9**
***p* (*kPa*)**	**106**	**118**	**133**	**154**	**181**	**223**

(*i*) **Draw a labelled diagram of the apparatus used in this experiment.** **4 × 3**

labelled diagram to show:
enclosed volume of gas
means of measuring/reading the volume scale
means of measuring/ reading the pressure e.g. pressure gauge
means of altering the pressure/volume e.g. pump
detail e.g. correct arrangement any 4 lines 4 × 3
NOTE: no labels deduct 2, accept valid alternatives

(*ii*) **How is the pressure varied in this experiment?** **3**

pump / valve // piston 3

(*iii*) **Each time the pressure is changed, the student must wait before taking the reading for volume. Explain why.** **3**

to allow the gas to settle (to room temperature/ to cool) 3

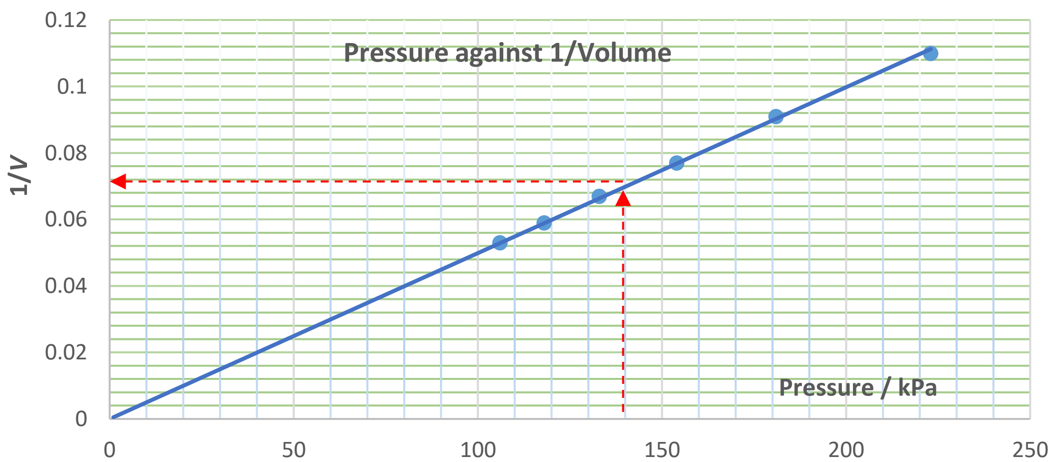
(*iv*) **Boyle's law states that for a fixed mass of gas, pressure is inversely proportional to volume.**
For each value of *V* in the table above, calculate $\frac{1}{V}$ to three decimal places. **6 × 1**

V (cm^3)	19	17	15	13	11	9
$\frac{1}{V}$ (*cm^{-3}*)	**0.053**	**0.059**	**0.067**	**0.077**	**0.091**	**0.111**

6 × 1

(*v*) **Plot a graph on graph paper of *p* against $\frac{1}{V}$.** **3 + 6 + 3**

label axes correctly, (name / symbol / unit acceptable) 3
plot six points correctly 6 × 1
straight line 3
if graph paper is not used, maximum mark 3 × 3



(*vi*) **Use your graph to calculate the volume of the gas when its pressure is 140 kPa.** **2 × 2**

reads $\frac{1}{V}$ value from graph e.g. 0.07 2
invert value to get *V* e.g. *V*= 14.3 cm^3 2

Question 3 **40 marks**

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

(*i*) Draw a labelled diagram of the apparatus used in this experiment. **4 × 3**

labelled diagram to show:

object e.g. crosswire, raybox	3
(converging) lens	3
screen	3
detail e.g. correct arrangement, optical bench, metre stick, etc.	3

NOTE: no labels deduct 2, accept valid alternatives

(*ii*) On your diagram, indicate and label the object distance *u* and the image distance *v* **6 or 3**

correctly marked *u* and *v* distances	6
partial answer e.g. one correct	(3)

(*iii*) Name the instrument used to measure the object distance and the image distance. **3**

metre stick, measuring tape, optical bench with scale, ruler 3

(*iv*) How did the student know that the correct image distance had been found? **3**

image in sharp focus 3

(*v*) State the formula used to calculate *f*. **6 or 3**

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$	6
one error	(3)

(*vi*) The student placed an object 16 cm in front of the converging lens. It produced an image at a distance of 48 cm from the lens. Calculate the focal length of this lens. **6 or 3**

$(\frac{1}{16} + \frac{1}{48} = \frac{1}{12} \quad \Rightarrow f =)$ 12 cm	6
partial answer e.g. correct substitution	(3)

(*vii*) Why will this experiment not work if the object is placed very close to the lens? **4 or 2**

virtual image (formed when $u < f$), cannot form image on screen	4
partial answer	(2)

Question 4 **40 marks**

A student carried out an experiment to measure *l*, the specific latent heat of vaporisation of water. Steam at 100 °C was passed into cold water in a copper calorimeter.

The student recorded the following results.

Mass of empty calorimeter	**= 0.0894 kg**
Mass of calorimeter and cold water	**= 0.1327 kg**
Initial temperature of calorimeter and cold water	**= 20 °C**
Final temperature of calorimeter, water and added steam	**= 36 °C**
Final mass of calorimeter, water and added steam	**= 0.1341 kg**

(*i*) **Draw a labelled diagram of the apparatus used in this experiment.** **4 × 3**

labelled diagram to show:

calorimeter with water
steam source
thermometer
insulation
steam trap

any 4 lines 4 × 3

NOTE: no labels deduct 2, incorrect experiment maximum mark 3× 3
accept valid alternatives

(*ii*) **Calculate the mass of the cold water (A).** **4**
(0.1327 – 0.0894 =) 0.0433 kg 4

(*iii*) **Calculate the mass of the added steam (B).** **4**
(0.1341 – 0.1327 =) 0.0014 kg 4

(*iv*) **Calculate the increase in temperature of the calorimeter and cold water (C).** **4**
(36 – 20 =) 16 °C 4

(*v*) **Calculate the decrease in temperature of the steam (D).** **4**
(100 – 36 =) 64 °C 4

(*vi*) **Use your values for A, B, C and D to complete the following calculations to find *l*.** **4 × 2 + 4**

Heat lost by steam			=	***Heat gained by water and calorimeter***		
$m_{steam}l$	+	$m_{steam}c_{water}\Delta\theta_{steam}$	=	$m_{water}c_{water}\Delta\theta_{water}$	+	$m_{cal.}c_{copper}\Delta\theta_{cal.}$
B × *l*	**+**	**B × 4200 × D**	**=**	**A × 4200 × C**	**+**	**0.0894 × 390 × C**

(*specific heat capacity of water = 4200 J kg^{-1} K^{-1}; specific heat capacity of copper = 390 J kg^{-1} K^{-1}*)

(0.0014) *l* + (0.0014)(4200)(64) = (0.0433)(4200)(16) + (0.0894)(390)(16)

correct substitutions 4 × 2

(0.0014) *l* = 3090 ⇒ $l = 2.2 \times 10^6$ J kg^{-1} 4

Question 5 **40 marks**

A student performed an experiment to investigate the variation of current *I* with potential difference (voltage) *V* for a metallic conductor.

(*i*) **Name the instrument used to measure voltage.** **6 or 3**

voltmeter 6

partial answer e.g. multimeter (3)

(*ii*) **Name the instrument used to measure current.** **6 or 3**

ammeter 6

partial answer e.g. multimeter (3)

(*iii*) **How did the student change the voltage across the conductor?** **6 or 3**

adjust variable voltage // adjust the variable resistor 6

partial answer (3)

The student recorded the following results.

I **(A)**	**0**	**0.06**	**0.12**	**0.18**	**0.24**	**0.36**
V **(V)**	**0**	**1**	**2**	**3**	**4**	**6**

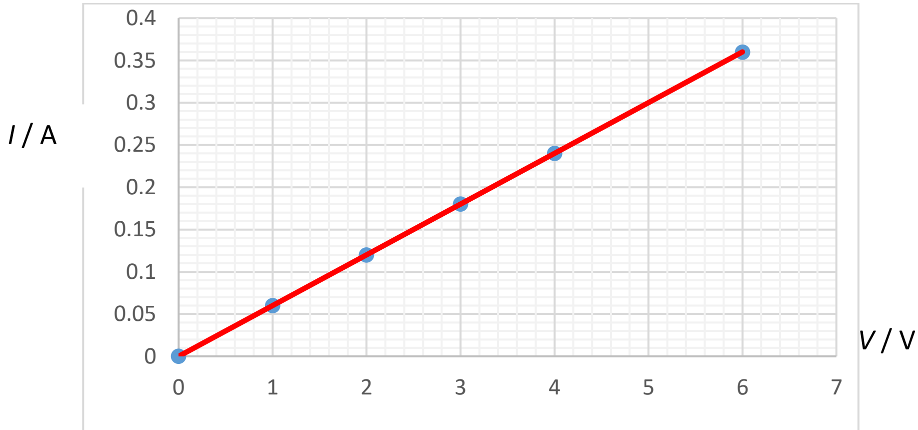
(*iv*) **Use the data to plot a graph on graph paper to show the relationship between *I* and *V*.** **3+6+3**

label axes correctly, (name / symbol / unit acceptable) 3

plot six points correctly 6 × 1

straight line 3

if graph paper is not used, maximum mark 3 × 3



(*v*) **Describe the relationship between current and voltage for this conductor.** **6 or 3**

$V \propto I$ // proportional 6

partial answer e.g. linear (3)

(*vi*) **What would you notice if the experiment was repeated using a filament bulb instead of a metallic conductor?** **4 or 2**

bulb would get hot // not proportional/curved graph 4

partial answer (2)

SECTION B (224 MARKS) Answer **four** questions from this section. Each question carries 56 marks.

Question 6. **Answer any eight of the following parts (*a*), (*b*), (*c*), etc.** **56 marks**

(*a*) **A student arranges a metre stick so that it is in <u>equilibrium</u>. Explain the underlined term.** **7 or 4**

no movement / no acceleration / nett force zero / balanced 7

partial answer e.g. no force acts (4)

(*b*) **A car starts from rest and has an acceleration of 6 m s^{-2}. Calculate the distance It travels in 12 s.** **7 or 4**

$(s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(6)(12)^2 =)$432 m 7

partial answer e.g. states equation of motion (4)

(*c*) **Water has a density of 997 kg m^{-3}. Calculate the pressure due to water at a depth Of 214 m.** **7 or 4**

$(P = h\rho g = (214)(997)(9.8) =)$ 2.1 × 10^6 Pa 7

partial answer (4)

(*d*) **Complimentary colours mix to form white light. Name the secondary colour which mixes with red light to form white light.** **7**

turquoise / cyan 7

(*e*) **What is the Doppler effect?** **7 or 4**

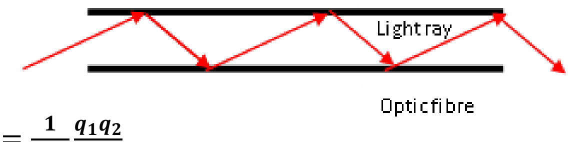
(apparent) change in (wave) frequency /wavelength due to moving source/observer 7

partial answer (4)

(*f*) **Draw a diagram to show how light is transmitted along an optical fibre.** **7 or 4**

diagram showing fibre and multiple internal reflections 7

partial answer (4)



(*g*) **Coulomb's law may be written as $F = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{d^2}$.**

What do the letters F, q, and d stand for in this expression? **7 or 4**

force, charge and distance (between charges) three correct 7

any one correct (4)

(*h*) **State the SI unit of (*i*) magnetic flux density, (*ii*) capacitance.** **7 or 4**

(i) tesla/T (ii) farad/F 7

partial answer e.g. one correct (4)

(*i*) **The picture on the right is an X-ray tube. The target in an X-ray tube is usually made of tungsten. What property of tungsten makes it suitable for this use?** **7 or 4**

high melting point // high atomic number//high density 7

partial answer (4)

(*j*) **Silicon is an example of a semiconductor. What is a semiconductor?** **7 or 4**

substance whose resistivity/conductivity is between that of a conductor and insulator 7

partial answer (4)

(*k*) **Draw a diagram to outline the Bohr model of the atom.** **7 or 4**

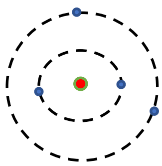


diagram showing nucleus, electron shell, another electron shell any two 7

partial answer (4)

(*l*) **What is the photoelectric effect?** **7 or 4**

emission of electrons (from a metal surface) by (incident) light 7

partial answer (4)

Question 7 **56 marks**

The Bagger 293 excavator is the world's largest land vehicle, with a mass of 14200 tonnes. (1 tonne = 1000 kg)
Bagger 293 has a maximum speed of 0.17 m s^{-1}.

(*i*) **Bagger 293 has a large momentum. What is meant by momentum?** **6 or 3**

mass multiplied by velocity / *mv* 6

partial answer (3)

(*ii*) **State the principle of conservation of momentum.** **6 or 3**

(in a closed system the total) momentum before (interaction) = (the total)momentum after // $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ 6

partial answer (3)

(*iii*) **Explain why Newton's second law of motion is consistent with the principle of conservation of momentum.** **4 or 2**

no force acting implies no change in momentum // states Newton's second law of motion 4

partial answer (2)

(*iv*) **Calculate the momentum of Bagger 293 when it is moving at its maximum speed.** **6 or 3**

(mv = $(14200 \times 10^3)(0.17)$ =) 2.4×10^6 kg m s^{-1} 6

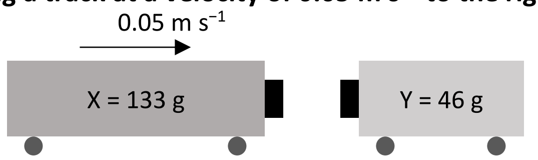
partial answer (3)

(*v*) **Bagger 293 is moving when it picks up a stationary load of 2700 tonnes. Would this cause its speed to increase or to decrease? Explain your answer.** **6 or 3**

decrease due to extra mass 6

partial answer (3)

Toy train X has a mass of 133 g and is moving along a track at a velocity of 0.05 m s^{-1} to the right. It collides with toy train Y of mass 46 g which is at rest. The two trains stick together and move down the track together.



(*vi*) **Calculate the initial momentum of train X.** **6 or 3**

(mv = $(0.133)(0.05)$ =) 6.65×10^{-3} kg m s^{-1} 6

partial answer (3)

(*vii*) **Calculate the speed of the two trains immediately after the collision.** **6 or 3**

($6.65 \times 10^{-3} = (0.179)v \;\Rightarrow v =$) 0.037 m s^{-1} 6

partial answer e.g. addition of masses (3)

(*viii*) **In which direction do the two trains move after the collision?** **4**

to the right // in the same direction as the moving train 4

(*ix*) **Calculate the loss in kinetic energy during this collision.** **3 × 3**

KE before = $\frac{1}{2}(0.133)(0.05)^2 = 1.66 \times 10^{-4}$ J 3

KE after = $\frac{1}{2}(0.179)(0.037)^2 = 1.22 \times 10^{-4}$ J 3

kinetic energy lost = 0.44×10^{-4} J 3

partial answer e.g. $\frac{1}{2}mv^2$ (3)

(*x*) **What happened to the kinetic energy that was lost in the collision?** **3**

converted into heat // converted into other forms 3

Question 8 **56 marks**

A wave can be described as a travelling disturbance that transports energy from one point to another.

(*i*)	**Describe an experiment to show that sound waves need a medium to travel through.**	**4 × 3**
	apparatus: bell jar with electric bell, battery, vacuum pump any two	2 × 3
	procedure: turn on pump	3
	observation/conclusion: no sound heard when air removed / sound needs a medium	3
	accept valid alternatives a labelled diagram may merit full marks	
(*ii*)	**What type of waves do not need a medium to travel through?**	**4**
	light / electromagnetic	4
(*iii*)	**Waves can be classified as either transverse or longitudinal. Distinguish between transverse and longitudinal waves. (A labelled diagram may help your answer.)**	**2 × 3**
	the disturbance is parallel to the direction of motion for longitudinal waves	3
	the disturbance is perpendicular to the direction of motion for transverse waves	3
	partial answer e.g. longitudinal waves need a medium//transverse waves may be polarised	(3)
	a labelled diagram may merit full marks	
(*iv*)	**The frequency of a certain radio station is 107 MHz. It broadcasts waves of length 2.804 m. Calculate the speed of the radio waves.**	**6 or 3**
	($v = f\lambda = (107 \times 10^6)(2.804) =$) 3×10^8 m s^{-1}	6
	partial answer	(3)

Light and sound waves both display the properties of reflection, refraction, diffraction and interference.

(*v*)	**Describe one example of the reflection of sound waves.**	**4**
	(When sound is reflected from a distant obstacle it produces) an echo	4
(*vi*)	**Light strikes a glass block with an angle of incidence of 23°. The light undergoes refraction as it travels from the air into the glass. The angle of refraction is 15°. Calculate the refractive index of the glass.**	**6 or 3**
	$(n = \frac{\sin i}{\sin r} = \frac{0.3907}{0.2588} =)$ 1.51	6
	partial answer	(3)
(*vii*)	**The wave fronts shown below diffract as they pass through the gap. Copy and complete the diagram to show this wave undergoing diffraction**	**6 or 3**

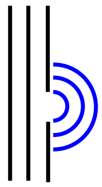


diagram to show: waves spreading out from the slit	6
partial answer	(3)

(*viii*)	**Describe an experiment to show that sound undergoes interference.**	**2 × 3**
	method: e.g. slowly rotate vibrating tuning fork near the ear	3
	observation/conclusion: e.g. change in loudness due to interference	3
	partial answer	(3)
(*ix*)	**Light waves undergo polarisation but sound waves do not. Explain with the aid of a labelled diagram what is meant by polarisation.**	**6 or 3**
	labelled diagram to show the restriction of (transverse) wave vibrations to a single plane	6
	partial answer	(3)
	NOTE: no labels deduct 2	

Question 9 **56 marks**

As electrons move through a metal, the metal resists this movement. The electrons collide with atoms of the metal and lose kinetic energy. This lost energy is converted into heat.

(*i*) Define resistance. **6 or 3**

$R = \frac{V}{I}$ 6

partial answer (3)

(*ii*) Name the instrument used to measure resistance. **6 or 3**

ohmmeter 6

partial answer e.g. multimeter (3)

The photograph shows a rheostat, which is a variable resistor. When the sliding contact is moved,the current flows through a different length of wire, thus changing the resistance of the rheostat.

(*iii*) State the relationship between resistance and length. **6 or 3**

$R \propto l$ / proportional 6

partial answer (3)

A 4.8 m length of circular nichrome wire has a radius of 0.2 mm. Nichrome has a resistivity of 1.1×10^{-6} Ω m.

(*iv*) Calculate the circular cross-sectional area of the wire. **6 or 3**

$(A = \pi r^2 = \pi(0.2 \times 10^{-3})^2 =)$ 1.26×10^{-7} m^2 6

partial answer (3)

(*v*) Calculate the resistance of the wire. **6 or 3**

$\left(R = \frac{\rho l}{A} = \frac{(1.1 \times 10^{-6})(4.8)}{1.2566 \times 10^{-7}} = \right)$ 42 Ω 6

partial answer (3)

Examine the circuit diagram shown on the right.

(*vi*) Show that the combined resistance of the three resistors in parallel (i.e. resistors R_1, R_2 and R_3) is 1.05 Ω. **6 or 3**

$\left(\frac{1}{R} = \frac{1}{5} + \frac{1}{2} + \frac{1}{4} = \frac{19}{20} \quad \Rightarrow\right)$ R= 1.05 Ω 6

partial answer e.g. correct equation (3)

(*vii*) Calculate the total resistance in the circuit. **6 or 3**

R_T = 3 + 1.05 = 4.05 Ω 6

partial answer (3)

(*viii*) Calculate the total current flowing through the ammeter, A. **6 or 3**

$\left(I = \frac{V}{R} = \frac{12}{4.05} = \right)$ 2.96 A 6

partial answer (3)

The diagram on the left shows the parts of an electrical plug.

(*ix*) The wire labelled P is yellow and green. What is the function of this wire? **4**

safety/ earth (the equipment) 4

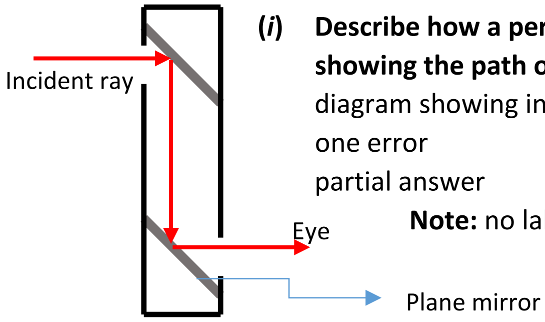
(*x*) Name the wire labelled Q. **4 or 2**

live 4

partial answer e.g. brown (2)

Question 10 **56 marks**

A periscope is used on a submarine. The periscope uses plane mirrors to allow a person on the submarine to see above the surface of the water.



(*i*) **Describe how a periscope works. Your answer should include a labelled diagram showing the path of a ray of light through the periscope.** **10 or 7 or 4**

diagram showing incident ray, two reflections and emerging ray	10
one error	(7)
partial answer	(4)

Note: no labels deduct 2, no diagram maximum mark 7

(*ii*) **State the laws of reflection of light.** **3 + 3**

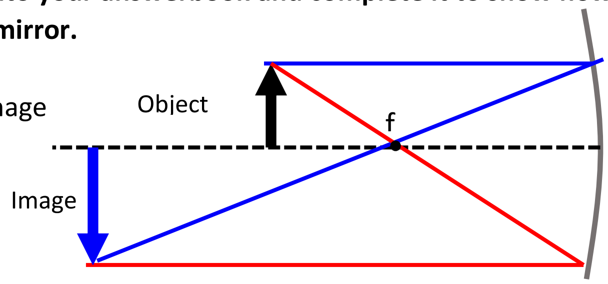
the incident ray, the normal and the reflected ray are in the same plane	3
the angle of incidence is equal to the angle of reflection	3
partial answer	(3)

(*iii*) **Describe an experiment to demonstrate the laws of reflection.** **4 × 3**

apparatus: plane mirror, sheet of paper, raybox / pins, protractor	any two	2 × 3
	any one	(3)
procedure: draw the incident ray, normal and reflected ray // measure *I* and *r*		3
observation / conclusion: the angle of incidence is always equal to the angle of reflection		3

Light can also be reflected from spherical mirrors. Two types of spherical mirrors are concave mirrors and convex mirrors.

(*iv*) **Copy the ray diagram below into your answerbook and complete it to show how a real image is formed in a concave mirror.** **10 or 7 or 4**



correct diagram showing two correct rays and an inverted image	10
one error	(7)
partial answer	(4)

An object of height 2 cm is placed 17 cm in front of a concave mirror.
An image with a height of 3 cm is formed.

(*v*) **Calculate the magnification.** **6 or 3**

$(M = \frac{v}{u} =)\ \frac{3}{2}$	6
partial answer	(3)

(*vi*) **Calculate the image distance.** **6 or 3**

$\left(\frac{v}{u} = \frac{3}{2} \quad \Rightarrow v = 1.5u = (1.5)(17) = \right)$ 25. 5 cm	6
partial answer	(3)

(*vii*) **State one use of a concave mirror.** **3**

cosmetics, shaving mirror, dentist, etc.	3

(*viii*) **State one use of a convex mirror.** **3**

car mirror, security mirror in shops, road reflectors, etc.	3

Question 11 **56 marks**

The normal human body temperature is 37 °C. This temperature increases when a person is fighting an infection. The thermometer in the photograph on the right measures infrared radiation emitted from a person's forehead.

(*i*) **Heat may be transferred by radiation and by conduction. Name the other way in which heat may be transferred.** **3**

convection 3

(*ii*) **Distinguish between heat and temperature.** **6 or 3**

heat is a measure of the energy in a body while temperature is a degree of hotness 6

partial answer (3)

(*iii*) **Convert the normal human body temperature from degrees Celsius (°C) into kelvin (K).** **6 or 3**

(37 °C = 37 + 273 =) 310 K 6

partial answer e.g. 37-273 (3)

(*iv*) **Thermometers are designed to make use of thermometric properties. What is a thermometric property?** **6 or 3**

(measurable) property which changes with temperature change 6

partial answer (3)

(*v*) **State one example of a thermometric property.** **3**

colour, voltage, volume, pressure, resistance, etc. any one 3

(*vi*) **Two thermometers may not give the same reading for a person's temperature, even though both thermometers are working correctly. Explain why this is the case.** **4 or 2**

different thermometric properties behave differently with changing temperature 4

partial answer (2)

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}.

The diagram on the right shows a rectangular garden. On a particular day, sunlight falls on the garden for exactly 12 hours.

(*vii*) **Calculate the area of the garden.** **4**

(A=(6)(9) =) 54 m^2 4

(*viii*) **Calculate how many seconds there are in 12 hours.** **3**

((12)(60)(60)=) 43200 s 3

(*ix*) **Calculate how much energy will fall on the garden in the 12 hours.** **6 or 3**

$E=(1.36 \times 10^3)(43200)(54) = 3.17 \times 10^9$ J 6

partial answer (3)

(*x*) **Heat is transferred at different rates depending on the material it is moving through. Describe an experiment to compare the rate of conduction through different solids.** **3 × 3**

apparatus 3

method 3

observation/conclusion 3

partial answer (3)

(*xi*) **U–value is a measure of the rate of heat loss through walls and windows. Describe two ways of reducing heat loss from a building.** **6 or 3**

Insulation and double glazing 6

partial answer (3)

Question 12 **56 marks**

Lise Meitner was an Austrian physicist who was the first woman to become a full professor of physics in Germany. In 1938, together with chemist Otto Hahn, she discovered nuclear fission.

(*i*) **What is nuclear fission?** **6 or 3**

splitting up of a nucleus (into two parts) with the emission of particles /energy 6

partial answer (3)

Fission reactors are used to generate electricity.

(*ii*) **What is the function of the control rods in a fission reactor?** **6 or 3**

absorb neutrons // slow down the rate of fission/reaction 6

partial answer (3)

(*iii*) **A fission reactor is surrounded by shielding. What is the purpose of the shielding? What material is used as shielding?** **2 × 3**

protection / safety /prevent radiation escaping 3

lead / concrete 3

(*iv*) **State one disadvantage of nuclear fission.** **6 or 3**

radioactive waste/ explosions/nuclear accidents 6

partial answer (3)

Meitner never won a Nobel Prize for her discovery, although Hahn did. She was honoured after she died by having an element named after her. The element is called meitnerium, Mt.

(*v*) **How many electrons are in an atom of Mt? (Refer to page 79 of the *Formulae and Tables* booklet.)** **4**

($Mt_{109}^{268} =$) 109 electrons 4

Marie Curie also has an element named after her, curium, Cm. Curie was the first woman to win a Nobel Prize, which was for her study into radioactivity.

(*vi*) **What is meant by radioactivity?** **6 or 3**

(spontaneous) emission of (alpha and beta particles and gamma) rays from unstable nuclei 6

partial answer (3)

There are three types of nuclear radiation: alpha, beta and gamma.

(*vii*) **Which type of nuclear radiation is the most penetrating?** **4**

gamma 4

(*viii*) **Describe an experiment to compare the penetrating power of the three types of nuclear radiation.** **3 × 3**

apparatus: radioactive sources, barriers, detector/GM tube any two 3

procedure: place different barriers between the sources and the detector 3

observation/conclusion: alpha is stopped first // gamma penetrates best 3

Curie also developed techniques for isolating radioactive isotopes.

(*ix*) **What are isotopes?** **6 or 3**

atoms of the same element with different numbers of neutrons 6

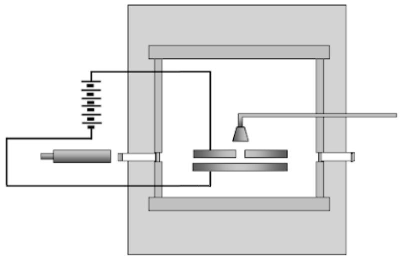
partial answer e.g. named isotope (3)

(*x*) **One isotope of curium is Cm_{96}^{247}. How many neutrons are in this isotope?** **3**

(247 – 96 =) 151 neutrons 3

Question 13 **56 marks**

Read the following passage and answer the questions below.



The Millikan Oil Drop Experiment

An experiment performed by Robert Millikan in 1909 determined the size of the charge on an electron. He also determined that there was a smallest unit charge. He received the Nobel Prize for his work.

The experiment Millikan performed involved putting a charge on a tiny drop of oil using X-rays and measuring how strong an applied electric field had to be in order to stop the oil drop from falling. By attaching a battery to the plates above and below the chamber, Millikan was able to apply an electric voltage. The electric field produced in the chamber by this voltage would act on the charged oil drop. If the voltage was just right, the electromagnetic force would just balance the force of gravity on a drop, and the drop would hang suspended in mid-air.

Using a microscope, he measured the radius of the drop. Given that the density of the oil was known, Millikan could calculate the mass of each oil drop. Using this mass, he could calculate the weight of one drop. He could then determine the electric charge on the drop.

By varying the charge on different drops, he noticed that the charge was always a multiple of 1.6×10^{-19} C, the charge on a single electron.

Adapted from ffden-2.phys.uaf.edu/212_fall2003.web.dir/ryan_mcallister

(*a*) **What did Millikan determine with his 1909 oil drop experiment?** **7**

size of the charge on an electron/there was a smallest unit charge 7

(*b*) **What is the size of the charge on one electron?** **7**

1.6×10^{-19} C 7

(*c*) **X-rays are made by accelerating electrons across an X-ray tube. How are the electrons produced in an X-ray tube?** **7 or 4**

thermionic emission // hot cathode 7

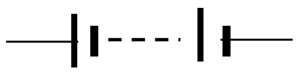
partial answer (4)

(*d*) **A drop has a volume of 2.03×10^{-17} m^3 and a density of 886 kg m^{-3}. Calculate the mass of the drop.** **7 or 4**

($M = \rho V = (886)(2.03 \times 10^{-17}) =$) 1.8×10^{-14} kg 7

partial answer (4)

(*e*) **Draw the circuit symbol for a battery.** **7 or 4**



7

partial answer e.g. capacitor //supply symbol (4)

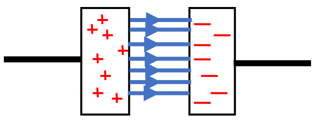
(*f*) **In the oil drop experiment, Millikan applied an electric field between the plates until the drop no longer moved up or down. What is an electric field?** **7 or 4**

region/space around a charge in which another charged particle will experience a force 7

partial answer (4)

(*g*) **Sketch the electric field that is formed between two oppositely charged parallel plates.** **7 or 4**

correct diagram 7



partial answer (4)

(*h*) **Show the forces acting on the drop when it is not moving up or down.** **7 or 4**

labelled diagram to show electric force acting up and gravity down 7

partial answer (4)

Question 14 **56 marks**

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

(*a*) A SpaceX Falcon 9 rocket carrying two astronauts launched from the Kennedy Space Centre in Florida on 30th May 2020. The rocket was headed for the International Space Station (ISS).

(*i*) The rocket was visible in Irish skies 15 minutes after take-off. At that time it had travelled a distance of 6484 km. Calculate the rocket's average speed during this part of the journey. **6 or 3**

$(v = \frac{s}{t} = \frac{6484 \times 10^3}{(15)(60)} =)$ 7.2 km s^{-1} 6

partial answer (3)

(*ii*) The rocket later docked on the ISS. The ISS orbits the Earth every 93 minutes. How many full orbits of the Earth does the ISS complete each day? **6 or 3**

(number of orbits $= \frac{(24)(60)}{93} = 15.48 =$) 15 6

partial answer (3)

(*iii*) Newton's law of universal gravitation describes the force of attraction between the ISS and the Earth. State Newton's law of universal gravitation. **6 or 3**

Force of attraction between two point masses is proportional to the product of the masses and inversely proportional to the square of the distance between them

$// F \propto \frac{m_1 m_2}{d^2}$ $// F = G\frac{m_1 m_2}{d^2}$ 6

partial answer (3)

The ISS is located 400 km above the Earth's surface. At this altitude, the acceleration due to gravity is 90% as strong as it is on the Earth's surface. Before travelling to the ISS, the mass of one of the astronauts was measured to be 85 kg.

(*iv*) Calculate the astronaut's weight on Earth. **4 or 2**

(weight = mg = (85)(9.8) =) 833 N 4

partial answer (2)

(*v*) What is the astronaut's mass at the altitude of the ISS? **3**

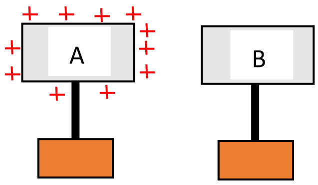
(mass does not change) 85 kg 3

(*vi*) Calculate the astronaut's weight at the altitude of the ISS. **3**

((0.9)(833) =) 749.7 N 3

(*b*) **Lightning is a naturally occurring electrostatic discharge. It is caused by an imbalance between two electrically charged regions, usually a cloud and the ground.**

(*i*) **As charge builds up on a cloud, the cloud induces a charge on objects on Earth. Explain how objects can be charged by induction.**
(A labelled diagram may help your answer.) **10 or 7 or 4**



a charged object A is brought near to
but not touching a neutral conducting object B
object B is then earthed.

three lines correct 10
two lines correct (7)
partial answer (4)
marks may be obtained from a diagram

Static electricity builds up in the cloud and releases 0.9 GJ of energy in a time of 0.3 ms as it discharges.

(*ii*) **Calculate the power generated when lightning discharges.** **6 or 3**

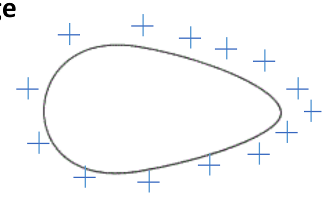
$\left(P = \frac{E}{t} = \frac{0.9 \times 10^9}{3 \times 10^{-4}} = \right) 3\times 10^{12}$ W 6

partial answer (3)

(*iii*) **Draw a diagram to show the distribution of charge on a pear shaped conductor** **6 or 3**

diagram showing more concentration at point 6

partial answer (3)



(*iv*) **Describe an experiment to show that static charge accumulates on the outside of a metal object.** **3 × 2**

apparatus: e.g. charged hollow conductor, proof plane, GLE 2

procedure: e.g. touch the proof plane against the inside of the charged conductor and then against the cap of the GLE. Repeat touching the proof plane against the outside of the charged conductor. 2

observation/conclusion: the leaf of the GLE deflects/moves when the proof plane was touched against the outside of the conductor but not the inside. 2

(*c*) **Magnetism is the force exerted by magnets when they attract or repel each other.**

(*i*) **What is a magnetic field?** **6 or 3**

region/space around a magnet where magnetic forces act 6

partial answer (3)

(*ii*) **Describe an experiment to plot the magnetic field around a bar magnet.** **3 × 2**

apparatus: magnet, plotting) compass / iron filings 2

procedure: use the apparatus to locate the field lines e.g. (place the compass on the paper and) mark the dots // sprinkle filings 2

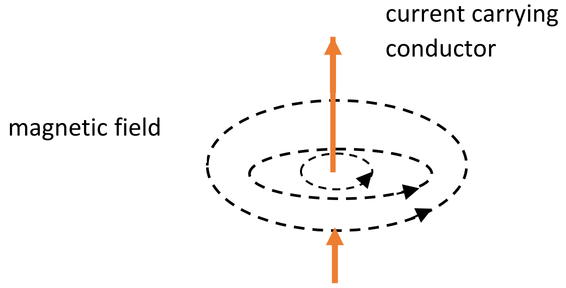
observation/conclusion: join the dots/ show field lines / lines go from north to south/ field lines are concentrated at the magnet poles // tap filings 2

marks may be obtained from a diagram

(*iii*) **Draw a diagram to show the magnetic field around a current-carrying conductor.** **6 or3**

correct diagram 6

partial answer (3)



(*iv*) **How could a student show that a current-carrying conductor experiences a force in a magnetic field?** **3 × 2**

apparatus: current carrying conductor e.g. 6V battery, tin foil, magnet, leads 2

procedure: (briefly) connect the circuit 2

observation/conclusion: e.g. tin foil moves when magnet is near 2

marks may be obtained from a diagram

(*v*) **State one use of magnets.** **4 or 2**

specific use e.g. in compass for direction, to seal fridge door, etc 4

general use e.g. in radio, cars, etc (2) (*d*) **Sounds are produced when something vibrates.**

(*i*) **What is the unit of sound intensity level?** **3**

bel / B / decibel / dB 3

(*ii*) **Resonance is the transfer of energy between two bodies with the same natural frequency. Describe an experiment to demonstrate resonance.** **3 × 3**

apparatus: two objects with the same natural frequency e.g. two mounted tuning forks (of the same frequency) 3

procedure: e.g. set one vibrating and bring the other close 3

observation/conclusion: energy transfer e.g. the second tuning fork vibrates 3

partial answer (3)

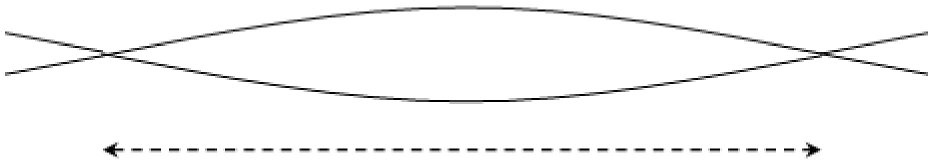
marks may be obtained from a diagram

(*iii*) **A sonometer, shown above, can be used to investigate the relationship between the frequency of a stretched string and its length. State this relationship.** **6 or 3**

frequency is inversely proportional to the length // *fl* = k // $f \propto \frac{1}{l}$ 6

partial answer (3)

Waves on a stretched string travel at a speed of 380 m s^{-1}. When a stationary wave is set up on a string, the distance between two adjacent nodes is 40 cm.



(*iv*) **Calculate the wavelength of the wave.** **6 or 3**

(λ = 2(0.4) =) 0.8 m 6

partial answer (3)

(*v*) **Calculate the frequency of the wave.** **4 or 2**

$\left(f = \frac{v}{\lambda} = \frac{380}{0.8} = \right)$ 475 Hz 4

partial answer (2)