



Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2017

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.

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, in final answers one mark is deducted, unless otherwise indicated.
- 7.** When drawing graphs, one mark is deducted for use of an **inappropriate scale**.
- 8.** Each time an arithmetical slip occurs in a calculation, one mark is deducted.

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 which was then allowed to swing about a fixed point and through a small angle. The time t for 40 oscillations was measured. This procedure was repeated for different lengths of the pendulum. The following data were recorded.

| | | | | | | | | |
|----------|------|------|------|------|------|------|------|------|
| l (cm) | 20.0 | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 |
| t (s) | 34.7 | 42.8 | 51.6 | 56.6 | 62.5 | 65.8 | 70.3 | 77.3 |

Why did the student use a small angle?

formula is valid only for a small angle / SHM occurs only for a small angle (3)

How did the student ensure that the pendulum was suspended from a fixed point?

split cork / two coins (3)

Between which points was the length of the pendulum measured?

bottom of cork/coins (2)

middle of bob (2)

Which t value is most accurate? Explain your answer.

77.3 s (3)

smallest percentage error (3)

Draw a suitable graph to show the relationship between the length of a pendulum and its period.

| | | | | | | | | |
|--------------------------|------|------|------|------|------|------|------|------|
| l /(m) | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| T^2 /(s ²) | 0.75 | 1.14 | 1.66 | 2.00 | 2.44 | 2.71 | 3.09 | 3.73 |

divide t values by 40 and square them (3)

axes labelled (3)

points plotted (3)

(-1 for each incorrectly plotted point)

straight line through origin (3)

good fit (3)

Use your graph to calculate g , the acceleration due to gravity.

slope calculated using two points on line (3)

substitute into formula $T^2 = \frac{4\pi^2 l}{g}$ (3)

$g \approx 9.8 \text{ m s}^{-2}$ (3)

2. The variation of the fundamental frequency of a stretched string with its tension was investigated. The length of the string and its mass per unit length were kept constant.

Draw a labelled diagram of the apparatus used.

string, bridge(s), tuning fork/signal generator, paper rider, tension key/pan with weights (5 × 2)
(–3 if none of these labelled)

Show on your diagram how (i) the tension and (ii) the length were measured.

(i) newton balance/pan with weights (3)

(ii) indication of where length is measured (3)

How was the fundamental frequency determined?

change tuning fork / adjust signal generator / adjust tension (3)

until resonance observed (3)

How would a student use the measurements taken in this experiment to draw a graph showing the relationship between frequency and tension?

graph of f // graph of f^2 (3)

against \sqrt{T} // against T (3)

Explain how the graph verifies this relationship.

straight line (3)

through origin (3)

For a string of constant length l , the mass per unit length μ can be determined using the slope m of the graph. Write an expression for μ in terms of l and m .

$$f = \frac{1}{2l} \sqrt{\frac{T}{\mu}} \quad (3)$$

$$\mu = \frac{1}{4l^2 m^2} \text{ or equivalent} \quad (-1 \text{ if } \mu \text{ not subject of equation}) \quad (3)$$

3. In an experiment to determine the specific latent heat of fusion of ice, warm water and ice were mixed in a copper calorimeter. The following data were recorded.

| | |
|---|-----------|
| Mass of calorimeter | = 61.8 g |
| Mass of calorimeter + warm water | = 110.2 g |
| Initial temperature of calorimeter + warm water | = 26.5 °C |
| Initial temperature of ice | = 0.0 °C |
| Mass of added ice | = 8.2 g |
| Final temperature of calorimeter + water + melted ice | = 12.0 °C |

Describe how

- (i) the mass of added ice was measured
mass of calorimeter + water + melted ice (3)
– mass of calorimeter + water (3)
- (ii) it was ensured that the temperature of all the added ice was at 0.0 °C.
crushed (3)
melting (3)

State two ways in which the calorimeter could have been insulated during this experiment.

- named insulator wrapped around calorimeter** (3)
lid (3)

Calculate the specific latent heat of fusion of ice.

$$m_w = 48.4, \Delta\theta_w = 14.5, \Delta\theta_i = 12.0 \quad (3 \times 2)$$

$$m_i l + m_i c_w \Delta\theta_i = m_w c_w \Delta\theta_w + m_c c_c \Delta\theta_c \quad (-3 \text{ for each } \Delta\theta \text{ block omitted/incorrect}) \quad (6)$$

(allow 3 marks out of 6 if any one block of the equation is given and no marks have already been awarded for the equation)

$$(8.2)l + (8.2)(4180)(12) = (48.4)(4180)(14.5) + (61.8)(390)(14.5) \quad (3)$$

$$l = 3.5 \times 10^5 \text{ J kg}^{-1} \quad (3)$$

State two characteristics of a thermometer suitable for use in this experiment.

- small heat capacity, graduated to 0.1 °C, suitable range, reacts quickly** (2 + 2)

4. A student investigated the relationship between current I and potential difference V for a filament bulb.

Draw a circuit diagram for the apparatus used in this experiment.

power supply, bulb, ammeter, voltmeter (-1 for each missing component) (3)

power supply, bulb and ammeter in series (3)

voltmeter in parallel with bulb (3)

means of varying voltage (3)

The following data were recorded.

| | | | | | | | | | | |
|----------|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| V (V) | 0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 |
| I (mA) | 0 | 11 | 23 | 33 | 44 | 51 | 57 | 63 | 68 | 72 |

Draw a suitable graph to illustrate the relationship between current and potential difference.

labelled axes (3)

points plotted (-1 for each incorrectly plotted point) (3)

good fit (3)

Use your graph to calculate the resistance of the filament (*i*) at 0.5 V and (*ii*) at 8.5 V.

$I = 5.5 \text{ mA}$ at 0.5 V or $I = 70 \text{ mA}$ at 8.5 V (from graph) (3)

$R = \frac{V}{I}$ (3)

(i) $R = 90.9 \Omega$ and (ii) $R = 121.4 \Omega$ (3)

As the potential difference was increased, at what point did the resistance of the filament begin to change significantly?

4.0 V to 6.0 V (4)

Why does the resistance of a filament change with its potential difference?

as potential difference increases current increases

as current increases temperature increases

as temperature increases resistance increases (any two lines) (2 × 3)

5. (a) State Boyle's law.
pressure is inversely proportional to volume (4)
at constant temperature / for a fixed mass of gas (3)
- (b) Sphere A of mass 400 g is travelling horizontally with a speed of 6 m s^{-1} when it collides with sphere B of mass 150 g travelling in the opposite direction with a speed of 9 m s^{-1} . Sphere A comes to rest as a result of the collision. Calculate the new velocity of sphere B.
 $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ (3)
 $(0.4)(6) + (0.15)(-9) = (0.15)v$ (2)
 $v = 7 \text{ m s}^{-1}$ (2)
- (c) What is the thermometric property (i) of a thermocouple and (ii) of a mercury thermometer?
(i) **emf** (ii) **length/volume** (4 + 3)
- (d) The diffraction effects of sound waves are noticeable in everyday life, whereas the diffraction effects of light waves are not. Explain why.
sound has a long wavelength / light has a short wavelength (7)
- (e) Explain how point discharge occurs.
charge accumulates at a point (4)
air is ionised around the point / like charges are repelled / unlike charges are attracted (3)
- (f) What is the electric field strength 53 pm from a proton?
 $E = \frac{F}{q}, F = \frac{Q_1 Q_2}{4\pi\epsilon d^2}$ (3 + 2)
 $E = 5.1 \times 10^{11} \text{ N C}^{-1}$ (accept V m^{-1} for unit) (2)
- (g) What is meant by sound intensity?
power // $I = \frac{P}{A}$ (4)
per unit area // **correct notation** (3)
- (h) A certain RCD has a rating of 30 mA. What is the significance of this number?
current is cut off (4)
if the difference between live and neutral currents is greater than 30 mA (3)
(-1 if no reference made to current)
- (i) What is the function of the moderator in a fission reactor?
slows down neutrons / increase fission (7)
- (j) Explain why the gravitational force can be ignored for sub-atomic particles.
masses are very small / force is proportional to mass / gravitational force is the weakest (7)
or
How can a galvanometer be converted into a voltmeter?
large resistance (4)
in series (3)

6. State the principle of conservation of energy.
energy cannot be created or destroyed (3)

Derive the expression $v^2 = u^2 + 2as$ for uniform accelerated motion.

$$v = u + at \quad (3)$$

$$v^2 = (u + at)^2 \quad (3)$$

$$v^2 = u^2 + 2uat + a^2t^2 \quad (3)$$

$$v^2 = u^2 + 2a(ut + \frac{1}{2}at^2), \text{ therefore } v^2 = u^2 + 2as \quad (3)$$

(-1 if final expression not stated)

The cord is 32 m long and Henry, of mass 60 kg, falls from rest while attached. Calculate his speed when he has fallen 16 m.

$$v^2 = u^2 + 2as / v^2 = 0 + 2(9.8)(16) \quad (3)$$

$$v = 17.7 \text{ m s}^{-1} \quad (3)$$

A stretched elastic cord obeys Hooke's law and the weight attached to the cord oscillates with simple harmonic motion.

State Hooke's law.

(restoring) force proportional to displacement (3)

What is meant by simple harmonic motion?

acceleration proportional to displacement (3)

The elastic constant of the cord is 250 N m^{-1} . Calculate the length the cord would have if Henry was suspended at rest.

$$F = ks \quad (3)$$

$$(9.8)(60) = (250)s \quad (3)$$

$$\text{length of cord} = 34.35 \text{ m} \quad (-1 \text{ if answer left as } s = 2.35 \text{ m}) \quad (3)$$

After the end of the fall, Henry oscillates with simple harmonic motion.

The maximum displacement from his rest position is 1.2 metres. Calculate

(i) his maximum acceleration as he oscillates and

$$\omega^2 = \frac{k}{m} \quad (3)$$

$$a = -\omega^2 s \quad (3)$$

$$a = -(4.17)(1.2) = -5.00 \text{ m s}^{-2} \quad (3)$$

(ii) his period of oscillation.

$$T = \frac{2\pi}{\omega} \quad (3)$$

$$T = \frac{2\pi}{\sqrt{4.17}} = 3.08 \text{ s} \quad (3)$$

Draw a diagram to show the forces acting on Henry when he is at his lowest point.

arrow showing force down (3)

arrow showing larger force up *(-1 for each incorrect arrow)* (2)

7. Colour filters and polarising filters can be used to enhance photographs.
We see objects because light reflects from them. What is reflection?
rebouncing (of light) from an object (3)

What primary colours of light (*i*) are absorbed and (*ii*) are reflected
when white light shines on a red book?

(i) **green and blue** (3)

(ii) **red** (3)

What colour would the red book appear to be if colour filters were used so that the book
was illuminated (*iii*) with green light and (*iv*) with red light?

(iii) **black** (3)

(iv) **red** (3)

What is polarisation?

wave vibrations (3)

in one plane only (3)

Describe how polarisation can be demonstrated in the laboratory.

two parallel polarising plates and a source of light (3)

rotate one plate (3)

until no light passes through the plates (3)

Give an application of stress polarisation.

checking for defects (3)

Speed cameras use the Doppler effect to calculate the speed of vehicles.

Describe, with the aid of a labelled diagram, how the Doppler effect occurs.

source, observer and labelled non-concentric circular wavefronts (3)

source moving towards observer (3)

wavelength is shorter (3)

frequency is higher (2)

A source that is emitting a sound wave of a certain frequency is approaching an observer.

The frequency observed is 15% more than the frequency of the sound wave emitted.

What is the speed of the source?

$$f' = \frac{fc}{c-u} \quad (3)$$

$$1.15f = \frac{f(340)}{340-u} \quad (3)$$

cancel f (3)

$$u = 44.3 \text{ m s}^{-1} \quad (3)$$

8. Distinguish between resistance and resistivity.

$$R = \frac{V}{I} \text{ and notation} \quad (2 + 2)$$

$$\rho = \frac{RA}{l} \text{ and notation} \quad (2 + 2)$$

What is the effect on the resistance of a length of wire if the diameter of the wire is increased by a factor of three?

decreases (3)

by a factor of 9 (3)

In the circuit diagram shown, the a.c. supply has an rms voltage of 12 V.

The variable resistor is set at 500 Ω .

What is meant by rms?

average voltage / root mean squared (3)

What is meant by a.c.?

current that changes direction / alternating current (3)

Calculate

(i) the effective resistance of the circuit

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \quad (3)$$

$$R_p = 143 \quad (3)$$

$$R_T = 193 \Omega \quad (3)$$

(ii) the current flowing in the 200 Ω resistor.

$$I_T = \frac{V}{R} \quad (3)$$

$$I_T = 0.062 \quad (3)$$

$$I = \frac{5}{7}(0.062) = 0.044 \text{ A} \quad (3)$$

The variable resistor is then removed.

What effect will this have on the current flowing in the 50 Ω resistor?

current will reduce (3)

Explain your answer.

resistance of circuit is larger / appropriate calculations (3)

In further investigations, the 50 Ω resistor was then replaced with

(i) a coil of resistance 50 Ω and (ii) a diode, as shown.

In each of the investigations, what effect did the replacement have on the current flowing?

Justify your answer in each case.

(i) **current reduces** (3)

back emf (3)

(ii) **current flows** (3)

in one direction only (3)

9. Describe Rutherford's experiment to investigate the structure of the atom.
- alpha particle, gold foil, zinc sulfide / screen** (state/imply) (3)
- alpha particles fired at foil** (state/imply) (3)
- some passed straight through, some deflected, some rebounded** (state/imply) (3)
- What conclusions about the nature of the atom did Rutherford make?
- mostly empty space** (3)
- small/dense/positive core** (3)

One of his students, Niels Bohr, further developed Rutherford's model of the atom. The Bohr model helps us identify different elements using emission line spectra.

Explain, using the Bohr model, how line spectra are formed.

- energy supplied** (3)
- electrons move to a higher/excited energy level** (3)
- electrons fall down** (3)
- emitting light** (3)

Draw a labelled diagram of a spectrometer and describe how a spectrometer and diffraction grating can be used to observe (i) a line spectrum and (ii) a continuous spectrum.

- collimator (labelled)** (3)
- table** (3)
- telescope (labelled)** (3)
- correct arrangement** (3)
- (i) **vapour lamp** (3)
- (ii) **filament bulb / white light** (3)

Sodium emits visible light with a wavelength of 589 nm. This light is passed through a diffraction grating of 300 lines per mm. Calculate the angular separation between the first line to the left of the central image and the first line to the right of the central image.

- $d = 3.33 \times 10^{-6}$** (3)
- $n\lambda = d \sin \theta$** (3)
- $\theta = 10.2^\circ$** (3)
- angular separation = 20.4°** (2)

10. What are X-rays?

photons / electromagnetic radiation (3)

with high energy / short wavelength / high frequency (3)

Electrons are produced and used in an X-ray tube.

How are the electrons produced?

thermionic emission (3)

Where in the tube does this take place?

cathode/filament (3)

A certain X-ray tube is designed to emit X-rays with wavelengths as small as 0.02 nm.

Calculate

(i) the energy of an X-ray photon of wavelength 0.02 nm

$$E = hf \quad (3)$$

$$c = f\lambda \quad (3)$$

$$E = 9.9 \times 10^{-15} \text{ J} \quad (3)$$

(ii) the maximum velocity of an electron in the tube

$$E = \frac{1}{2}mv^2 \quad (3)$$

$$v = 1.48 \times 10^8 \text{ m s}^{-1} \quad (3)$$

(iii) the voltage applied to the electrons.

$$V = \frac{W}{q} \quad (3)$$

$$V = 62000 \text{ V} \quad (3)$$

Electrons are also produced and used in a photocell.

Draw a labelled diagram of a photocell.

anode (3)

semi-cylindrical cathode (*-3 if neither cathode nor anode labelled*) (3)

case and vacuum (3)

Describe how a photocell conducts current.

light (of suitable frequency) falls on cathode (*state/imply*) (3)

electrons are emitted (3)

A current of 2 μA is flowing in a photocell. How many electrons are generated in the photocell during each minute?

$$Q = It = (2 \times 10^{-6})(60) \quad (3)$$

$$Q = 1.2 \times 10^{-4} \quad (3)$$

$$\text{number of electrons} = 7.5 \times 10^{14} \quad (2)$$

11. (a) Draw a labelled diagram of an arrangement of apparatus that could be used to demonstrate the principle that a current-carrying conductor experiences a force in a magnetic field.
- power supply, magnet, conductor** (3 × 1)
- correct arrangement** (4)
- (b) Explain how this principle is used in the definition of the ampere.
- current flows in two (parallel) conductors** (3)
- 1 metre apart (in a vacuum)** (2)
- force of 2×10^{-7} N per metre** (–1 if per metre is missing) (2)
- (c) Draw a circuit diagram of a Wheatstone bridge.
- four resistors in correct arrangement** (4)
- galvanometer/ammeter in correct position** (3)
- (d) Why did *Telstar* not allow transatlantic signals to be transmitted constantly?
- period of *Telstar* different to period of Earth / not in geostationary orbit / not always above the same place** (7)
- (e) Calculate the radius of orbit of *Telstar*.
- $$T^2 = \frac{4\pi^2 r^3}{GM} \quad (3)$$
- $$(2.6 \times 60 \times 60)^2 = \frac{4\pi^2 r^3}{(6.7 \times 10^{-11})(6 \times 10^{24})} \quad (2)$$
- $$r = 9.6 \times 10^6 \text{ m} \quad (2)$$
- (f) With the aid of a labelled diagram, explain how light is transmitted through optical fibres.
- angle of incidence greater than critical angle** (4)
- total internal reflection occurs** (3)
- (–1 if no diagram drawn)
- (g) Light travels a distance of 5500 km along the *Hibernia Express* between London and New York. Calculate the refractive index of the glass used in the cable.
- $$v = \frac{s}{t}, n = \frac{v_1}{v_2} \quad (3 + 2)$$
- $$n = 1.58 \quad (2)$$
- (h) What particles are used for transatlantic communication
- (i) in telegraph cables **electrons** (3)
- (ii) in satellite signals **photons** (2)
- (iii) in optical fibres? **photons** (2)

12. (a) State the laws of equilibrium.

sum of forces = 0

sum of moments = 0 / (net) clockwise moment = (net) anti-clockwise moment (6 + 3)

A sign weighing 400 N is suspended at the end of a uniform horizontal rod. The rod touches the wall at position X.

The rod weighs 330 N and is 1.2 m long.

A support cable makes an angle of 35° with the rod, as shown in the diagram.

Calculate the clockwise moment acting on the rod (due to the weight of the sign and the weight of the rod) about X.

$$m = Fd \quad (3)$$

$$m = (400)(1.2) + (330)(0.6) \quad (3)$$

$$m = 678 \text{ N m} \quad (3)$$

Hence calculate the tension in the cable.

$$678 = F_u(1.2) / F_u = 565 \text{ N} \quad (3)$$

$$T = \frac{F_u}{\sin 35} = \frac{565}{\sin 35} = 985 \text{ N} \quad (3)$$

A rotating object can be in equilibrium. Explain how this can happen.

constant angular velocity (4)

- (b) Potassium-40 is a significant source of radioactivity in the human body. Bananas are a principle source of potassium in our diet.

Potassium-40 has a half-life of 1.25×10^9 years and it is a beta-emitter.

What is meant by radioactivity?

(spontaneous) disintegration of a nucleus (3)

with the emission of (alpha, beta and/or gamma) radiation (3)

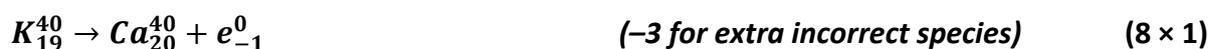
Name a device used to detect beta-radiation and explain its principle of operation.

Geiger-Müller tube / solid-state detector (3)

ionisation /current flows (3)

The activity of a human body due to potassium-40 is 5400 Bq.

Write the nuclear equation for this decay.



Calculate the number of potassium-40 nuclei in this person.

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} \quad (3)$$

$$A = -\lambda N \quad (3)$$

$$N = 3.07 \times 10^{20} \quad (2)$$

- (c) It has been recently suggested that the 17th century Dutch artist Rembrandt used a concave mirror to help him etch self-portraits by projecting an inverted image of himself onto a copper sheet.

Draw a ray diagram to illustrate how Rembrandt used a concave mirror in this way.

concave mirror (3)

object outside focal point (3)

two correct rays (2)

correct image at intersection of rays (2)

Rembrandt used a concave mirror of focal length 60 cm so that the image on the copper sheet was only half the size of the object.

Calculate

- (i) the distance from the sheet to the mirror and

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

$$m = \frac{v}{u} / m = \frac{1}{2} \quad (3)$$

$$v = 90 \text{ cm} \quad (3)$$

- (ii) the distance from the object to the mirror.

$$u = v \times 2 = 180 \text{ cm} \quad (3)$$

A concave mirror can also be used to produce an upright image.

Explain why this image was not of use to Rembrandt.

virtual image (3)

cannot be formed on a sheet (3)

(d) Answer **either** part (i) **or** part (ii).

(i) In the Cockcroft and Walton experiment, accelerated protons collided with lithium nuclei. In each collision a proton collided with a lithium nucleus to produce two alpha-particles, as shown in this commemorative coin.

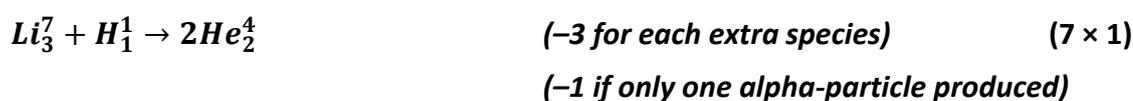
Explain

(a) how the protons were produced,
ionisation / discharge tube (2)

(b) how the protons were accelerated and
high voltage (2)

(c) how the alpha-particles were detected.
flashes / zinc sulphide / screen (2)

Write the nuclear equation for this reaction.



For this reaction, calculate the loss in mass and hence the energy released (in MeV).

$$\text{mass of lithium nucleus} = 1.165 \times 10^{-26} \text{ kg} / 7.016005 \text{ u} \quad (3)$$

$$\text{loss in mass} = 3.09 \times 10^{-29} \text{ kg} \quad (3)$$

$$E = mc^2 \quad (3)$$

$$\text{energy released} = 2.78 \times 10^{-12} \text{ J} = 17.35 \text{ MeV} \quad (3)$$

(−1 if energy not converted from J to MeV)

(−1 if 7 is used for mass of Li-7)

(no penalty if electron masses not subtracted from mass of Li)

Explain the historical significance of this experiment.

verified $E = mc^2$ / first transmutation by an artificially accelerated particle / important step in development of the particle accelerator / Nobel prize (3)

(ii) Draw a diagram to show the basic structure of the bi-polar transistor.

n, p, n layers; c, b, e connections

(6 × 1)

State the relationship between the three currents flowing in a transistor circuit.

I_E, I_B, I_C

(3 × 1)

$I_E = I_B + I_C$

(3)

Draw the circuit diagram for a transistor circuit that can be used as a voltage inverter (NOT gate).

transistor and resistor in series

(3)

collector connected to positive, emitter connected to earth

(3)

correct input indicated

(3)

correct output indicated

(3)

Draw the truth table for a NOT gate.

input = 0, output = 1

(2)

input = 1, output = 0

(2)

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