Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2013

Marking Scheme

Physics

Higher 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.

General Guidelines

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. For omission of appropriate units, or incorrect units, one mark is deducted, when indicated

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

SECTION A (120 marks)

Each question carries 40 marks.

1. The laws of equilibrium for a set of co-planar forces acting on a metre stick were investigated by a student. She first found the centre of gravity of the metre stick and then determined its weight as 1.3 N.

How did the student find the centre of gravity of the metre stick?

balanced (horizontally) at a point (fulcrum) / suspended (horizontally) from a string 3

The centre of gravity was at the 50.3 cm mark rather than the mid-point of the metre stick. Explain.

metre stick not uniform / stick chipped / extra material on one end 3

The metre stick was suspended from two spring balances graduated in newtons. The student made use of a set of three weights, which she hung from the metre stick. She adjusted them until the metre stick was at equilibrium. How did the student ensure that the system was at equilibrium?

system not moving 6

Draw a diagram of the experimental arrangement that the student used.

metre stick horizontal 3

metre stick suspended from *two* spring balances with only *three* weights suspended from stick 3

The student recorded the positions of the forces acting on the metre stick and the direction in which each force was acting.

Position of force on metre stick/cm	**11.4**	**21.8**	**30.3**	**65.4**	**80.0**
Force/N	**2.0**	**3.0**	**5.7**	**4.6**	**4.0**
Direction	**downward**	**downward**	**upward**	**upward**	**downward**

Taking the moments of the forces about the mid-point of the metre stick (50 cm mark), use the student's data to calculate

(i) the total of the clockwise moments

(ii) the total of the anti-clockwise moments.

<u>torque</u> / <u>(turning) moment</u> / <u>M</u> / <u>T</u> = force ×distance (= $F \times d$) *(stated or implied)* 3

correct calculation of the moment of any force about any fulcrum 3

moment due to weight of metre stick (= 1.3 × 0.003 = 0.0039 N m) 3

moments (i): (2.0 × 0.386) + (3.0 × 0.282) + (4.6 × 0.154)

= 0.772 + 0.846 + 0.7084 = 2.3264 N m 3

moments (ii): (5.7 × 0.197) + (1.3 × 0.003) + (4.0 × 0.3) = 1.1229 + 0.0039 + 1.2 = 2.3268 N m 3

(–3 for moments taken about any point other than the 50 cm mark)

(–1 for omission of or incorrect units)

Explain how these results verify the laws of equilibrium.

forces up = forces down (= 10.3 N)

total clockwise moments ≈ total anticlockwise moments 4 + 3

2. In an experiment to verify Boyle's law, a student took the set of readings given in the table below.

X	**120**	**160**	**200**	**240**	**280**	**320**
Y	**52**	**39.1**	**31.1**	**25.9**	**22.2**	**19.6**

What physical quantities do *X* and *Y* represent?

pressure and volume/height/length *(any order)* 2 × 3

Name the units used when measuring these quantities.

e.g. N m^{-2} , kPa, Pa, mbar, atmosphere, cm Hg, torr *etc.* // cm^3 (m^3, mm^3, cm, litre, *etc.*) 2 × 2

(order of units must match the preceding order in the physical quantities)

Draw a labelled diagram of the apparatus that the student used in the experiment.

gas labelled in container with graduations 3

labelled pressure gauge 3

labelled means of adjusting pressure or volume 3

Describe the procedure he used to obtain these readings.

method of changing pressure (e.g. valve) / volume (e.g. piston) 3

read (new) pressure and volume *(stated or implied)* 3

Use the data in the table to draw an appropriate graph on graph paper.

label axes correctly 3

plot six points correctly *(–1 for each incorrectly plotted point)* 6

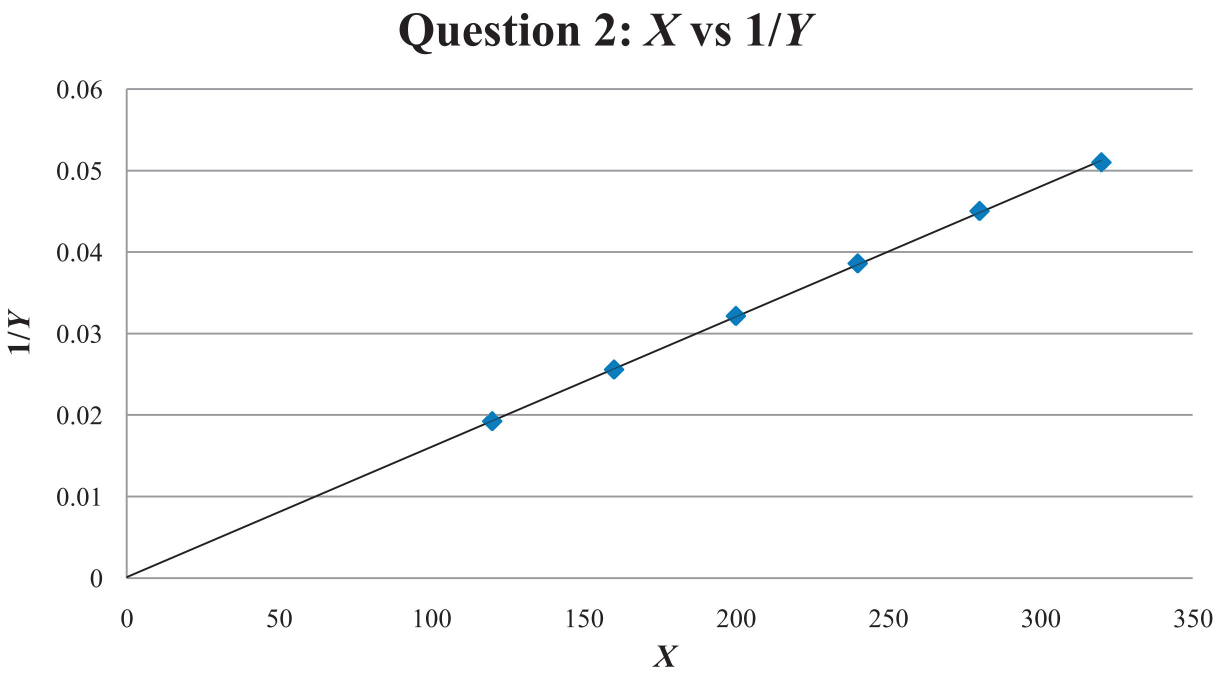
straight line with good distribution 3

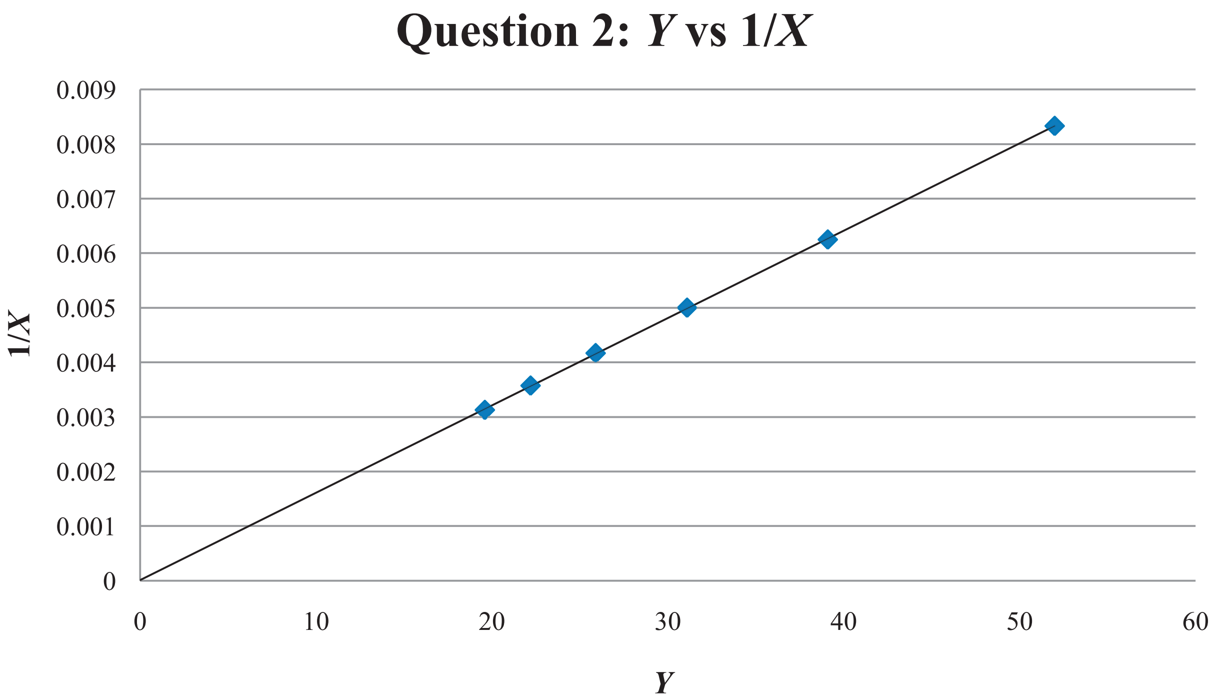
(–1 for inappropriate scale)

X	**120**	**160**	**200**	**240**	**280**	**320**
1/X	0.0083	0.00625	0.005	0.0042	0.0036	0.0031
Y	**52**	**39.1**	**31.1**	**25.9**	**22.2**	**19.6**
1/Y	0.019	0.026	0.032	0.039	0.045	0.051

Explain how your graph verifies Boyle's law.

straight line through the origin implies *p* inversely proportional to *V* / $p \propto \frac{1}{V}$ / *pV* constant 3


Question 2: X vs 1/Y
0.06
0.05
0.04
0.03
0.02
0.01
0
1/Y
0
50
100
150
200
250
300
350
X


Question 2: Y vs 1/X
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1/X
0
10
20
30
40
50
60
Y

3. The following is part of a student's report on an experiment to measure the focal length of a concave mirror.

"I started with the object 6 cm from the mirror but couldn't get an image to form on the screen. I moved the object back a few centimetres and tried again, but I couldn't get an image to form on the screen until the object was 24 cm from the mirror. From then on I moved the object back 8 cm each time and measured the corresponding image distances. I wrote my results in the table."

***u*/cm**	**24.0**	**32.0**	**40.0**	**48.0**
***v*/cm**	**72.5**	**40.3**	**33.0**	**27.9**

Draw a labelled diagram of the apparatus used.

apparatus: e.g. bulb, mirror, screen 3

(components appropriately consistent and each labelled)

correct arrangement 3

correct shape of mirror 3

Give two precautions that should be taken when measuring the image distance.

measure from the back of the mirror / measure from the centre (pole) of the mirror / avoid parallax error / ensure image is sharp / have both screen and mirror vertical, *etc.* *(any two)* 2 × 3

Explain why the student was unable to form an image on the screen when the object was close to the mirror.

object inside the focal length / virtual image formed 6

Use all of the data in the table to calculate a value for the focal length of the mirror.

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

calculation of *f* *(3 marks for each correct value for f to a maximum of 3 × 3)* 3 × 3

average of *f* values *(f ≈ 17.9 cm)* 3

OR

label axes correctly 3

plot four points correctly *(–1 for each incorrectly plotted point)* 3

straight line with good distribution 3

read intercept points *(–1 if only one intercept point used)* 3

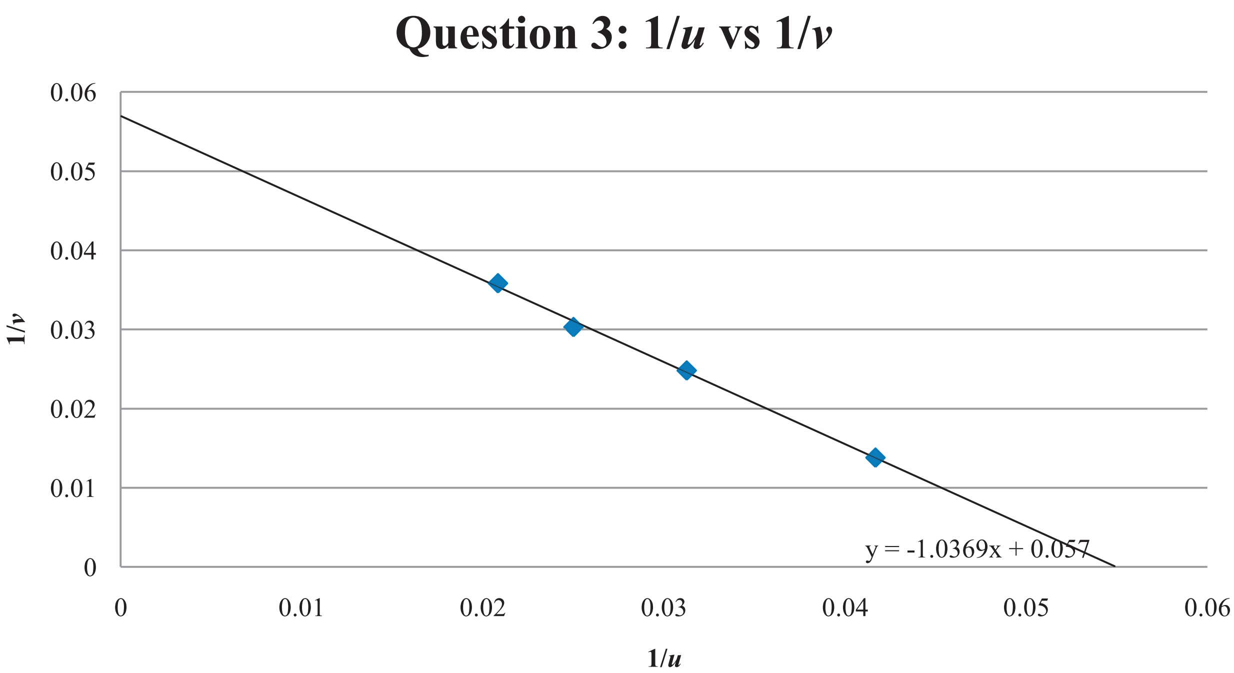
calculation of *f* value *(f ≈ 17.9 cm)* 3

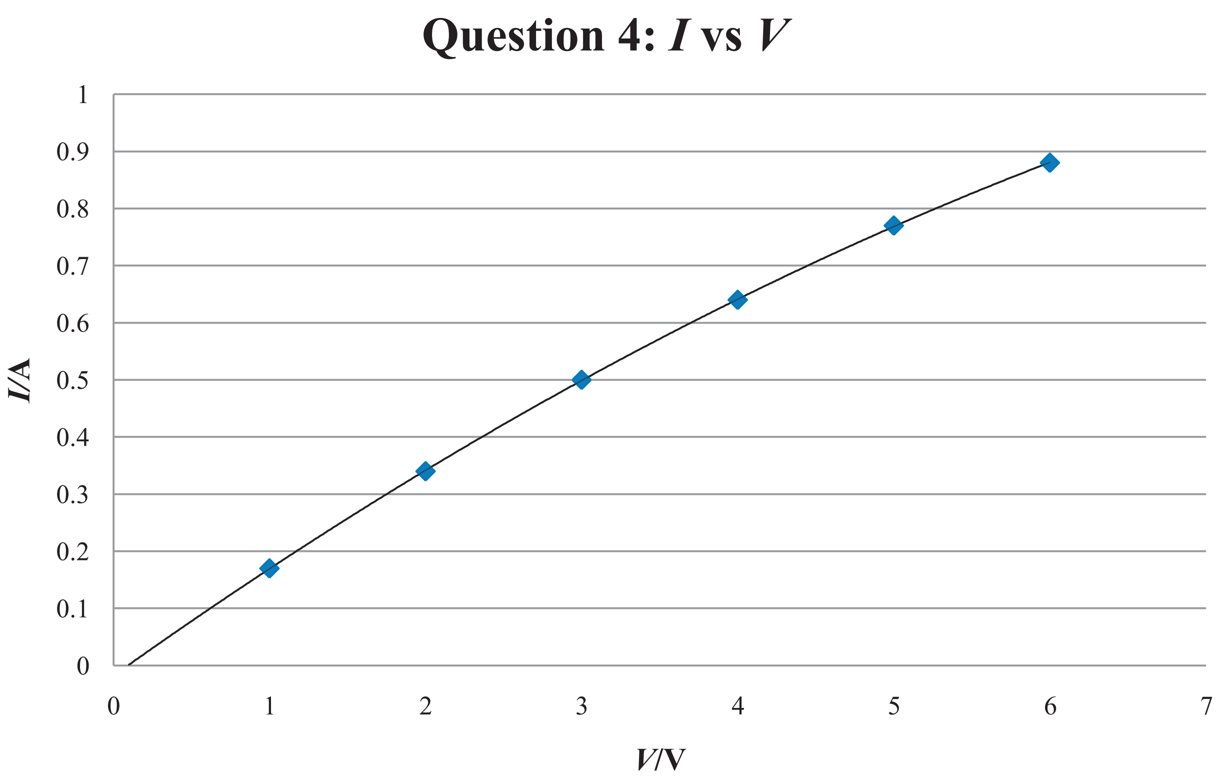
(–1 for inappropriate scale)

***u*/cm**	**24.0**	**32.0**	**40.0**	**48.0**
1/*u*	0.042	0.031	0.025	0.021
***v*/cm**	**72.5**	**40.3**	**33.0**	**27.9**
1/*v*	0.014	0.025	0.030	0.036

Describe how the student could have found an approximate value for the focal length of the mirror before starting the experiment.

measure image distance for distant object 4


Question 3: 1/u vs 1/v
1/v
1/u
0.06
0.05
0.04
0.03
0.02
0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
y = -1.0369x + 0.057


Question 4: I vs V
I/A
V/V
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7

4. A student was asked to investigate the variation of current with potential difference for a thin metallic conductor. The student set up a circuit using appropriate equipment. The student recorded the values of the current *I* passing through the conductor for the corresponding values of potential difference *V*. The recorded data are shown in the table.

***V*/V**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
***I*/A**	**0.17**	**0.34**	**0.50**	**0.64**	**0.77**	**0.88**

Draw and label the circuit diagram used by the student.

apparatus: p.s.u. / battery, ammeter, voltmeter 3
ammeter in series with conductor 3
voltmeter in parallel with conductor 3
(–1 if no label)

Name the device in the circuit that is used to vary the potential difference across the conductor.

variable p.s.u. / variable resistor (rheostat) / potential divider 6

Explain how the student used this device to vary the potential difference.

e.g. rotated the dial / moved sliding contact 3

Use the data in the table to draw a graph on graph paper to show the variation of current with potential difference.

label axes correctly 3
plot six points correctly *(–1 for each incorrectly plotted point)* 3
good distribution (for curved or linear graph) 3
(–1 for inappropriate scale)

Use your graph to find the value of the resistance of the conductor when the current is 0.7 A.

$V \approx 4.5$ V (when $I = 0.7$ A on graph) // slope method 3
$R \approx 6.4\ \Omega$ // answer compatible with graph drawn 3
(–1 for omission of or incorrect units)

Explain the shape of your graph.

resistance (of conductor) increases
with increasing temperature *(stated or implied)* 4 + 3
(*for appropriate reference to Ohm's law and to resistance, 4 + 3 marks)*

SECTION B (280 marks)
Answer five questions from this section. Each question carries 56 marks.

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

(*a*) What is the shortest stopping time for a car which is travelling at 16 m s^{-1} and has a maximum deceleration of 2.5 m s^{-2}?

$v = u + at$ / $s = ut + ½at^2$ / $v^2 = u^2 + 2as$ 4

$t = 6.4$ s *(–1 for omission of or incorrect units)* 3

(*b*) State the law of conservation of momentum.

momentum before = momentum after 4

in a closed system / provided no external forces act 3

(*c*) Explain why heat does not travel through solids by means of convection.

the particles cannot move (freely) 7

(*d*) Storage heaters are frequently used to heat buildings. State the principle that underlies the operation of an electrical storage heater.

large heat capacity 4

heated when electricity is inexpensive (off peak) / store a large quantity of energy / release energy slowly (during the day) *(any one)* 3

(*e*) If a diamond has a refractive index of 2.42, what is the speed of light in the diamond?

$n = \frac{c_1}{c_2}$ 4

$c_2 = \frac{3\times10^8}{2.42} = 1.24 \times 10^8 \text{ m s}^{-1}$ *(–1 for omission of or incorrect units)* 3

(*f*) Define the volt.

potential difference (between two points)

if 1 J (of work) is needed to move 1 C (from one point to the other) 4 + 3

(*g*) A positively charged rod is brought near to a neutral, conducting sphere that is on top of an insulating stand, as shown in the diagram. How would a student charge the sphere negatively by induction?

earth the sphere *(stated or implied)* 4

remove earth (connection) and then remove rod 3

(*h*) Explain what is meant by the statement: "Zinc has a threshold frequency of 1.04 × 10^{15} Hz".

below this frequency

e.m.r. /photons will not cause emission of electrons (from zinc surface) 4 + 3

(stated or implied)

(or for a correct vice versa statement, 4 + 3)

(*i*) Give one benefit of switching from fossil fuels to nuclear power for the generation of electricity. Explain your answer.

more energy per kg / less carbon dioxide produced / production of useful radioisotopes *etc.* 4

explanation 3

(*j*) Give an expression for the minimum frequency of a photon that can form an electron and a positron by pair production.

$(f =)\ \frac{2m_e c^2}{h}$ *(4 marks for hf or mc^2)* 7

or

What event inside an LED causes the release of a photon?

electron combines 4

with (positive) hole 3

(electron drops to lower energy level/band, 7 marks)

6. (i) State Newton's law of universal gravitation.

force proportional to product of masses // $F \propto \frac{m_1 m_2}{d^2}$ / $F = \frac{Gm_1m_2}{d^2}$ 3

inversely proportional to square of distance // correct notation given 3

(ii) Explain what is meant by angular velocity. Derive an equation for the angular velocity of an object in terms of its linear velocity when the object moves in a circle.

rate of change of angle // $\frac{\theta}{t}$ and correct notation given 3

$\omega = \frac{\theta}{t}$ *(stated or implied)* 3

$\omega = \frac{vt}{rt}$ / $\frac{v}{r}$ 3

The International Space Station (ISS), shown in the photograph, functions as a research laboratory and a location for testing of equipment required for trips to the moon and to Mars. The ISS orbits the earth at an altitude of 4.13 × 10^5 m every 92 minutes 50 seconds.

(iii) Calculate (*a*) the angular velocity, (*b*) the linear velocity, of the ISS.

$\omega = \frac{2\pi}{T}$ 3

$\omega = \frac{2\pi}{5570}$ /1.1 × 10^{-3} s^{-1} *(–1 for omission of or incorrect units)* 3

$v = r\omega$ 3

$v = (6.783 \times 10^6) \times (1.1 \times 10^{-3}) = 7651.5$ m s^{-1} 3

(–1 for omission of or incorrect units)

(iv) Name the type of acceleration that the ISS experiences as it travels in a circular orbit around the earth.

centripetal / gravitational 3

What force provides this acceleration?

gravitational *(do <u>not</u> accept "gravity")* 3

(v) Calculate the attractive force between the earth and the ISS.

$F = \frac{mv^2}{r}$ // $F = mr\omega^2$ 3

$F = 3.884 \times 10^6$ N *(–1 for omission of or incorrect units)* 3

Hence or otherwise, calculate the mass of the earth.

$F = \frac{GmM}{r^2}$ // $T^2 = \frac{4\pi^2 r^3}{GM}$ // $g = \frac{GM}{r^2}$ 3

$M = \frac{Fr^2}{Gm}$ // $M = \frac{4\pi^2 r^3}{GT^2}$ // $M = \frac{(8.63)r^2}{G}$ 3

$M = 5.95 \times 10^{24}$ kg *(–1 for omission of or incorrect units)* 3

(vi) If the value of the acceleration due to gravity on the ISS is 8.63 m s^{-2}, why do occupants of the ISS experience apparent weightlessness?

they are in freefall // ISS accelerating at the same rate as occupants 3

(vii) A geostationary communications satellite orbits the earth at a much higher altitude than the ISS. What is the period of a geostationary communications satellite?

1 day 5

(mass of ISS = 4.5 × 10^5 kg; radius of the earth = 6.37 × 10^6 m)

7. **What is meant by the term resonance?**

transfer of energy between two systems *(stated or implied)* 3
of similar natural frequencies 3

How would resonance be demonstrated in the laboratory?

apparatus (e.g. Barton's pendulums // column of air and tuning fork) 3
procedure (e.g. set one pendulum oscillating // hold vibrating fork over column of air etc.) 3
observation 3

A set of wind chimes, as shown in the diagram, is made from different lengths of hollow metal tubing that are open at both ends. When the wind blows, the wind chimes are struck by a clapper and emit sounds.

The sound from one of the tubes was analysed. The following frequencies were identified in the sound: 550 Hz, 1100 Hz and 1651 Hz.

What name is given to this set of frequencies?

overtones / harmonics 5

Draw labelled diagrams to show how the tube produces each of these frequencies.

550 Hz (f): antinodes (A) at both ends 3
linked correctly to one node (N) (in the centre) 3

1100 Hz ($2f$): antinodes at both ends 3
linked correctly to two nodes 3

1651 Hz ($3f$): antinodes at both ends linked correctly to three nodes 3
(−1 if no correct label)

The length of the metal tube is 30 cm. Use any of the above frequencies to calculate a value for the speed of sound in air.

$c = f\lambda$ 3
$\lambda = 0.60$ m 3
$c \approx 550 \times 0.60 = 330$ m s^{-1} *(–1 for omission of or incorrect units)* 3

A sample of wire, of length 12 m and mass 48 g, was being tested for use as a guitar string. A 64 cm length of the wire was fixed at both ends and plucked. The fundamental frequency of the sound produced was found to be 173 Hz. Calculate the tension in the wire.

$\mu = 0.048 \div 12 = 0.004$ kg m^{-1} 3
$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ 3
$T = 4(lf)^2\mu$ 3
T [$= 4 \times (0.64 \times 173)^2 \times 0.004$] $= 196$ N *(–1 for omission of or incorrect units)* 3

8. **(*a*)** **The diagram shows a circuit used in a charger for a mobile phone.**

Name the parts labelled F, G and H.

transformer / iron core (F)	3
diode (G)	3
capacitor (H)	3

Describe the function of G in this circuit.

rectifier / converts a.c. to d.c.	6

Sketch graphs to show how voltage varies with time for
(i) the input voltage
(ii) the output voltage, V_{XY}.

axes correctly labelled on at least one graph	3
correct shape of input voltage (sine wave)	3
correct shape of output voltage	6
(–1 if no indication of smoothing effect of capacitor)	

The photograph shows the device H used in the circuit. Use the data printed on the device to calculate the maximum energy that it can store.

$E = ½CV^2$	3
$E = ½ \times (2200 \times 10^{-6}) \times (16)^2$	3
$E = 0.2816$ J *(–1 for omission of or incorrect units)*	3

(*b*) **Electricity generating companies transmit electricity over large distances at high voltage. Explain why high voltage is used.**

(for a given power transmission) high voltage uses low current	3
minimising power (heat) loss	3

A 3 km length of aluminium wire is used to carry a current of 250 A. The wire has a circular cross-section of diameter 18 mm.

(i) Calculate the resistance of the aluminium wire.

$R = \frac{\rho l}{A}$	3
$A = \pi r^2$	3
$R = 0.33\ \Omega$ *(–1 for omission of or incorrect units)*	3

(ii) Calculate how much electrical energy is converted to heat energy in the wire in ten minutes.

$E = I^2Rt$	3
$E = (250)^2 \times 0.33 \times 600 = 1.238 \times 10^7$ J	2

(resistivity of aluminium = $2.8 \times 10^{-8}\ \Omega$ m)

9. **Define the becquerel.**

one disintegration per second 6

Name one device used to detect ionising radiations.

GM tube / solid state detector *etc.* 3

Compare alpha, beta, and gamma emissions using the following headings: (*a*) penetrating ability, (*b*) deflection in a magnetic field.

(*a*): gamma (most penetrating) > beta > alpha (least penetrating) 3

(*b*): alpha, beta deflected, gamma not deflected 3

alpha and beta deflected in opposite directions 3

The photograph shows one of the nuclear reactors at Chernobyl, where there was a fire in April 1986 that released large quantities of radioactive contaminants. Among the contaminants were iodine–131 and caesium–137, which are two of the unstable isotopes formed by the fission of uranium–235.

Explain what happens during nuclear fission.

large nucleus splits 3

into two smaller nuclei 3

with the emission of energy / neutrons 2

Iodine–131 decays with the emission of a beta-particle and has a half-life of 8 days.
Write an equation for the beta-decay of iodine–131.

$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e}$ *(accept β for e)*

(1 mark for each correct number and symbol) 9 × 1

Estimate the fraction of the iodine–131 that remained after 40 days.

40 days = 5 half-lives 3

$(½)^5$ / $^1⁄_{32}$ 3

Caesium–137 has a half-life of 30 years and it remains a significant contaminant in the region around Chernobyl. It is easily absorbed into the tissues of plants as they grow. Scientists collected a sample of berries growing near the abandoned power station. The activity of the sample was measured at 5000 Bq.
Calculate the decay constant of caesium–137.

$\lambda = \frac{\ln 2}{T_{½}}$ 3

$\lambda = 7.32 \times 10^{-10}\ \mathrm{s}^{-1}$ *(–1 for omission of or incorrect units)* 3

Hence calculate the number of caesium–137 atoms present in the sample. (You may assume that all of the activity was caused by caesium–137.)

$A = \lambda N$ 3

$N = 6.83 \times 10^{12}$ atoms 6

10. Answer either part (*a*) or part (*b*).

(a) **In 1932 J.D. Cockroft and E.T.S. Walton accelerated protons to energies of up to 700 keV and used them to bombard a lithium target. They observed the production of alpha-particles from the collisions between the accelerated protons and the lithium nuclei.**

How did Cockroft and Walton accelerate the protons?

high voltage / large electric field 6

How did they detect the alpha-particles?

scintillations / flashes of light / fluorescence 3

when particles hit (zinc sulfide) screen 3

Write the nuclear equation for the reaction that occurred and indicate the historical significance of their observation.

$^{7}_{3}Li + ^{1}_{1}H \rightarrow ^{4}_{2}He + ^{4}_{2}He$ 9

(–1 for each incorrect or omitted symbol or number)

1st experimental verification of $E = mc^2$ / first artificial splitting of the nucleus (atom) / first transmutation using artificially accelerated particles / awarded Nobel Prize 3

Calculate the speed of a proton that has a kinetic energy of 700 keV.

700 keV = 1.12×10^{-13} J 3

$E = ½mv^2$ 3

correct substitution 3

$v = 1.16 \times 10^7$ m s^{-1} *(–1 for omission of or incorrect units)* 3

Many modern particle accelerators, such as the Large Hadron Collider (LHC) in CERN, have a circular design. The diagram shows a simplified design of a circular accelerator.

Why is the tube evacuated?

so that particles do not collide with gas particles // to increase mean free path 3

What is the purpose of accelerating the particles to high velocities?

to overcome repulsive forces // to create new matter 4

What is the purpose of the magnets?

to contain the particles (in a circular path) *(stated or implied)* 4

Give an advantage of a circular accelerator over a linear accelerator.

takes up less space // particles can achieve greater energy / speed 3

Can an accelerator of this design be used to accelerate neutrons? Explain your answer.

no 3

neutrons have no charge and are therefore not affected by electric / magnetic fields 3

(b) **State the principle on which a moving-coil galvanometer is based.**

a current carrying conductor experiences a force 3
in a magnetic field 3

Draw labelled diagrams to show how a galvanometer may be converted to function as

(i) an ammeter
(small) resistance 3
connected in parallel 3

(ii) a voltmeter.
(large) resistance 3
connected in series 3

A galvanometer with a resistance of 100 Ω shows a full-scale deflection when a current of 2 mA passes through it. How can the galvanometer be converted to function as an ammeter reading up to 5 A?

$V_{shunt} = V_{galvanometer}$ *(stated or implied)* 3
$I_{shunt} \times R_{shunt} = I_{galvanometer} \times R_{galvanometer}$ 3
I_{shunt} = 4.998 A 3
correct substitution 3
R_{shunt} = 0.0400 Ω (= 40.016 mΩ) *(–1 for omission of or incorrect units)* 3

Name another device based on the same principle as the moving-coil galvanometer.
(d.c.) motor / moving-coil loudspeaker 6

The induction coil was invented by Dr Nicholas Callan, an Irishman. The diagram shows an induction coil that is used to produce a very high voltage from a low voltage source.
Explain the functions of the parts labelled A and B in the diagram.
A: to generate a large emf 6
B: to produce sparks 6

Give an application of the induction coil.
any correct answer, e.g. create a spark in engine of a car (spark plugs) / electric fence *etc.* 5

11. (*a*) **Seismic waves can be longitudinal or transverse. What is the main difference between them?**

direction of vibration parallel to direction of propagation of wave .. (longitudinal)
direction of vibration perpendicular to direction of propagation of wave .. (transverse) 4 + 3

(award 7 marks for "only transverse waves can be polarised")

(*b*) **An earthquake generates a seismic wave that takes 27 seconds to reach a recording station. If the wave travels at 5 km s^{-1} along the earth's surface, how far is the station from the centre of the earthquake?**

$s = vt$ 4
$s = 5000 \times 27 = 135000$ m = 135 km *(–1 for omission of or incorrect units)* 3

(*c*) **Draw a diagram to show the forces acting on the suspended mass when the seismometer is at rest.**

weight acting downwards
tension acting upwards 4 + 3

(–1 if vectors unequal; –3 for incorrect additional forces)

(*d*) **At rest, the tension in the spring is 49 N. What is the value, in kilograms, of the suspended mass?**

$W = mg$ 4
$m = 5$ kg 3

(*e*) **What type of motion does the frame have when it moves relative to the mass?**

simple harmonic motion 7

(award 4 marks for "wave motion" or "periodic motion" or "up-down motion")

(*f*) **During an earthquake the ground was observed at the recording station to move up and down as the seismic wave generated by the earthquake passed. Give an equation for the acceleration of the ground in terms of the periodic time of the wave motion and the displacement of the ground.**

$a = \frac{4\pi^2 s}{T^2}$ 7

(*g*) **If the period of the ground motion was recorded as 17 seconds and its amplitude was recorded as 0.8 cm, calculate the maximum ground acceleration at the recording station.**

$a_{max} = \frac{4\pi^2(0.008)}{17^2}$ 4
$a_{max} = 0.0011$ m s^{-2} *(–1 for omission of or incorrect units)* 3

(*h*) **In some modern seismometers a magnet is attached to the mass and a coil of wire is attached to the frame. During an earthquake, there is relative motion between the magnet and the coil. Explain why an emf is generated in the coil.**

magnetic field passing through the coil // coil cuts 4
is changing // (magnetic) flux 3

('due to Faraday's law', 4 marks ; 'due to Faraday's law of e.m.i.', 4 + 3)

(acceleration due to gravity, *g* = 9.8 m s^{-2})

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

(*a*) **State the law of conservation of energy.**

energy is neither created nor destroyed 4

The pendulum in the diagram is 8 m long with a small bob of mass 6 kg at its end. It is displaced through an angle of 30° from the vertical (position A) and is then held in position B, as shown. Calculate the height through which the bob has been raised and the potential energy that it has gained.

$h = l(1 - \cos\theta)$ / $h = 8 - 8\cos 30$ / $h = 1.07$ m 3

$E = mgh$ 3

$E = 6 \times 9.8 \times 1.07 = 63$ J *(–1 for omission of or incorrect units)* 3

The bob is then released and allowed to swing freely. What is the maximum velocity it attains?

kinetic energy = 63 J *(stated or implied)* 3

$\frac{1}{2}mv^2 = 63$ J 3

$v = 4.58$ m s^{-1} *(–1 for omission of or incorrect units)* 3

When the moving bob is at position A, a force is applied which brings the bob to a stop in a distance of 5 mm. Calculate the force applied.

$W = Fd$ // $F = ma$ 3

$F = 63 \div 0.005 = 12604.3$ N // $F = 6 \times 2100.7 = 12604.3$ N 3

(–1 for omission of or incorrect units)

(acceleration due to gravity, $g = 9.8$ m s^{-2})

(*b*) **A narrow beam of light undergoes dispersion when it passes through either a prism or a diffraction grating.**

What is meant by dispersion?

separation of light 3

into its different colours /frequencies / wavelengths 3

Give two differences between what is observed when a narrow beam of light undergoes dispersion as it passes through a prism, and what is observed when a narrow beam of light undergoes dispersion as it passes through a diffraction grating.

red light deviated least in a prism and deviated the most in a grating (or equivalent) 3

many spectra observable with a grating, only one with a prism 3

Give another example of light undergoing dispersion.

rainbow, *etc.* 4

Yellow light of wavelength 589 nm is produced in a low-pressure sodium vapour lamp. What causes the sodium atoms to emit this light?

electrons changing energy levels 3

Calculate the highest order image that could be produced when a beam of light of this wavelength is incident perpendicularly on a diffraction grating that has 300 lines per mm.

$n\lambda = d\sin\theta$ 3

$n \leq \frac{d}{\lambda}$ (= 5.65) / $\sin\theta = 1$ *(stated or implied)* 3

$n = 5$ 3

(*c*) **Define the unit of charge, the coulomb. State Coulomb's law.**

1 C = charge that passes when 1 A flows for 1 s	6
correct statement of Coulomb's law	3

Calculate the force of repulsion between two small spheres when they are held 8 cm apart in a vacuum. Each sphere has a positive charge of +3 µC.

$F = \frac{q_1 q_2}{4\pi\varepsilon_0 d^2}$		3
correct substitution		3
F = 12.64 N	*(–1 for omission of or incorrect units)*	3

Copy the diagram above and show on it the electric field generated by the charges. Mark on your diagram a place where the electric field strength is zero.

correct curved deviation of the field lines on interaction	3
correct direction of field	3
(neutral/null) point marked halfway between charges	4

(*d*) **What is meant by the term thermometric property?**

(physical) property that changes (measurably)	3
with temperature	3

This graph was obtained during an experiment where the resistance *R* of a thermistor was measured as its temperature *θ* was raised from 0 °C to 100 °C (as measured by a mercury-in-glass thermometer). The thermistor is used in a circuit to keep the water in a tank at a constant temperature. What is the temperature of the water when the resistance of the thermistor is 420 kΩ?

37 ± 1 °C	6

A thermocouple thermometer has emf values of 0 µV at 0 °C and 815 µV at 100 °C. When the thermocouple thermometer was placed in the tank of water, its emf was found to be 319µV. What is the temperature of the water in the tank as measured by the thermocouple thermometer?

$\theta = \frac{100(E_\theta - E_0)}{E_{100} - E_0}$	(assuming linearity):	815 µV → 100 °C divisions	3
$\theta = \frac{100(319-0)}{815-0}$		1 µV → 0.1227 °C divisions	3
$\theta = 39.14$ (°C)		319 µV → 39.14 (°C)	3

Why do the thermistor and the thermocouple thermometer give different temperature readings for the water in the tank?

each of the devices has a different thermometric property that changes differently with temperature	4 + 3

Blank Page

Blank Page

Blank Page

Blank Page