Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE 2008

MARKING SCHEME

PHYSICS

HIGHER LEVEL

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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)

Answer **three** questions from this section. Each question carries 40 marks.

Question 1

A student investigated the relationship between the period and the length of a simple pendulum. The student measured the length l of the pendulum.

The pendulum was then allowed to swing through a small angle and the time t for 30 oscillations was measured.

This procedure was repeated for different values of the length of the pendulum.

The student recorded the following data.

l / cm	40.0	50.0	60.0	70.0	80.0	90.0	100.0
t / s	38.4	42.6	47.4	51.6	54.6	57.9	60.0

Why did the student measure the time for 30 oscillations instead of measuring the time for one?

to reduce (%) error (in the period) / for greater accuracy (in the period) / to get average 3

How did the student ensure that the length of the pendulum remained constant when the pendulum was swinging?

inextensible string / string suspended at fixed point (e.g. split cork or two coins) 6

(state/imply, e.g. correct equation)

Using the recorded data draw a suitable graph to show the relationship between the period and the length of a simple pendulum. What is this relationship?

label axes correctly 3

plot points **(–1 for each omitted or incorrect point)** 2×3

straight line 3

good distribution 3

$T^2 \propto l$ / correct statement / correct equation for T 4

Use your graph to calculate the acceleration due to gravity.

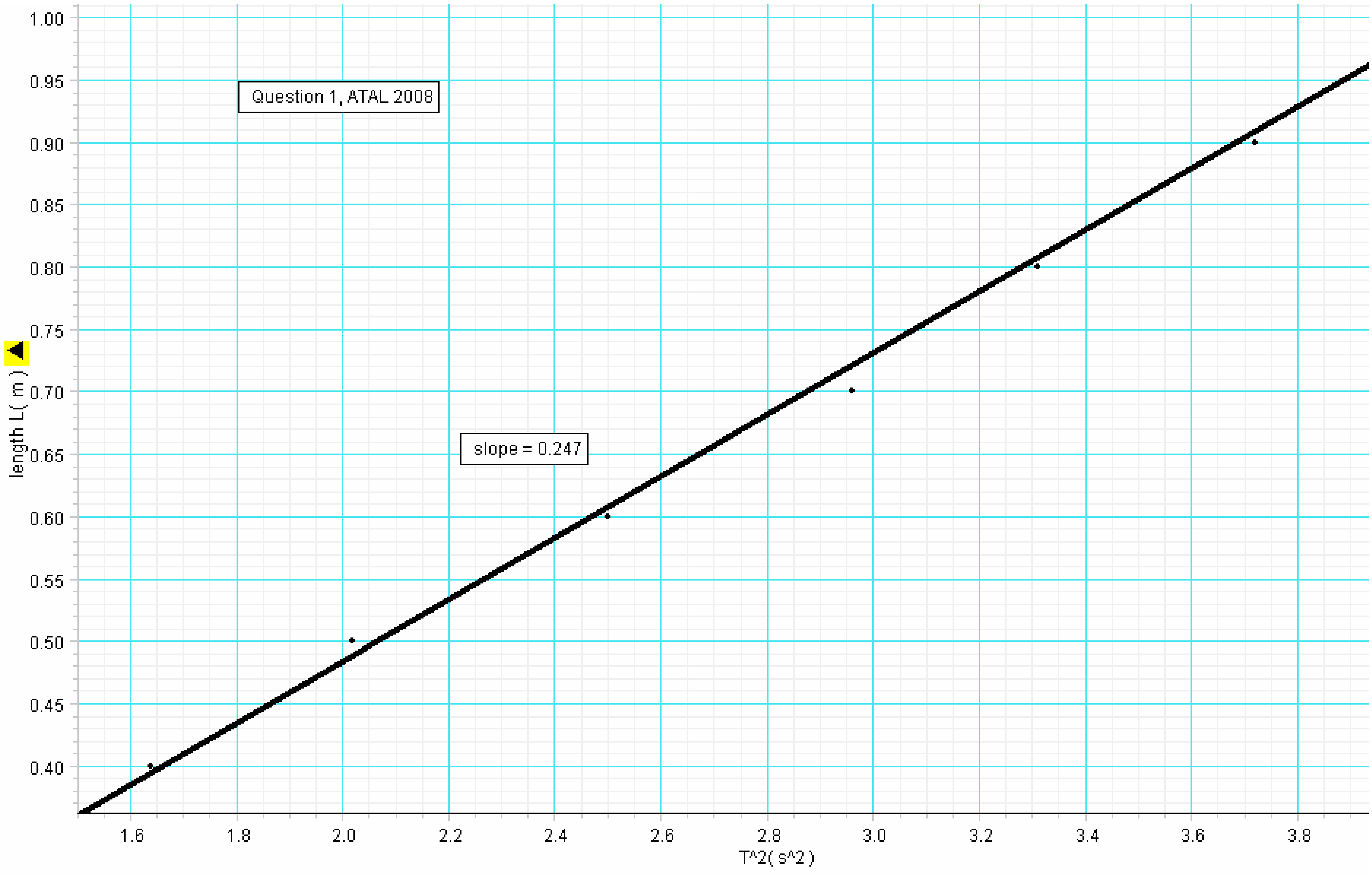
correct method for obtaining slope 3

slope = 0.2462 / 0.25 (m s^{-2}) [range: 0.24 – 0.25 m s^{-2}] 3

correct pendulum formula (any format) 3

g = 9.7196 / 9.72 m s^{-2} [range: 9.4 – 9.9 m s^{-2}] 3

(–1 for omission of or incorrect units)



Question 1, ATAL 2008
slope = 0.247
length L(m)
T^2(s^2)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8

Question 2

In an experiment to measure the specific latent heat of fusion of ice, warm water was placed in a copper calorimeter. Dried, melting ice was added to the warm water and the following data was recorded.

mass of calorimeter	60.5 g
mass of calorimeter + water	118.8 g
temperature of warm water	30.5 °C
mass of ice	15.1 g
temperature of water after adding ice	10.2 °C

Explain why warm water was used.

to speed up the melting of the ice / in order to melt a larger mass of ice / (concept of) balancing energy losses before and after the experiment 3

Why was dried, melting ice used?

to remove any <u>water</u>/<u>melted ice</u> // melted ice would have already gained latent heat //so that only ice is added // so that no water is added 3

melting ice is at 0 °C 4

Describe how the mass of the ice was found

final mass of calorimeter + contents minus mass of calorimeter + water (state/imply) 6

What should be the approximate room temperature to minimise experimental error?

20 ± 1.0 / midway between initial and final temperatures (of the water in the calorimeter) 6

Calculate:

(i) the energy lost by the calorimeter and the warm water;

{energy lost = } $(mc\Delta\theta)_{cal} + (mc\Delta\theta)_{warm\ water}$ 3

$= (0.0605)(390)(20.3) + (0.0583)(4200)(20.3)$ 3

$= 5449.6365$ / 5449.6 J 3

(–1 for omission of or incorrect units)

(ii) **the specific latent heat of fusion of ice.**

{energy gained by ice and by melted ice =}

$(ml)_{ice} + (mc\Delta\theta)_{melted\ ice}$ / $(0.0151)l + (0.0151)(4200)(10.2)$ / $0.0151\,l + 646.884$ 3

(equate:) $0.0151\,l + 646.884 = 5449.6365$ 3

$l = 3.181 \times 10^5 \approx 3.2 \times 10^5$ J kg^{-1} 3

(–1 for omission of or incorrect units)

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

Question 3

In an experiment to measure the wavelength of monochromatic light, a diffraction pattern was produced using a diffraction grating with 500 lines per mm. The angle between the first order images was measured. This was repeated for the second and the third order images.

The table shows the recorded data.

Angle between first order images	Angle between second order images	Angle between third order images
34.2^o	71.6^o	121.6^o

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

spectrometer // screen / metre stick 3
(monochromatic) light source // laser 3
(diffraction) grating labelled 3
correct arrangement 3

Explain how the first order images were identified.

nearest on either side to brightest/central/straight through/ zero order image (state/imply) 3

Describe how the angle between the first order images was measured.

procedure l.h.s. (e.g. crosshair / focus on 1st order image left of central image and note reading) 3
repeat for 1st order image on r.h.s. 3
subtract 3

Laser method:

measure x between 1st order images (3)
measure D from screen to grating (3)
reference to tan / radian / correct protractor method (3)

Use the data to calculate the wavelength of the monochromatic light.

$n\lambda = d \sin\theta \quad / \quad n\lambda = \frac{dx}{D}$ 3

(n=1) $\lambda = \frac{\sin(17.1)}{5\times10^5(1)} = 5.8808\times10^{-7} \approx 5.88\times10^{-7}$ m 3

(n=2) $\lambda = \frac{\sin(35.8)}{5\times10^5(2)} = 5.8496\times10^{-7} \approx 5.85\times10^{-7}$ m 3

(n=3) $\lambda = \frac{\sin(60.8)}{5\times10^5(3)} = 5.8195\times10^{-7} \approx 5.82\times10^{-7}$ m 3

$\lambda_{average} = 5.85\times10^{-7}$ m / 585 nm [range: (585 ± 2) nm] 4

(–1 for omission of or incorrect units)

{For any one of the following errors in the calculation for λ:

value of 2θ used / average of given angles used / incorrect d

➔ award a maximum of (3 +3 +4)

Question 4

A student investigated the variation of the resistance R of a metallic conductor with its temperature θ.
The student recorded the following data.

$\theta/^{o}C$	20	30	40	50	60	70	80
R/Ω	4.6	4.9	5.1	5.4	5.6	5.9	6.1

Describe, with the aid of a labelled diagram, how the data was obtained.

metallic conductor in container of liquid 3

heat source indicated + thermometer 3

labelled ohmmeter connected to conductor 3

Draw a suitable graph to show the relationship between the resistance of the metal conductor and its temperature.

axes labelled correctly 3

plot points correctly **(–1 for each incorrect point)** 3

straight line 3

good distribution 3

Use your graph to

(i) **estimate the resistance of the metal conductor at a temperature of –20 ^{o}C;**

any reference to slope / equation y = mx + c / y-intercept (value) 6

$R = 3.621$ / 3.6 (ohm) [range: $(3.6 \pm 0.1)\Omega$] 6

(for correct value from extrapolated graph, award full marks (6+6):

for estimate from table, award maximum of 6 marks)

(ii) **estimate the change in resistance for a temperature increase of 80 ^{o}C;**

for proper use of graph, (e.g. y-intercept value $\approx 4.12\ \Omega$)

$\Delta R = 1.979$ / 2 (ohm) [range: (2.0 ± 0.1)] 6

(estimate from table, maximum of 3 marks)

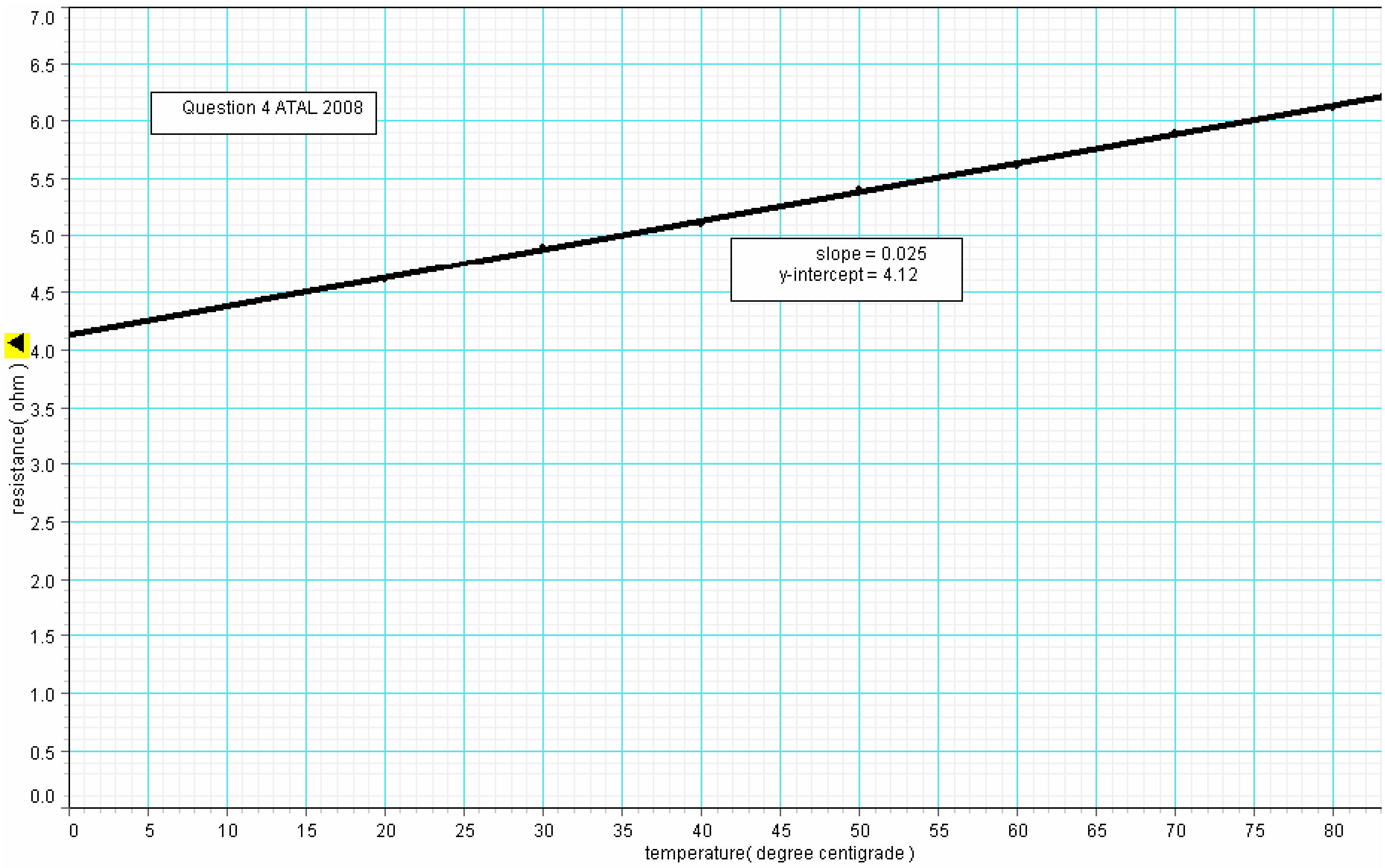
(iii) **explain why the relationship between the resistance of a metallic conductor and its temperature is linear.**

a (straight) line is obtained / any reference to $y = mx + c$ / any reference to microscopic model re molecular structure, etc. / e.g. 'linear over a narrow range of temperature' / e.g. 'linear at low temperatures' /any correct relevant answer 1

For '*non-linear*' statement:

(iii) explain why the relationship between the resistance of a metallic conductor and its temperature is not linear.

linear only for a narrow range of temperature / behaves as a superconductor at low T / R is non-linear at high T / plotted points form a curve / any correct relevant answer (1)


Question 4 ATAL 2008
slope = 0.025
y-intercept = 4.12
resistance(ohm)
temperature(degree centigrade)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

SECTION B (280 marks)

Answer **five** questions from this section. Each question carries 56 marks.

Question 5

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

(*a*) **State the law of flotation.**

(when a body floats,) its weight equals — 4

the weight of fluid/liquid/water displaced **(–1 if 'weight' term not used)** — 3

(*b*) **The head of a thumbtack has an area of 500 mm^2. Its point has an area of 0.3 mm^2. The pressure exerted at the head of the thumbtack is 12 Pa. What is the pressure exerted at the point of the thumbtack?**

(at head:) $F = P \times A$ / $F = 12(500 \times 10^{-6})$ / $F = 6.0 \times 10^{-3}$ (N) — 4

(at point:) $P = \frac{12(500\times10^{-6})}{(0.3\times10^{-6})}$ / 2.0×10^4 Pa (no penalty for units) — 3

(*c*) **What is the relationship between the frequency of a vibrating stretched string and its length?**

(they are) inversely / indirectly // $f \propto$ — 4

proportional // $\frac{1}{l}$ — 3

(*d*) **Why does diffraction not occur when light passes through a window?**

width of window / gap — 4

is too large — 3

["window is too wide (relative to wavelength of light)", 7 marks] state/imply

(*e*) **Why is a fluorescent tube an efficient source of light?**

(a relatively) <u>high percentage</u>/<u>most</u> of the (electrical) energy is converted to — 4

light (energy) state/imply — 3

(*f*) **What is the force exerted on an electron when it is in an electric field of strength 5 N C^{-1}?**

$F = E q$ — 4

$F = 5(1.6 \times 10^{-19})$ // $F = 8.0 \times 10^{-19}$ N (no penalty for units) — 3

(*g*) **What are the charge carriers when an electric current (i) passes through a semiconductor; (ii) passes through an electrolyte?**

(i) electrons and (positive) holes — 4

(ii) ions — 3

(*h*) **Give two ways of deflecting a beam of electrons.**

(by means of) <u>an electric field</u> and <u>a magnetic field</u> (any order) 4+3

(*i*) **Name an instrument used to detect radioactivity.**
What is the principle of operation of this instrument?

GM-tube // <u>Cloud</u>/<u>ionisation</u> chamber // solid state detector — 4

ionization // condensation/ cloud formation/ionization // (formation) of ion-pairs — 3

(*j*) **The existence of the neutrino was proposed in 1930 but it was not detected until 1956. Give two reasons why it is difficult to detect a neutrino.**

uncharged /very small (mass) /zero mass / interact weakly with matter (any two) 4+3

or

Draw a diagram to show how a galvanometer can be converted into a voltmeter.

galvanometer (symbol/sketch) in series with — 4

(large valued) resistor/multiplier — 3

(charge on electron = 1.6×10^{-19} C)

Question 6

State Newton's law of universal gravitation.

force proportional to product of masses // correct relationship for F, masses and d 3

inversely proportional to square of distance // correct notation (-1 for each one omitted) 3

The international space station (ISS) moves in a circular orbit around the equator at a height of 400 km.

What type of force is required to keep the ISS in orbit?

centripetal (force) / gravitational (force) 3

What is the direction of this force?

towards the centre (of the orbit) / inwards / towards the earth 3

Calculate the acceleration due to gravity at a point 400 km above the surface of the earth.

$GM = gR^2$ // $g \propto \frac{1}{R^2}$ 5

3

$g_1 = \frac{GM}{R^2}$ // $\frac{g_1}{g} = \frac{R^2}{R_1^2}$

$g_1 = 8.564 \approx 8.6 \text{ m s}^{-2}$ // $g_1 = 8.6898 \approx 8.7 \text{ m s}^{-2}$ (not awarded if h omitted) 3

(–1 for omission of or incorrect units)

An astronaut in the ISS appears weightless. Explain why.

any correct relevant answer, e.g. he/she is in a state of free-fall; there is no contact force; force of gravity is the only force acting; force of gravity cannot be felt; etc. 3

Derive the relationship between the period of the ISS, the radius of its orbit and the mass of the earth.

$\frac{GMm}{R^2} = \frac{mv^2}{R}$	$T = \frac{2\pi}{\omega}$	$T = \frac{2\pi R}{v}$	3
$GM = v^2 R$	$T^2 = \frac{4\pi^2}{\omega^2}$	$T^2 = \frac{4\pi^2 R^2}{v^2}$	3
$T = \frac{2\pi R}{v}$	$\omega^2 R^3 = GM$	$v^2 R = GM$	3
$T^2 = \frac{4\pi^2 R^3}{GM}$	$T^2 = \frac{4\pi^2 R^3}{GM}$	$T^2 = \frac{4\pi^2 R^3}{GM}$	3

Calculate the period of an orbit of the ISS.

$T^2 = \frac{4\pi^2 (6.8\times10^6)^3}{(6.6\times10^{-11})(6.0\times10^{24})}$ / 3.1347×10^7 (not awarded if h omitted) 3

$T = 5.599\times10^3$ s / 93.31 min / 1.56 h **(–1 for omission of or incorrect units)** 3

After an orbit, the ISS will be above a different point on the earth's surface. Explain why.

ISS has a different period to that of the earth's rotation / not in geostationary orbit /etc. any one 6

How many times does an astronaut on the ISS see the sun rise in a 24 hour period?

(24 ÷ 1.56 + 1) / 16 (sunrises) / 15 (sunrises) 6

(gravitational constant = 6.6×10^{-11} N m^2 kg^{-2};
mass of the earth = 6.0×10^{24} kg; radius of the earth = 6.4×10^6 m)

Question 7.

Define resistivity and give its unit of measurement.

resistance of cube of material // $\rho = \frac{RA}{l}$ 3

of side 1 m // correct notation **(–1 for each one omitted)** 3

unit: ohm metre / Ω m 3

An electric toaster heats bread by convection and radiation. What is the difference between convection and radiation as a means of heat transfer?

convection requires a medium, radiation does not (or correct reference to vacuum) / movement of medium in convection, no movement of medium with radiation, etc. any correct comparison 4 + 4

A toaster has a power rating of 1050 W when it is connected to the mains supply. Its heating coil is made of nichrome and it has a resistance of 12 Ω. The coil is 40 m long and it has a circular cross-section of diameter 2.2 mm.

Calculate:
(i) the resistivity of nichrome;

$\rho = \frac{RA}{l}$ (–1 if diameter used instead of radius) 3

$= \frac{12 \times \pi \left(1.1 \times 10^{-3}\right)^2}{40}$ 3

$\rho = 1.1404 \times 10^{-6}$ / 1.14×10^{-6} Ω m 3

(–1 for omission of or incorrect units)

(ii) the heat generated by the toaster in 2 minutes if it has an efficiency of 96%.

heat generated = power × time	any relevant formula		3
$H = 1050 \times 120$ / 1.26×10^5	substitution	(–1 if minutes used instead of seconds)	3
96% ➔ 1.21×10^5 J	answer		3

(-1 for omission of or incorrect units)

The toaster has exposed metal parts. How is the risk of electrocution minimised?

(metal parts are) earthed / reference to RCD / reference to (double) insulation / etc. 9

(award 6 marks for any relevant safety feature)

When the toaster is on, the coil emits red light. Explain, in terms of movement of electrons, why light is emitted when a metal is heated.

electrons <u>excited</u>/<u>gain energy</u> 3
jump to higher energy state 3
return to lower state 3
emit <u>energy</u> / <u>emr</u> /<u>i.r</u> / <u>light</u> / <u>photon</u> 3

[(4 × 3) marks awarded for appropriate diagram]

Question 8

What is electromagnetic induction?

<u>conductor</u> / <u>wire</u> /<u>coil</u> / <u>loop</u> cuts magnetic flux 3

<u>emf</u> / <u>voltage</u> induced 3

State the laws of electromagnetic induction.

(magnitude of the) induced emf is proportional to // $E \propto / = \frac{d\phi}{dt}$ 3

rate of cutting flux // notation **(–1 per missing item)** 3

induced <u>current</u> /<u>emf</u> in such a direction 3

as to oppose the change that causes it 3

[If laws given as: $E = -N\frac{d\phi}{dt}$ + notation award a maximum of (3×3) marks]

A bar magnet is attached to a string and allowed to swing as shown in the diagram. A copper sheet is then placed underneath the magnet. Explain why the amplitude of the swings decreases rapidly.

induced <u>voltage</u>/<u>emf</u> in copper 3

current flows (in copper sheet) 3

(generating a) magnetic field 3

opposing motion of magnet 3

(‘damping occurs’ or ‘motion is damped’ …. 2 × 3)

What is the main energy conversion that takes place as the magnet slows down?

kinetic/potential (energy) ➔ heat /electrical (energy) 6

(award 3 marks for any relevant conversion)

A metal loop of wire in the shape of a square of side 5 cm enters a magnetic field of flux density 8 T. The loop is perpendicular to the field and is travelling at a speed of 5 m s^{-1}.

(i) **How long does it take the loop to completely enter the field?**

$t = \frac{5\,\text{cm}}{500\,\text{cm}\,\text{s}^{-1}}$ 3

$t = 0.01$ s 3

(–1 for omission of or incorrect units)

(ii) **What is the magnetic flux cutting the loop when it is completely in the magnetic field?**

$\phi = B\,A$ 4

$\phi = (8)(0.05 \times 0.05)$ / 0.02 weber 3

(–1 for omission of or incorrect units)

(iii) **What is the average emf induced in the loop as it enters the magnetic field?**

$\text{average emf} = \frac{\Delta\phi}{\Delta t}$ (state/imply) 4

$\text{emf} = \frac{0.02}{0.01}$ / 2 volt 3

(–1 for omission of or incorrect units)

Question 9

What is meant by refraction of light?

bending of light 3

going from one medium to another (of different refractive index) 3

(appropriate diagram showing light ray passing through two different media .. 2 × 3)

State Snell's law of refraction.

the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant 6

$\sin i \propto \sin r$ / $\frac{\sin i}{\sin r} = \text{constant}(n)$ (3)

notation (3)

An eye contains a lens system and a retina, which is 2.0 cm from the lens system. The lens system consists of the cornea, which acts as a fixed lens of power 38 m^{-1}, and a variable internal lens just behind the cornea. The maximum power of the eye is 64 m^{-1}. Calculate:

(i) how near an object can be placed in front of the eye and still be in focus;

(ii) the maximum power of the internal lens.

(i) $P_{max:} = (64\ \text{m}^{-1} =)\ \frac{1}{f}$ 3

$f = 0.0156$ m $= 1.56$ cm 3

(For lens system:) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ / $\frac{1}{u} + \frac{1}{2} = \frac{1}{1.56}$ 3

(Object distance:) $u = 7.14\,\text{cm}$ 3

(–1 for omission of or incorrect units)

(ii) $P_{\max} = P_1 + P_2$ / $64 = 38 + P_2$ / $P_2 = 26\ (\text{m}^{-1})$ 3

Light is refracted as it enters the cornea from air as shown in the diagram. Calculate the refractive index of the cornea.

$n = \frac{\sin i}{\sin r}$ / $\frac{\sin 37}{\sin 27}$ 3

$n = 1.3256$ / 1.33 3

Draw a diagram to show the path of a ray of light as it passes from water of refractive index 1.33 into the cornea.

line representing interface between two media 3

straight line (accept a *slight* refraction) representing the light ray through the two media 3

A swimmer cannot see properly when she opens her eyes underwater. When underwater:

(i) why does the cornea not act as a lens?

light not refracted at cornea (state/imply) 3

water and cornea have the same n value 3

(ii) what is the maximum power of the eye?

26 (m^{-1}) / maximum power of the internal lens 3

(iii) why do objects appear blurred?

internal lens not powerful enough to focus light on retina / eye is long-sighted

/ light not brought to a focus (on the retina) 3

(iv) explain how wearing goggles allows objects to be seen clearly.

light refracted on passing from air to cornea 3

cornea (now) acts as a lens (state/imply) 2

Question 10

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

(*a*) Baryons and mesons are made up of quarks and experience the four fundamental forces of nature. List the four fundamental forces and state the range of each one.

strong (nuclear)	--- short (range) (10^{-15} m)	1+1
weak (nuclear)	--- short (range) (10^{-18} m)	1+1
gravitational	--- infinite (range) / $\propto \frac{1}{d^2}$	1+1
electromagnetic	--- infinite (range) / $\propto \frac{1}{d^2}$	1+1

Name the three positively charged quarks.

up, top, charm / u, t, c 2+2+2

What is the difference in the quark composition of a baryon and a meson?

(baryon): three quarks 3

(meson): one quark and one antiquark 3

What is the quark composition of the proton?

up, up, down **(–1 per incorrect item)** 3

In a circular accelerator, two protons, each with a kinetic energy of 1 GeV, travelling in opposite directions, collide. After the collision two protons and three pions are emitted.

What is the net charge of the three pions? Justify your answer.

zero 6

(electric) charge is conserved 3

Calculate:

(i) the combined kinetic energy of the particles after the collision;

(energy equivalent of a pion:) $E = mc^2$ 3

$E = (2.4842\times10^{-28})(2.9979\times10^{8})^2$ 3

$E = 2.2327\times10^{-11}$ J 3

$E = 1.3935\times10^{8}$ eV 3

(for 3 pions :) $E = 6.6980\times10^{-11}$ J / 4.18047×10^{8} eV 3

energy after collision $= (2\times10^{9}) - (4.18047\times10^{8})$ / 1.58195×10^{9} eV / 2.535×10^{-10} J 3

(–1 for omission of or incorrect units)

(ii) the maximum number of pions that could have been created during the collision.

$\text{number of pions} = \frac{1.581953\times10^{9}}{1.3935\times10^{8}}$ / $11.3524 \Rightarrow 11$ pions 3

$\Rightarrow$ maximum number of pions $= 3 + 11$ / 14 pions 3

(charge on electron = 1.6022×10^{-19} C; mass of proton = 1.6726×10^{-27} kg;
mass of pion = 2.4842×10^{-28} kg; speed of light = 2.9979×10^{8} m s^{-1})

(*b*) The transistor was one of the most important inventions of the twentieth century.
Draw the basic structure of a bi-polar transistor.

three layers 3

three labelled e, b, c 3

Name the three currents flowing in a transistor

emitter, base, and collector currents / I_e , I_b , I_c 3

State the relationship between them.

$I_e = I_c + I_b$ 6

The diagram shows the circuit of a voltage amplifier. What is the purpose of:

(i) the bias resistor;

to keep the base-emitter junction forward biased (at all times) / to set a suitable base voltage (V_b) state/imply 6

(ii) the load resistor?

converts large changes in I_c to large changes in the voltage across it 6

[$V = I_c R$ .. award 3 marks]

A varying voltage is applied to the amplifier. Draw a sketch of the input and output voltages, using the same axes and scales.

'alternating' graph of input and output (showing V varying with t) 3

output having larger amplitude 3

output inverted (180^0 phase difference) 3

A NOT gate is a voltage inverter. Draw a circuit diagram to show how a transistor can be used as a voltage inverter.

diagram showing:

R in series with transistor across battery 3

limiting/protective resistor at base 3

V_{in} indicated (across base/emitter) 3

V_{out} indicated (across collector/emitter) 3

Give the truth table of a NOT gate.

table with header 'input' and 'output' 4

completed table with two states correctly shown 4

Question 11

Read the following passage and answer the accompanying questions.

The Miracle Year: 1905

"There is nothing new to be discovered in physics now," Lord Kelvin reportedly said in 1900. He was wrong.

Isaac Newton had laid the foundations of classical physics in the late seventeenth century. He developed laws that described a mechanical universe: a falling apple and an orbiting moon governed by the same rules of gravity, mass, force and motion. In the mid-1800s, Newtonian mechanics was joined by another great advance. Michael Faraday discovered the properties of electric and magnetic fields.

James Clerk Maxwell subsequently showed how changing electric and magnetic fields united to form electromagnetic radiation.

Physics was upended in the early twentieth century by Albert Einstein. In 1905 he devised a revolutionary quantum theory of light to explain the photoelectric effect, helped prove the existence of atoms, united the concepts of space and time, and produced science's best-known equation.

(Adapted from "Einstein: His Life and Universe"; Isaacson; 2007)

(*a*) The SI unit is named in honour of Lord Kelvin. What is the temperature of the boiling point of water in kelvin?

373(.15 K) 7

(*b*) Define the newton, the unit of force.

(the force that) gives a mass of 1 kg // $F = m\ a$ 4

an acceleration of 1 m s^{-2} // F = 1 N when m = 1 kg and a = 1 m s^{-2} 3

(*c*) A force of 9 kN is applied to a golf ball by a golf club. The ball and club are in contact for 0.6 ms. Using Newton's laws of motion, calculate the change in momentum of the ball.

$F = \frac{mv - mu}{\Delta t}$ / $\frac{\Delta p}{\Delta t} = \frac{mv - mu}{\Delta t}$ / $\Delta p = F \times t$ 4

$\Delta p = (9 \times 10^3)(0.6 \times 10^{-3})$ / $5.4\,\text{kg m s}^{-1}$ / $5.4\,\text{N s}$ 3

(–1 for omission of or incorrect units)

(*d*) Name three different electromagnetic radiations.

first type (e.g. x-rays) 4

next two types (e.g. microwaves, ultra-violet) 3

(*e*) What is the photoelectric effect?

emission of electrons from <u>metal surface</u> 4

when <u>light</u> /<u>radiation</u> (of suitable frequency) falls on it 3

(*f*) Why was the quantum theory of light revolutionary?

light <u>travels in</u> /<u>consists of</u> packets of energy / photons / quanta // light has a particle nature (as well as a wave nature) // (the theory suggested) $E = h\,f$ / $E \propto f$ // in conflict with wave theory 7

(*g*) High-energy radiation of frequency 3.3 × 10^{14} Hz is used in medicine. What is the energy of a photon of this radiation?

$E = h\,f$ 4

$E = (6.6 \times 10^{-34})(3.3 \times 10^{14})$ J / 2.178×10^{-19} J / 2.18×10^{-19} J 3

(–1 for omission of or incorrect units)

(*h*) 100 MJ of energy are released in a nuclear reaction. Calculate the loss of mass during the reaction.

$E = m\,c^2$ / $m = \frac{E}{c^2}$ 4

$m = \frac{1 \times 10^8}{9 \times 10^{16}}$ / 1.11×10^{-9} kg 3

(–1 for omission of or incorrect units)

Question 12

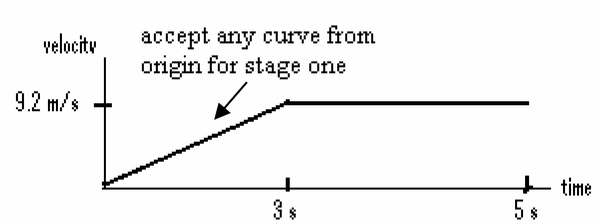
Answer any **two** of the following parts (*a*), (*b*), (*c*), (*d*).

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

energy cannot be created // total energy of an isolated system / sum of K.E + P.E — 2

nor destroyed // remains constant — 2

In a pole-vaulting competition an athlete, whose centre of gravity is 1.1 m above the ground, sprints from rest and reaches a maximum velocity of 9.2 m s^{-1} after 3.0 seconds. He maintains this velocity for 2.0 seconds before jumping. Draw a velocity-time graph to illustrate the athlete's horizontal motion.



both axes labelled — 3

two stages shown on graph — 3

Use your graph to calculate the distance travelled by the athlete before jumping.

distance (s) = area under curve // any one correct 'equation of motion' — 3

$s = \frac{1}{2}(3)(9.2) + 2(9.2)$ / $13.8 + 18.4$ / $32.2\,\text{m}$ // 32.2 m — 3

(–1 for omission of or incorrect units)

What is the maximum height above the ground that the athlete can raise his centre of gravity?

K.E. converted to P.E. (state/imply) // $|v_i| = |u_j|$ state/imply — 3

$h_{\max} = \frac{\frac{1}{2}v^2}{g}$ // $v^2 = u^2 + 2as$ — 3

$h_{\max} = \frac{\frac{1}{2}(9.2)^2}{9.8}$ // $0 = (9.2)^2 + 2(-9.8)s$ — 3

$(h_{\max} = 4.32\,\text{m}) \quad \Rightarrow \text{max.height} = 4.32 + 1.1 = 5.42\,\text{m}$ — 3

(–1 only, if final answer given as 4.32 m)

(*b*) The pitch of a musical note depends on its frequency. On what does (i) the quality, (ii) the loudness, of a musical note depend?

(i) (number or relative strengths of) <u>overtones</u> /<u>harmonics</u> // wave form — 3

(ii) amplitude / frequency/ λ / intensity / rate at which (acoustic) energy enters ear — 3

What is the Doppler effect?

(apparent) change in frequency — 3

due to *relative motion* (stated or implied) between source and observer — 3

A rally car travelling at 55 m s^{-1} approaches a stationary observer. As the car passes, its engine is emitting a note with a pitch of 1520 Hz. What is the change in pitch observed as the car moves away?

$f' = \frac{f\,v_a}{v_a \pm v}$ (accept + or – format) — 3

$f' = \frac{1520(340)}{340+55}$	$f'_{in} = \frac{340 \times 1520}{340-55} = 1813.33\,\text{Hz}$ — 3
$f' = 1308.35$	$f'_{out} = 1308.35\,\text{Hz}$ — 3
$\Delta f = 211.65\,\text{Hz}$	$\Delta f = 504.98 \approx 505\,\text{Hz}$ — 3

(-1 for omission of or incorrect units)

Give an application of the Doppler effect.

calculate speeds of stars or galaxies / reference to red (or blue) shift / radar / speed traps / etc. — 4

(*c*) In 1939 Lise Meitner discovered that the uranium isotope U–238 undergoes fission when struck by a slow neutron. Barium–139 and krypton–97 nuclei are emitted along with three neutrons. Write a nuclear reaction to represent the reaction.

$^{238}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{56}Ba + ^{97}_{36}Kr + 3\ ^{1}_{0}n$ **(-1 mark per each incorrect/omitted item)** 4×3

In a nuclear fission reactor, neutrons are slowed down after being emitted. Why are the neutrons slowed down?

(only) slow neutrons cause fission / to prevent (radiative) capture 6

How are they slowed down?

(they collide with) <u>heavy water</u> / <u>a moderator</u> / <u>graphite</u> 3

Fission reactors are being suggested as a partial solution to Ireland's energy needs. Give one positive and one negative environmental impact of fission reactors.

positive: no CO_2 emissions / no greenhouse gases / no gases to result in acid rain / less dependence on fossil fuels / etc.

negative: radioactive waste / (potential for) major accidents / etc.

(any order) 4+3

(*d*) Define capacitance.

(ratio of)charge // $C = \frac{Q}{V}$ 3

<u>to</u>/<u>over</u> potential / per unit voltage // correct notation 3

(–1 per incorrect/omitted item)

Describe how an electroscope can be charged by induction.

charged object adjacent to electroscope 4

earth electroscope (briefly) 3

remove charged object 3

(award full credit for a correct sequence of diagrams: award a maximum of 4 marks if 'conduction' is used)

How would you demonstrate that the capacitance of a parallel plate capacitor depends on the distance between its plates?

arrangement: connect digital multimeter with capacitance setting (state/imply) to plates 3

method: switch on meter (state/imply) 3

(slowly)separate plates 3

observation: capacitance (reading) is lowered 3

<u>Alternative method:</u>

arrangement: connect electroscope correctly to parallel plate capacitor (3)

method: (earth one plate and) place a charge on the other (using a h.t. power supply) (3)

(slowly) separate plates (3)

observation: leaves diverge indicating (voltage increasing) capacitance is lowered (3)