Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE 2011

MARKING SCHEME

PHYSICS

ORDINARY LEVEL

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. Marks shown in brackets represent marks awarded for partial answers as indicated in the scheme.

3. Words, expressions or statements separated by a solidus, /, are alternatives which are equally acceptable.

4. 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.

5. The descriptions, methods and definitions in the scheme are **not** exhaustive and alternative valid answers are acceptable. Marks for a description may be obtained from a relevant diagram, depending on the context.

6. Where indicated, 1 mark is deducted for incorrect/ no units.

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

8. The context and the manner in which the question is asked and the number of marks assigned to the answer in the examination paper, determine the detail required in any question. Therefore, in any instance, it may vary from year to year.

Section A (120 marks)

Three questions to be answered.

Question 1 40 marks

The following is an extract from a student's report of an experiment to verify the principle of conservation of momentum.

"I arranged the apparatus. I then measured the mass of each trolley. During the experiment I took further measurements to determine the velocities of the trolleys. I used my measurements to verify the principle of conservation of momentum".

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

labelled diagram to show:

2 trolleys / 2 riders
runway / air-track
timer: photo- gates (and timer)// tickertape (and timer) /other valid variation
detail e.g. means of measuring mass/ distance

three lines correct 3 × 3
two lines correct (2 × 3)
one line correct (3)

means of measuring velocity e.g. motion sensor / data logger (2 × 3)

NOTE: no labels, deduct 2
valid alternatives e.g. data logging methods, which fit the scheme

(ii) How did the student measure the mass of a trolley? **6 or 3**

used (electronic) balance / (weighing) scales / weighed them 6
partial answer e.g. mentions spiral spring, scales (3)

(iii) How did the student determine the velocity of a moving trolley? **4 × 3**

$(\text{velocity} =)\frac{\text{distance}}{\text{time}}$ / $\frac{s}{t}$ 4 × 3

measure distance, time or divide stated or implied (2 × 3)
partial answer e.g. measure time, measure distance, using the equation, detail (3)

reference to a motion sensor / data logger would merit at least 2×3

(iv) How was the momentum of a trolley determined? **6 or 3**

mv 6
partial answer e.g. using the equation /*m* / *v* (3)

(v) How did the student verify the principle of conservation of momentum? **7 or 4**

(upon repeating the experiment a number of times) the value for momentum before and after was always the same (within the limits of the experimental error) // $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ / $m_1 u = (m_1 + m_2)v$ 7
partial answer (4)

Question 2 40 marks

During an experiment to measure the specific latent heat of vaporisation of water, cold water was placed in an insulated copper calorimeter. Dry steam was passed into the water causing a rise in temperature of the water and the calorimeter. The following data was recorded.

Mass of calorimeter	= 73.40 g
Mass of cold water	= 67.50 g
Initial temperature of water + cal.	=10 °C
Temperature of steam	=100 °C
Mass of steam added	=1.03g
Final temperature of water + cal.	=19 °C

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

labelled diagram to show:

calorimeter (containing water)
thermometer (in water) / temperature sensor
steam source
detail e.g. insulation, steam delivery tube, stirrer, etc.

three lines correct 3 × 3

NOTE: no labels, deduct 2

(ii) What was the rise in temperature of the water in the experiment? **6 or 3**

(19 −10 =) 9 (°C) 6

partial answer e.g. 29 (3)

(iii) Describe how the mass of the cold water was found. **7 or 4**

(mass of calorimeter and cold water) − (mass of calorimeter) 7

partial answer e.g. subtract (4)

(iv) How was the steam dried? **6 or 3**

steam trap / delivery tube sloping up 6

partial answer (3)

(v) Calculate:

(a) the heat gained by the water and the calorimeter **6 or 3**

2797 (J) 6

($m_w\, c_w\, \Delta\theta_w$ / (0.0675)(4180)(9) /) 2539.4 (J) (3)

($m_c\, c_c\, \Delta\theta_c$ / (0.0734)(390)(9) /) 257.6 (J) (3)

(b) the heat lost by the condensed steam **3**

($m_{cs}\, c_w\, \Delta\theta_{cs}$ = (0.00103)(4180)(81) =) 348.7 (J) 3

(c) the latent heat of vaporisation of water **3**

($1.03\times10^{-3}\, l_v$ = 2797 − 348.7 =) 2448 (J) 3

l_v = 2.37×10^6 (J kg^{-1}) (3)

Question 3 40 marks

You carried out an experiment to measure the speed of sound in air by measuring the frequency and wavelength of a sound wave.

(i) Draw a labelled diagram of the apparatus that you used. **3 × 3**

labelled diagram to show:

frequency source e.g. tuning fork / signal generator
tube, resonance, interference
detail e.g. means of altering length

three lines correct 3 × 3

NOTE: no labels, deduct 2
valid alternatives

(ii) How did you find the frequency of the sound wave? **6 or 3**

(read it) from the tuning fork / signal generator // used tuning forks of known frequency 6

partial answer (3)

(iii) How was the wavelength of the sound wave measured? **3 × 3**

equation $\lambda = 4(l + (0.3d))$ // $\lambda = 2(l_2 - l_1)$ 3 × 3

measure length (of vibrating air at resonance) and diameter //
measure length one (of vibrating air at resonance) and length two // resonance (2 × 3)

partial answer e.g. measure length/diameter of tube (3)

measurements may be inferred from the diagram

valid alternatives
marks may be obtained from a diagram

(iv) How did you use the measurements to calculate the speed of the sound wave? **4 × 3**

$c=f\lambda$ // $c = 4f(l+(0.3d))$ // $c = 2f(l_2 - l_1)$ 4 × 3

substituted frequency and wavelength (into the) formula (3 × 3)

partial answer (3)

(v) Why should you repeat the experiment? **4 or 2**

greater accuracy 4

partial answer e.g. get an average, to get a better answer (2)

Question 4 **40 marks**

The diagram shows a circuit used to investigate the variation of current with potential difference for a filament lamp.

(i) Name the instrument X. What does it measure? **4 or 2**

voltmeter/multimeter measures voltage 4

voltmeter / voltage // answer consistent with named apparatus (2)

(ii) Name the component Y. What does it do? **2 × 3**

rheostat / (variable) resistor / potential divider / potentiometer 3

change in one of: resistance, voltage, potential, current, power, /
answer consistent with named apparatus 3

Y is a resistor and limits the current (2 × 3)

(iii) Draw a graph, on graph paper, of the current against the potential difference. **4 × 3**

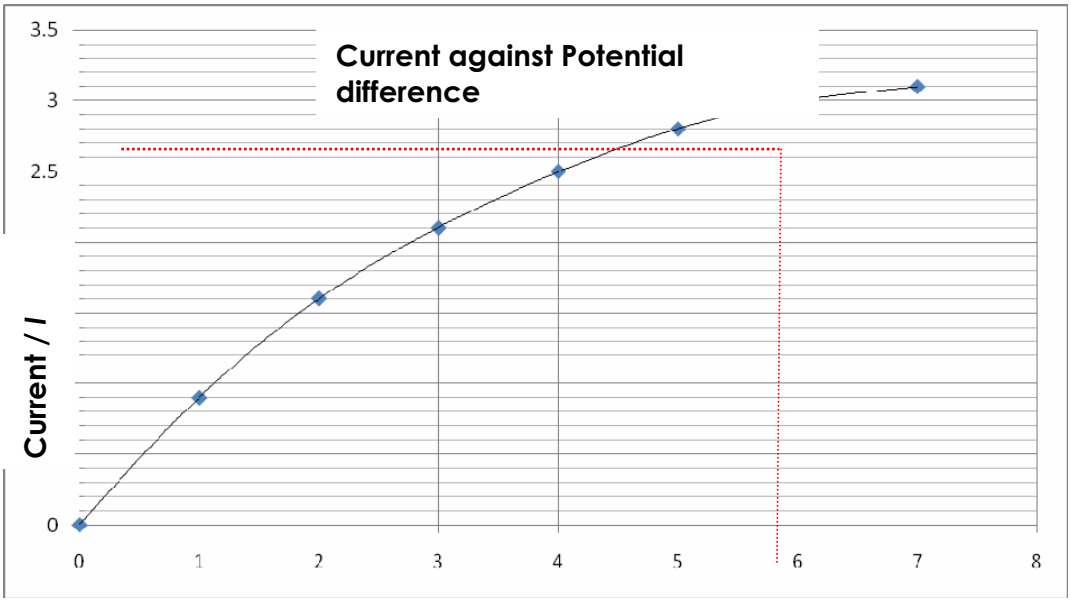
label one axis correctly- name/symbol/unit acceptable 3

plot four points correctly 3

plot another three points correctly 3

plot (smooth) curve 3

if graph paper is not used maximum mark 3×3



(iv) What does your graph tell you about the variation of current with the potential difference for a filament lamp? **9 or 6 or 3**

current rises with voltage (rise) // non linear / not proportional // non ohmic 9

incomplete answer consistent with graph e.g. linear initially (6)

partial answer e.g. they are related by a curve, refers to Ohm's law (3)

(v) Using your graph, calculate the resistance of the lamp when the potential difference across the lamp is 5.5 V **3 × 3**

($R = 5.5 \div 2.9 =$) 1.9 ± 0.2 (Ω) 3 × 3

$R = \frac{V}{I} =$ // $I = 2.9$ (A) (2 × 3)

partial answer e.g. $V = I\,R$, evidence of using the graph (3)

SECTION B (280 Marks)

Five questions to be answered

Question 5 56 marks any *eight* parts Take the best 8 from 10 parts.

(*a*) What is friction? **7 or 4**

force that resists motion // force between two bodies in contact // example 7

partial answer (4)

(*b*) What is the relationship between *G*, the gravitational constant and *g*, the acceleration due to gravity? **7 or 4**

$$g = \frac{G M}{R^2}$$ 7

partial answer (4)

(*c*) A crowbar is an example of a lever; give another example of a lever. **7 or 4**

any other lever e.g. door handle, scissors, wheelbarrow, tongs etc

one correct 7

partial answer e.g. metre stick (4)

(*d*) Which one of the following terms is associated with wave motion? **7**

half-life interference induction doping 7

(*e*) Name the three ways by which heat can travel from one place to another. **7 or 4**

conduction, convection, radiation three correct 7

partial answer e.g. metal one correct (4)

(*f*) Give two uses of a concave mirror. **7 or 6 or 4**

headlights, makeup, shaving mirrors, etc. two correct 7

one correct (6)

partial answer e.g. two uses for a lens (4)

(*g*) What is the colour of the earth cable in a standard 3-pin plug? **7 or 4**

yellow & green 7

partial answer e.g. yellow, green, correct colour of other cable (4)

(*h*) How does a miniature circuit breaker (MCB) improve safety in a domestic circuit? **7 or 4**

prevent too high current flowing // turns off current 7

partial answer e.g. incomplete answer (4)

(*i*) Give a use for an electroscope **7 or 4**

test for charge, identify charge, measure potential, etc

one correct 7

partial answer (4)

(*j*) Give a disadvantage of a named renewable source of energy? **7 or 4**

biomass/ tide /sun / wind is not always there 7

valid alternatives

partial answer e.g. named source (4)

Question 6 56 marks

State Newton's first law of motion. **6 or 3**

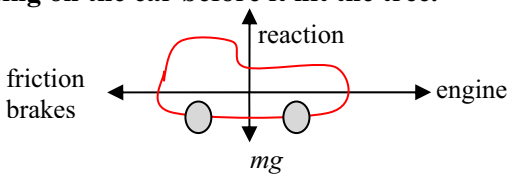
A body will remain at rest or moving at a constant velocity unless acted on by an (external) force 6

partial answer e.g. incomplete answer, Newton's 2nd or 3rd law (3)

A car of mass 1400 kg was travelling with a constant speed of 15 m s^{-1} when it struck a tree and came to a complete stop in 0.4 s.

(i) Draw a diagram of the forces acting on the car before it hit the tree. **3 × 3**

diagram to show
gravity /weight
friction
(normal) reaction
engine (force)
air resistance
brakes



three named forces and directions correct 3 × 3

each force merits 2 marks each direction merits 1 mark

(ii) Calculate the acceleration of the car during the collision. **3 × 3**

($a = \frac{v-u}{t} = \frac{0-15}{0.4} =$ −) 37.5 (m s^{-2}) 3 × 3

$a = \frac{v-u}{t}$ // $\frac{0.4}{15}$ / 0.0266 (2× 3)

partial answer e.g. $v = u + at$ (3)

(iii) Calculate the net force acting on the car during the collision. **6 or 3**

(F=1400 × 37.5 =) 52500 (N) // answer consistent with (ii) 6

partial answer e.g. $F = ma$ (3)

(iv) Calculate the kinetic energy of the moving car before it struck the tree. **2 × 3**

(E = 0.5 × 1 400 × 15^2 =) 157500 (J)) 2 × 3

partial answer e.g. E = ½ m v^2 (3)

(v) What happened to the kinetic energy of the moving car? **3 × 3**

converted to heat
converted to sound
converted to potential energy
used to deform car / tree

two lines correct 3 × 3

one line correct (2 × 3)

partial answer (3)

(vi) A back seat passenger could injure other occupants during a collision. Explain, with reference to Newton's laws of motion, how this could occur. How is this risk of injury minimised? **4 or 2 + 7**

states or implies use of Newton's law(s) in explanation 4

partial answer (2)

by wearing a seat belt. 7

Question 7 56 marks

(i) Explain the underlined terms. **2×(6 or 3)**

reflection is the bouncing of a wave off an obstacle / mirror // correct diagram	6
partial answer e.g. light reflects off a mirror	(3)
refraction is the bending of a wave when it enters a different substance // correct diagram	6
partial answer	(3)
reversed explanations	(6)

(ii) Give a practical application of the reflection of light. **3**

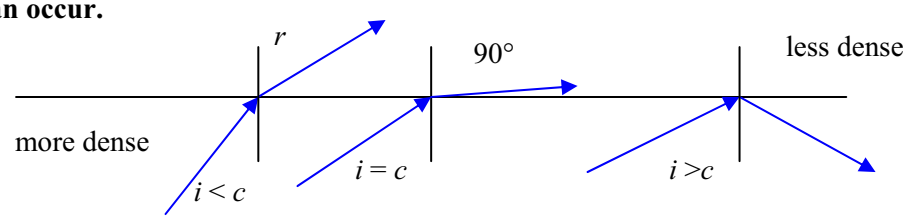
mirrors / optic fibres / binoculars, etc	3

(iii) State the laws of reflection of light? **9 or 6 or 3**

angle of incidence is equal to the angle of reflection
incident ray, the normal, and the reflected ray are coplanar

two lines correct	9
one line correct	(6)
partial answer	(3)

(iv) Explain, with the aid of a diagram how total internal reflection can occur. **9 or 6 or 3**

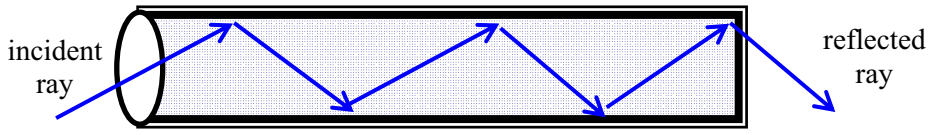


correct diagram and explanation	9
middle diagram // right hand diagram // correct explanation without diagram	(6)
partial answer e.g. left hand diagram	(3)

(v) What is meant by the 'critical angle' in total internal reflection? **6 or 3**

the angle of incidence above which total internal reflection occurs / the angle of incidence where the angle of refraction is 90º	6
partial answer e.g. angle in the more dense medium	(3)

(vi) Draw a diagram to show how light waves travel along an optical fibre. **9 or 6 or 3**



correct diagram to include fibre, indication of two media, multiple reflections	9
one omission	(6)
partial answer	(3)

(vii) Give two advantages of using optical fibres instead of copper wires when transmitting data. **5 or 3**

cheaper, can carry more signals, faster, less power consumption, etc

two correct	5
one correct	(3)

(viii) Optical fibres are also used in medicine. Give an example of their use in medicine **3**

endoscope / to look inside body /(keyhole) surgery , etc	3

Question 8 56 marks

(*a*) (i) What is meant by a thermometric property? **6 or 3**

a property that changes with temperature /heat (change) 6
partial answer (3)

(ii) Name two different thermometric properties. **6 or 5 or 3**

length of mercury column, colour, E, V, R , etc.
two correct 6
one correct (5)
partial answer e.g. mercury and alcohol (3)

(iii) Name two different thermometers **2 × 2**

mercury, alcohol, thermocouple/thermopile, pyrometer, resistance, constant volume gas, digital thermometer, etc.
two correct 2 × 2
one correct (2)

(iv) Describe how to calibrate a thermometer. **4 × 3**

apparatus: container of water, heat source, un-calibrated thermometer
calibrated thermometer, marker three pieces 2 × 3
one piece (3)
procedure: place the thermometers in water, heat to different temperatures 3
and mark / plot calibration curve 3
marks may be obtained from a diagram
valid alternatives

(v) Why is there a need for a standard thermometer? **6 or 3**

because different thermometric properties give different results //
thermometers respond differently // to ensure a consistent measure //
for calibration, etc. 6
partial answer e.g. accuracy (3)

(*b*) An electric kettle is filled with 500 g of water and is initially at a temperature of 15 °C. The kettle has a power rating of 2 kW.

(i) Calculate the energy required to raise the temperature of the water to 100 °C **3 × 3**

1.78×10^5(J) 3 × 3
substitutes at least 2 quantities correctly into the equation (2 × 3)
substitutes at least one quantity correctly into the equation (3)

(ii) How much energy is supplied by the kettle every second? **3**

2000 (J) 3

(iii) How long will it take the kettle to heat the water to 100 °C? **6 or 3**

89 (s) // answer consistent with (i) and (ii) 6
partial answer e.g. $E = P\,t$ (3)

(iv) Name a suitable material for the handle of the kettle. Justify your answer. **2 × 2**

plastic / wood 2
good insulators / will not burn hand 2

Question 9 56 marks

(*a*) State Faraday's law of electromagnetic induction. **3 × 3**

induced emf / E 3
is directly proportional to / $\propto$ 3
rate of change of magnetic flux / $\frac{d\varphi}{dt}$ 3
partial answer e.g. Lenz's law (3)

A coil of wire is connected as shown in the diagram to a sensitive ammeter.

(i) What is observed on the meter when the magnet is moved towards the coil? **6 or 3**

needle deflected / moves 6
partial answer (3)

(ii) What is observed on the meter when the magnet is stationary in the coil? **3**

no movement of needle 3

(iii) Explain these observations **3 × 3**

emf // when current 3
induced // flows / induced 3
when change in magnetic field // needle moves 3
partial answer (3)

(iv) How would changing the speed of the magnet affect the observations? **5 or 3**

more deflection if faster / less deflection if slower 5
partial answer e.g. incomplete answer (3)

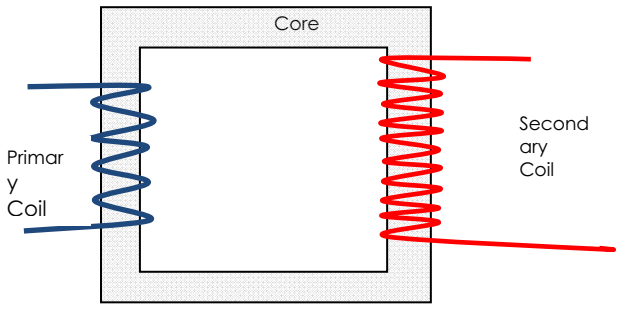
(*b*) Transformers can be used to step up or step down a.c. voltages.

(i) What is meant by a.c.? **2 × 3**

alternating 3
current 3
electric current that reverses/changes its direction (at regular intervals) (6)
partial answer (3)

(ii) Draw a labelled diagram showing the structure of a transformer. **3 × 3**

labelled diagram to show:



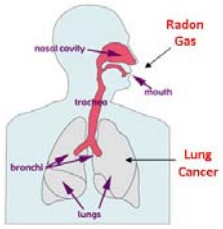
(primary) coil 3
(secondary) coil 3
(soft iron) core 3

NOTE: no labels, deduct 2

(iii) The input coil of a transformer has 200 turns of wire and is connected to a 230 V a.c. supply. What is the voltage across the output coil when it has 600 turns? **3 × 3**

690 (V) 3 × 3
substituted at least 2 quantities correctly into the equation (2 × 3)
partial e.g. $\frac{V_s}{V_p} = \frac{N_s}{N_p}$ (3)

Question 10 **56 marks**



Radon gas is a radioactive gas which emits alpha particles. Radon gas comes into houses through gaps in the floors. Exposure to radon gas can cause lung cancer.

(i) What is radioactivity? **2 × 3**

(the spontaneous) breakup of the nucleus /atom 3
(with the) emission of radiation/ α / β / γ / energy 3
partial answer (3)

(ii) Name the other two types of radiation emitted by radioactive sources **6 or 5 or 3**

beta / β, gamma / γ two correct 6
one correct (5)
partial answer e.g. electrons, em radiation (3)

(iii) Describe an experiment to distinguish between the three types of radiation. **4 × 3**

apparatus: radioactive source (in lead container), magnetic / electric field,
photographic (plate) any two 2 × 3
any one (3)
procedure: place the radioactive source in the electric/magnetic field 3
observation: note three different marks on the photographic plate 3

marks may be obtained from a diagram
valid alternatives

(iv) List three properties of any one of the radiations. **3 × 3**

	nature	**charge**	**ionising**	**range**	**mass**
α	He nucleus	+(2)	V good	Few cm in air	4 amu
β	Electron	-(1)	good	Few mm in Al	≈ 1/2000 amu
γ	em radiation	0	poor	Many cm in Pb	0

three properties correct for one radiation 3 × 3

The most stable isotope of radon has a half-life of 4 days.

(v) What are isotopes? **2 × 3**

atoms of the same elements / same number of protons 3
with different mass numbers / different number of neutrons 3
partial answer e.g. reference to neutrons (3)

(vi) Why is it important to prevent radon gas entering your home? **5 or 3**

because it causes (lung) cancer / causes disease 5
partial answer e.g. it is dangerous (3)

(vii) If no more radon gas entered your home, how long would it be until one eighth of the radon gas was left? **6 or 3**

12 (days) 6
partial answer e.g. implies 3 half-lives such as 64 days (3)

(viii) Give two uses of radioisotopes. **6 or 5 or 3**

medical, industrial, agriculture, smoke detectors, energy source, etc
two correct 6
one correct (5)
partial answer (3)

Question 11 56 marks

Read this passage and answer the questions below

Einstein explained the photoelectric effect by using Plank's quantum theory ($E=hf$). The German physicist Heinrich Hertz in 1887 was the first to discover that when light shines on certain metals, they emit electrons. Metals have the property that some of their electrons are only loosely bound within atoms which is why they are such good conductors of electricity. When light strikes a metallic surface it transfers its energy to the metal, in the same way as when light shines on your skin, causing you to feel warmer. This transfer of energy from the light can agitate electrons in the metal, and some of the loosely bound electrons can be knocked off the surface of the metal.

But the strange features of the photoelectric effect become apparent when one studies the more detailed properties of the released electrons. As the intensity of the light - its brightness - is increased the number of released electrons will also increase, but their speed stays the same. On the other hand the speed of the released electrons will increase if the frequency of the light shining on the metal is increased.

(Adapted from '*Elegant Universe' by Brian Greene, Vintage 2000*)

(*a*) Who discovered the photoelectric effect? **7**
Hertz 7

(*b*) Who explained the photoelectric effect? **7 or 4**
Einstein 7
partial answer (4)

(*c*) What happens when light shines on certain metals? **7 or 4**
it transfers its energy to metal/ electrons // electrons are emitted 7
partial answer e.g. transfer of energy (4)

(*d*) Why is a metal a good conductor of electricity? **7 or 4**
electrons are only loosely bound 7
partial answer (4)

(*e*) Why does your skin feel warm when light shines on it? **7 or 4**
energy transferred from the light/radiation 7
partial answer (4)

(*f*) In the photoelectric effect, what happens when the intensity of light is increased? **7 or 4**
number of electrons released increases. 7
partial answer (4)

(*g*) How can the speed of electrons emitted in the photoelectric effect be controlled? **7 or 4**
change the frequency of the radiation 7
partial answer (4)

(*h*) Give one application of the photoelectric effect? **7 or 4**
photocell, alarms, photocopiers, light meters, photodiodes, etc 7
partial answer e.g. TV, solar cell, non specific use (4)

Question 12 56 marks

(*a*) State Boyle's law. **6 or 3**

(for a fixed mass of gas kept at a constant temperature) the pressure is inversely proportional to the volume // $PV = k$ (when T and m are fixed) 6

partial answer e.g. incomplete statement (3)

Describe an experiment to demonstrate that the atmosphere exerts a pressure. **4 × 3**

apparatus: can (containing water)	// can (of air)	// glass of water	3
procedure: boil water in can	// pump	// cardboard / lid	3
seal / invert in cold water	// air out	// invert	3
observation/conclusion: can crushes / collapses		// lid supported	3

marks may be obtained from a diagram
valid alternatives

Atmospheric pressure on the peak of Mount Everest is very low at 3.0×10^4 Pa, which is why climbers need oxygen tanks. A climber uses a 5.0 litre tank with an internal gas pressure of 4.2×10^6 Pa to supply oxygen.
What volume of gas will be available at the top of Mount Everest, when the gas is released from the tank? **10 or 7 or 4**

(V=) 700 (litres) 10

$(4.2 \times 10^6)(5) = (3.0 \times 10^4)(V_2)$

at least two quantities substituted correctly into the equation (7)

partial e.g. PV = constant (4)

(*b*) Loudness, pitch and quality are characteristics of a musical note.
Name the physical property of the sound wave on which each characteristic depends. **6 + 2 × 3**

loudness depends on amplitude / frequency
pitch depends on frequency
quality depends on overtones / harmonics

three correct	6 + 2 × 3
two correct	(6 + 3)
any one correct	(6)

A bat detector allows us to hear the sounds emitted by bats. The detector is needed as humans cannot hear the sounds emitted by bats as they are outside the *frequency limits of audibility*.

(i) What is meant by the frequency limits of audibility? **6 or 3**

are the lowest and highest frequencies which humans can hear //
range of frequencies which we can hear // 20 – 20 000 Hz 6

partial answer e.g. incomplete statement / 20 Hz (3)

(ii) What name is given to a sound whose frequency is greater than our upper frequency limit of audibility **4 or 2**

ultrasonic 4

partial answer e.g. incomplete statement / supersonic (2)

(iii) A bat emitted a sound wave and detected its reflection from a wall 0.02 s later. Calculate the distance of the bat from the wall. **6 or 3**

3.4 (m) 6

partial answer e.g. correct equation (3)

(*c*) What is an electric current, and give its unit of measurement? **3 × 3**

flow / movement 3
of charge / electrons 3
amp /A 3

State the three effects of an electric current. **4 or 2**

magnetic, heating/lighting, chemical two correct 4
one correct (2)

How would you demonstrate one of these effects? **3 × 3**

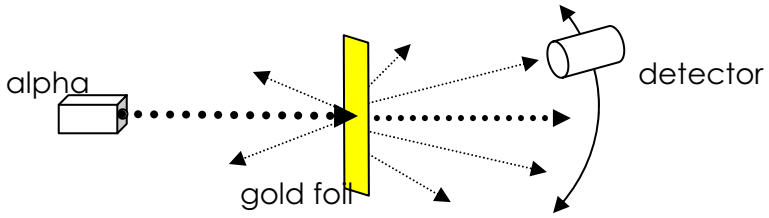
apparatus; e.g. filament bulb, battery, leads 3
procedure; e.g. connect up circuit and pass current through the bulb 3
observation / conclusion; e.g. the bulb lights / gets hot 3

valid alternatives
partial answer (3)

An electric screwdriver has a power rating of 120 W when connected to its 24 V battery. Calculate the current supplied by the battery when the screwdriver is turned on. **6 or 3**

(120= *I*(24)) = 5 (A) 6
partial answer e.g. correct equation $P = IV$ (3)

(*d*) The diagram shows an arrangement used to investigate the structure of the atom. During the investigation alpha-particles were fired at a thin sheet of gold foil in a vacuum.



(i) What are alpha particles? **6 or 3**

consist of two protons and two neutrons // helium (nucleus) 6
partial answer e.g. radioactive particles, any alpha property (3)

(ii) What happened to the alpha particles in the experiment? **6 or 3**

some deflected, some un-deviated, some reflected
two correct 6
one correct (3)

(iii) What did the experiment reveal about the structure of the atom? **6 or 3**

mainly empty space // (positive) nucleus at centre 6
partial answer (3)

(iv) Name the scientist who designed the experiment? **6 or 3**

Rutherford 6
partial answer e.g. other named nuclear scientist (3)

(v) Name a suitable detector of alpha-particles. **4 or 2**

GM tube, solid state detector, cloud chamber, ionisation tube, ZnS screen, gold leaf electroscope, photographic film, etc. 4
partial answer e.g. (monitor) badge (2)