Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2018

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 for 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. In an experiment to verify the principle of conservation of momentum, body A was set in motion with a velocity *u*. It collided with body B, which was initially at rest. Bodies A and B then moved with a common velocity *v*. The following data were recorded.

Mass of body A	= 360.7 g
Mass of body B	= 340.9 g
Distance travelled by A for 0.12 s before the collision	= 161 mm
Distance travelled by A and B for 0.12 s after the collision	= 83 mm

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

two bodies, means of coalescing bodies, timing apparatus **(3×3)**

External forces were minimised in the experiment.
State the two principal external forces that were minimised. How were they minimised?

gravitational, frictional **(3+3)**

horizontal track **// slope track** **(3)**

correct reference to air track **// gravitational force = frictional force**

/ method of reducing friction **(3)**

Calculate velocities *u* and *v*.
Use the data to verify the principle of conservation of momentum.

$u = 1.342 \text{ m s}^{-1}, v = 0.692 \text{ m s}^{-1}$ **(2+2)**

$p = mv$ **(2)**

$p_1 = 0.484 \text{ kg m s}^{-1}, p_2 = 0.485 \text{ kg m s}^{-1}$ **(2+2)**

$p_1 \cong p_2$ **statement** **(3)**

Calculate the loss of kinetic energy in the bodies during the collision.
What form of energy could account for this loss of kinetic energy?

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

$\Delta E = 0.325 - 0.168 = 0.157 \text{ J}$ **(2)**

sound/heat **(2)**

2. A student measured the angle of incidence *i* and the angle of refraction *r* for a ray of light passing through a transparent block. She repeated this experiment for different values of *i* and used her data to investigate the relationship between the angle of incidence and the angle of refraction. The following data were recorded.

i (degrees)	20	30	40	50	60	70
r (degrees)	14	20	26	31	35	38

Describe, with the aid of a labelled diagram, how the student determined the angle of refraction.

diagram of block, pins / ray box / laser *(labelled)* **(3)**

correct method of finding refracted ray *(state/imply)* **(3)**

draw normal in block at point of incidence **(3)**

measure angle between normal and refracted ray with a protractor **(3)**

Draw a suitable graph to show the relationship between the angle of incidence and the angle of refraction. State this relationship and explain how your graph verifies it.

12 calculations of $\sin i$ and $\sin r$ **(3)**

$\sin i$	**0.34**	**0.5**	**0.64**	**0.77**	**0.87**	**0.94**
$\sin r$	**0.24**	**0.34**	**0.44**	**0.52**	**0.57**	**0.62**

labelled axes **(3)**

6 points plotted **(3)**

straight line with good fit **(3)**

$\sin i \propto \sin r$ **(3)**

straight line through origin **(3)**

Use your graph to determine the refractive index of the material used.

$\text{slope} = n = \frac{y_2 - y_1}{x_2 - x_1}$ **(3)**

$n = 1.50$ **(3)**

What would be observed if the incident ray was perpendicular to the block?

ray passes straight through **(4)**

3. A student used a narrow beam of monochromatic light and a diffraction grating to determine λ, the wavelength of the monochromatic light. The following data were recorded.

ϕ, the angle between the two first order images = 34.1°

The number of lines per mm on the diffraction grating = 500

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

screen, diffraction grating, laser // spectrometer, diffraction grating, sodium lamp(3×2)

Describe how the angle between the two first order images was obtained.

s_1 between grating and screen // record θ_l at n=1 to left **(3)**

s_2 between first order images // record θ_r at n=1 to right **(3)**

correct method of calculating ϕ or θ **(3)**

Calculate the wavelength of the beam of light.

$\boldsymbol{d = 2 \times 10^{-6}}$ **(3)**

$\boldsymbol{\theta = 17.05°}$ **(3)**

$\boldsymbol{n\lambda = d \sin\theta}$ **(3)**

$\boldsymbol{\lambda = 5.86 \times 10^{-7} \mathrm{m}}$ **(3)**

Describe the effect on the size of the angle ϕ, the angle between the two first order images, if the diffraction grating above was replaced with a diffraction grating of 80 lines per mm.

ϕ decreases **(3)**

Hence determine which grating would give a more accurate value for λ.
Justify your answer.

500 lines per mm grating **(3)**

larger measurements give smaller percentage error **(3)**

What would the student observe if the source of monochromatic light was replaced with a source of white light?

spectrum **(4)**

4. In an experiment to verify Joule's law, a constant current, *I*, was passed through a heating coil immersed in water. The current was allowed to flow for 3 minutes and the final temperature θ of the water was then measured.
This was repeated for a number of different currents.

In each case, the initial temperature of the water was 18 °C and the mass of the water was 90 g. The following data were recorded.

I (A)	1.5	2.0	2.5	3.0	3.5	4.5	5.5
θ (°C)	20.0	22.0	24.0	27.5	30.5	38.0	49.5

Draw a diagram of the apparatus used in this experiment.

power supply, means of varying voltage, coil, ammeter in series **(4×3)**
thermometer and coil in water **(3)**

Draw a suitable graph to verify Joule's law.

6 calculations of I^2 and 6 calculations of $\Delta\theta$ **(3)**

I^2	**2.25**	**4.00**	**6.25**	**9.00**	**12.25**	**20.25**	**30.25**
$\Delta\theta$	**2.0**	**4.0**	**6.0**	**9.5**	**12.5**	**20.0**	**31.5**

labelled axes **(3)**
6 points plotted **(3)**
straight line with good fit **(3)**
through origin **(3)**

Calculate the slope of the graph and hence calculate the resistance of the heating coil.

$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1}$ **(3)**

$\text{slope} = 1.04$ **(3)**

$\text{slope} = \frac{Rt}{mc}$ **(2)**

$R = 2.2\ \Omega$ **(2)**

5.

(*a*) Draw a labelled diagram to show the forces acting on a skydiver falling with a constant velocity.

labelled force arrow down **(2)**

labelled force arrow up **(2)**

arrows of equal length **(3)**

(*b*) A horizontal metre stick is in equilibrium when a weight of 8 N hangs from the 10 cm mark, a weight of 12 N hangs from the 60 cm mark and an unknown weight (X) hangs from the 82 cm mark. The metre stick is supported at its centre of gravity, 50 cm. Calculate X.

$\boldsymbol{M = Fd}$ **(4)**

$\boldsymbol{x = 6.25\ \mathrm{N}}$ **(3)**

(*c*) Heat energy can be transferred by conduction, convection and radiation. Distinguish between the three methods of heat transfer.

conduction: no net movement of medium

convection: circulation of a fluid

radiation: electromagnetic / photons / through a vacuum **(3+2+2)**

(*d*) A fire-engine travelling at a speed of 30 m s^{-1} emits a sound of frequency 2.3 kHz as it approaches an observer. Calculate the frequency observed.

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

$\boldsymbol{f' = \frac{(2300)(340)}{340-30}}$ **(2)**

$\boldsymbol{f' = 2523\ \mathrm{Hz}}$ **(2)**

(*e*) The refractive index of a material is 2.4. Calculate the speed of light in this material.

$\boldsymbol{n = \frac{c}{v}}$ **(3)**

$\boldsymbol{2.4 = \frac{3\times10^8}{v}}$ **(2)**

$\boldsymbol{v = 1.25\times10^8\ \mathrm{m\ s^{-1}}}$ **(2)**

(*f*) Explain how electrons are (*i*) produced and (*ii*) accelerated in an X-ray tube.

produced by thermionic emission (at cathode) **(4)**

accelerated through a high voltage **(3)**

(*g*) Write an expression for the electric field intensity E at a distance d from a charge Q.

$\boldsymbol{\frac{Q}{4\pi\epsilon d^2}}$ ***(allow 4 for*** $\boldsymbol{F = \frac{Q_1Q_2}{4\pi\epsilon d^2}}$ ***or*** $\boldsymbol{E = \frac{F}{Q}}$***)*** **(7)**

(*h*) What are the charge carriers in (*i*) metals, (*ii*) gases, (*iii*) semiconductors?

metals: electrons **(3)**

gases: ions/electrons **(2)**

semiconductors: electrons/holes **(2)**

(*i*) Calculate the effective resistance of a 5 Ω resistor and a 7 Ω resistor when they are connected in parallel.

$\boldsymbol{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}}$ **(3)**

$\boldsymbol{\frac{1}{R_T} = \frac{1}{5} + \frac{1}{7}}$ **(2)**

$\boldsymbol{R_T = 2.9\ \Omega}$ **(2)**

(*j*) State (*i*) a physical quantity that is the same for a quark and its anti-quark and (*ii*) a physical quantity that is different for a quark and its anti-quark.

same: mass/magnitude of charge

different: (sign of) charge **(4+3)**

Draw the truth table for an AND gate.

$\boldsymbol{0 + 0 \rightarrow 0}$

$\boldsymbol{0 + 1 \rightarrow 0}$

$\boldsymbol{1 + 1 \rightarrow 1}$ **(3+2+2)**

6. (*a*) During the discus event, Ashton swings a discus of mass 2.0 kg in uniform circular motion. The radius of orbit of the discus is 1.2 m and the discus has a velocity of 20.4 m s^{-1} when Ashton releases it.

(*i*) Derive an expression to show the relationship between the radius, velocity and angular velocity of an object moving in uniform circular motion.

$\boldsymbol{\theta = \frac{s}{r}}$

$\boldsymbol{\frac{\theta}{t} = \frac{s}{rt}}$

$\boldsymbol{\omega = \frac{v}{r}}$ **(6+3+3)**

(*ii*) Calculate the angular velocity of the discus immediately prior to its release.

$\boldsymbol{\omega = \frac{20.4}{1.2} = 17\ \mathbf{rad\ s^{-1}}}$ **(3)**

(*iii*) Calculate the centripetal force acting on the discus just before Ashton releases it. In what direction does this force apply?

$\boldsymbol{F = mr\omega^2 = (2)(1.2)(17)^2 = 693.6\ \mathbf{N}}$ **(3)**

towards the centre **(3)**

(*b*) During the long jump, Ashton has a velocity of 10.9 m s^{-1} at an angle of 43° to the horizontal when he begins his jump. He lands 1.03 seconds after he takes off.

Calculate

(*i*) his velocity in the horizontal direction

$\boldsymbol{v_H = v\cos\theta}$ **(3)**

$\boldsymbol{v_H = 10.9\cos 43° = 7.97\ \mathbf{m\ s^{-1}}}$ **(3)**

(*ii*) the length of the jump.

$\boldsymbol{s = vt}$ **(3)**

$\boldsymbol{s = (7.97)(1.03) = 8.21\ \mathbf{m}}$ **(3)**

(*c*) During the pole vault Ashton has a horizontal speed of 9.2 m s^{-1} just before he jumps. He converts most of his kinetic energy into elastic potential energy in the pole and then into gravitational potential energy. At his maximum height he has a horizontal speed of 1.1 m s^{-1}.

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

energy cannot be created or destroyed **(3)**

(*ii*) What is meant by the centre of gravity of a body?

the point of a body where its weight appears to act **(3)**

(*iii*) Ashton's centre of gravity when he is standing is 98 cm above the ground. During the vault, what is the maximum height above the ground to which he can raise his centre of gravity?

$\boldsymbol{mgh\ /\ \frac{1}{2}mv^2}$ **(3)**

gain in potential energy = loss in kinetic energy **(3)**

$\boldsymbol{h = \frac{9.2^2 - 1.1^2}{2(9.8)} = 4.26\ \mathbf{m}}$ **(3)**

height above ground = $\boldsymbol{4.26 + 0.98 = 5.24\ \mathbf{m}}$ **(3)**

(*iv*) Draw a diagram to show any forces acting on Ashton when he is at his highest point, as shown in the photograph.

one labelled arrow downwards **(5)**

7. Resonance is a phenomenon that is associated with musical instruments. What is resonance?

transfer of energy **(3)**

between two bodies of the same natural frequency **(3)**

Describe an experiment to demonstrate resonance.

e.g. two tuning forks of the same frequency on a wooden board **(3)**

set one tuning fork vibrating **(3)**

second tuning fork starts vibrating **(3)**

A stretched string of a violin has a length of 328 mm and a mass of 0.126 g. It emits a note of 660 Hz when it vibrates at its fundamental frequency.

Calculate

(*i*) the tension in the string

$\mu = \frac{0.126 \times 10^{-3}}{0.328} = 3.84 \times 10^{-4}$ **(3)**

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

$T = 72 \text{ N}$ **(3)**

(*ii*) the speed of sound in the string.

$\lambda = 2(0.328) = 0.656$ **(3)**

$v = f\lambda$ **(3)**

$v = 433 \text{ m s}^{-1}$ **(3)**

Draw a labelled diagram to represent the fundamental frequency of a stationary wave in a pipe that is closed at one end.

node at closed end **(3)**

antinode at open end with no other nodes **(3)**

(–1 if neither node nor antinode labelled)

Define sound intensity.

$I = \frac{P}{A}$ **// power** **(3)**

notation **// per unit area** **(3)**

A source emits sound in all directions.

Describe the effect of doubling the distance from the source to an observer on

(*iii*) the sound intensity measured

$I \propto \frac{1}{d^2}$ **(3)**

4 times **(2)**

smaller **(2)**

(*iv*) the sound intensity level measured.

idea of 3 decibel change **(2)**

6 decibels lower **(2)**

8. Explain the terms nuclear fission and specific heat capacity.

splitting of a (large) nucleus into two (similar sized) nuclei **(3)**

with the emission of energy/neutrons **(3)**

(–1 for atom instead of nucleus)

the energy required to change the temperature **(3)**

of 1 kg by 1 K **(3)**

Water can act as both a moderator and a coolant in a nuclear fission reactor.
What effect does a moderator have on the rate of fission?

increases the rate of fission **(3)**

How does a moderator have this effect?

slows down neutrons **(3)**

In a nuclear reactor core, 5000 kg of water is heated so that its temperature increases by 70 K and it is converted into steam. Calculate the energy absorbed by the water.

$\boldsymbol{E = ml + mc\Delta\theta}$ **(3+3)**

$\boldsymbol{E = (5000)(2.23 \times 10^6) + (5000)(4180)(70)}$ **(3)**

$\boldsymbol{E = 1.26 \times 10^{10}}$ **J** **(3)**

In a fission reaction a neutron is absorbed by a uranium–235 nucleus.
Barium–139 and krypton–94 nuclei are released as well as some neutrons.

Write a nuclear equation for this reaction.

$\boldsymbol{{}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{139}_{56}Ba + {}^{94}_{36}Kr + 3{}^{1}_{0}n}$ **(10×1)**

Calculate the energy released, in MeV, in this reaction.

loss in mass $\boldsymbol{= 3.0 \times 10^{-28}}$ **kg** **(3)**

$\boldsymbol{E = mc^2}$ **(3)**

$\boldsymbol{E = 2.74 \times 10^{-11}}$ **J** **(3)**

$\boldsymbol{E = 171\ \mathrm{MeV}}$ ***(unit not required)*** **(2)**

Nuclear fusion reactors could supply more energy than fission reactors. Explain why fusion reactors are not yet a practical source of energy on Earth.

too much energy is required (to overcome force of repulsion between nuclei) **(3)**

Give one other advantage that a fusion reactor would have over a fission reactor.

raw material readily available / less radioactive waste **(2)**

9. James Clerk Maxwell, a Scottish physicist, is considered the greatest theoretical physicist of the nineteenth century. Early in his career he investigated colour and light.

Maxwell created a colour triangle to illustrate the relationship between primary and secondary colours of light. Using his triangle or otherwise (*i*) list the primary colours of light, (*ii*) name a pair of complementary colours of light.

(*i*) **red, green, blue** **(3×1)**

(*ii*) **any primary and secondary colour** **(3)**

correct combination **(3)**

Maxwell later published equations that described how electric charges and electric currents create electric and magnetic fields. He also described how a changing electric field can generate a changing magnetic field.

What is a magnetic field?

region where magnetic forces are felt **(3)**

Draw labelled diagrams to show the magnetic field about (*iii*) a long straight current-carrying wire, (*iv*) a current-carrying solenoid.

(*iii*) **circle(s) with wire at centre** **(3)**

arrow on circle(s) indicating direction **(3)**

(*iv*) **correct shape of field lines with arrows** **(3)**

One of Maxwell's equations is equivalent to Faraday's law of electromagnetic induction.

State Faraday's law of electromagnetic induction.

emf induced is proportional to **//** $E = -\frac{\Delta\emptyset}{\Delta t}$ **(3)**

the rate of change of magnetic flux **// notation** **(3)**

Describe an experiment to demonstrate this law.

coil, galvanometer and magnet in correct arrangement **(3)**

move magnet relative to coil and note current **(3)**

move magnet more quickly and note larger current **(3)**

A square coil of 40 turns with a side of length 20 cm is perpendicular to a magnetic field of flux density 50 mT. What is the average emf induced in the coil when it is rotated through 90° in ¼ of a second?

$\emptyset = BA$ **(3)**

$\emptyset = (50 \times 10^{-3})(0.2)^2 = 2 \times 10^{-3}$ **(3)**

$E = -\frac{\Delta\emptyset}{\Delta t}$ **(3)**

$E = (40)\frac{2\times10^{-3}}{0.25} = 0.32\text{ V}$ **(2)**

Maxwell also showed that visible light is an electromagnetic wave and that some types of invisible waves belong in the electromagnetic spectrum too.

The eye is the sense organ that detects light. Where in the eye is light detected?

retina **(3)**

List two invisible parts of the electromagnetic spectrum that have a shorter wavelength than visible light.

ultraviolet, X-rays, gamma rays **(2×3)**

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

(*a*) Momentum, energy and charge are conserved in all nuclear reactions.

In beta-decay an unstable nucleus emits an electron.
In the early 20th century it was found that momentum and energy did not appear to be conserved during beta-decay. To solve this apparent problem, Wolfgang Pauli predicted the existence of an unknown particle, about which he said,

I have done a terrible thing. I have postulated a particle that cannot be detected.

Name the particle which Pauli predicted and explain how it solved the problem.

neutrino **(2)**

had the missing energy and momentum **(3)**

Write a nuclear equation for beta-decay.

$\mathbf{{}^1_0n \rightarrow {}^1_1H + {}^{\ 0}_{-1}e + \nu}$ **(10×1)**

Why did Pauli think that the particle could not be detected?

no charge **(3)**

very small mass **(3)**

The conservation laws also apply to pair annihilation.
Pair annihilation can be described using the following equation for an electron and positron at rest.

$$e^0_{-1} + e^0_1 \rightarrow 2\gamma$$

Why are two gamma-ray photons produced?

to conserve momentum **(3)**

Explain how charge is conserved in the annihilation.

since particle and antiparticle have equal and opposite charges, charge before = 0 **(3)**

photons have no charge **(3)**

Calculate the maximum frequency of each emitted photon.

$\mathbf{E = mc^2}$ **(2)**

$\mathbf{E = hf}$ **(3)**

$\mathbf{hf = mc^2}$ **(3)**

substitution **(3)**

$\mathbf{f = 1.24 \times 10^{20}\ Hz}$ **(3)**

Electrons are negatively charged leptons. List the two other negatively charged leptons.

muon, tau **(3+3)**

List the three forces that these leptons experience, in decreasing order of strength.

electromagnetic, weak, gravitational **(3×1)**

in correct order **(3)**

(*b*) Sketch current-time graphs to compare alternating current and direct current.

axes labelled for at least one graph **(3)**

correct shape for a.c. **(3)**

correct shape for d.c. **(3)**

A rectifier circuit converts alternating current to direct current. Draw a circuit diagram of a half-wave rectifier circuit.

diode **(3)**

correct arrangement including input and output voltages **(3)**

Sketch a graph to illustrate the output current from a half-wave rectifier.

correct shape **(3)**

An induction coil is used to increase the magnitude of d.c. voltage.

Draw a labelled diagram of an induction coil.

coil and d.c. power supply in primary circuit **(3)**

coil with more turns in secondary circuit **(3)**

labelled make and break mechanism and iron core **(3)**

Describe how the induction coil can be used to increase d.c. voltage.

primary coil switches off **(3)**

changing magnetic field cutting the secondary coil **(3)**

emf induced in secondary coil **(3)**

An induction coil is not used to increase a.c. voltage.

Name the device used to increase a.c. voltage.

transformer **(3)**

Draw a labelled diagram of this device.

a.c. input and primary coil **(3)**

secondary coil and output **(3)**

both coils on common iron core **(3)**

Describe how this device can be used to increase a.c. voltage.

current in primary coil always changing **(2)**

changing magnetic field from primary coil cutting the secondary coil **(2)**

emf induced in secondary coil **(2)**

induced emf is larger due to greater number of turns in secondary coil **(2)**

11.

(*a*) Calculate the minimum frequency of the radio waves detected by I-LOFAR.

$\boldsymbol{\lambda = 30\ \text{m}}$ **(2)**

$\boldsymbol{v = f\lambda}$ **(2)**

$\boldsymbol{f = 1 \times 10^7\ \text{Hz}}$ **(3)**

(*b*) Draw a diagram of the magnetic field around the Earth.

correct shape of field lines around the Earth **(4)**

correct direction of field lines **(3)**

(*c*) Explain how information is transmitted using optical fibres.

angle of incidence (always) greater than critical angle

total internal reflection **(4+3)**

(*d*) Calculate the position of the image of a person standing 75 cm from the Leviathan mirror.

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

79 cm **(2)**

behind the mirror **(2)**

(*e*) Where, with respect to the concave mirror, will an image of the moon be formed? Justify your answer.

at its focal point **(4)**

incoming rays are parallel **(3)**

(*f*) A concave mirror can also be used as a microscope to magnify images. Draw a ray diagram to show the formation of an upright, magnified image in a concave mirror.

object inside focal point of concave mirror **(3)**

two correct reflected rays **(2)**

correct image at apparent intersection of rays **(2)**

(*g*) Calculate the velocity of the Hubble telescope as it orbits the Earth.

$\boldsymbol{v = \frac{2\pi r}{T}}$ **(4)**

$\boldsymbol{v = 7650\ \text{m s}^{-1}}$ **(3)**

(*h*) Name one optical phenomenon which reduced the effectiveness of the Leviathan and which is eliminated by the location of the Hubble telescope. How does the location of the Hubble telescope eliminate this problem?

refraction **(4)**

Hubble is above the atmosphere **(3)**

12.

(*a*) A simple pendulum can execute simple harmonic motion.

Explain the underlined term.

acceleration is proportional to	**// correct equation**	**(3)**
displacement	**// notation**	**(3)**

When does a simple pendulum execute simple harmonic motion?

oscillating at a small angle **(3)**

What is the relationship between the period of a simple pendulum and its length?

period squared proportional to length / correct equation **(3)**

A stretched spring can also execute simple harmonic motion.

A spring has a natural length of 50 cm.

A mass of 60 g is hung from the spring and the mass is allowed to oscillate with simple harmonic motion.

It has a period of oscillation of 0.85 seconds.

Calculate

(*i*) the spring constant

$\boldsymbol{T = \frac{2\pi}{\omega}}$ **(2)**

$\boldsymbol{\omega = 7.39}$ **(2)**

$\boldsymbol{\omega^2 = \frac{k}{m}}$ **(2)**

$\boldsymbol{k = 3.28\ \mathrm{N\ m^{-1}}}$ **(2)**

(*ii*) the length of the spring when the mass is at rest.

$\boldsymbol{F = -ks}$ **(3)**

$\boldsymbol{s = 0.18}$ **(3)**

$\boldsymbol{l = 0.68\ \mathrm{m}}$ **(2)**

(*b*) The radioactivity of an isotope of radon was measured each day for a week and the following data was collected.

Time (days)	0	1	2	3	4	5	6	7
Activity (MBq)	600	490	400	330	270	220	180	150

What is meant by radioactivity?

(spontaneous) disintegration of a nucleus **(3)**

with the emission of radiation **(3)**

On graph paper, draw a decay curve (a graph of activity against time).

8 points plotted correctly **(3)**

curve with good fit **(3)**

Use the decay curve to determine the half-life of the isotope.

time measured for $\frac{A}{2}$ **(2)**

$T_{\frac{1}{2}} = 3.3 \text{ days}$ **(2)**

Calculate the number of nuclei in the sample at the beginning of the investigation.

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

$\lambda = 2.4 \times 10^{-6}$ **(3)**

$A = \lambda N$ **(3)**

$N = 2.5 \times 10^{14}$ **(3)**

(*c*) Define capacitance and state its unit.

ratio of charge to voltage / $\frac{Q}{V}$ with notation **(3)**

farad **(3)**

A capacitor is an important component of a defibrillator. A simple defibrillator circuit is shown.

Each plate of a parallel plate capacitor in a defibrillator stores a charge of 0.11 C when a potential difference of 4.0 kV is applied across it.

Calculate the energy stored in the capacitor.

$\boldsymbol{C = 2.75 \times 10^{-5}}$ **(3)**

$\boldsymbol{E = \frac{1}{2}CV^2}$ **(3)**

$\boldsymbol{E = 220\ \mathrm{J}}$ **(3)**

What is the net charge of the capacitor when it stores this energy?

0 C ***(unit not needed)*** **(3)**

The capacitor discharges in a time of 15 ms. Calculate the average current flowing as the capacitor discharges.

$\boldsymbol{I = \frac{Q}{t}}$ **(3)**

$\boldsymbol{I = 7.3\ \mathrm{A}}$ **(3)**

Draw a diagram of the electric field between the charged plates of a parallel plate capacitor.

plates with charges indicated **(2)**

field lines in correct direction **(2)**

(*d*) A typical solar panel consists of a sandwich made of a p-n junction surrounded by a pair of conductors. When light falls on the solar panel, the photoelectric effect occurs and a current flows.

What is a p-n junction?

where a p–type semiconductor and an n-type semiconductor meet **(3)**

In 1921, Albert Einstein was awarded the Nobel Prize in Physics for his explanation of the photoelectric effect. Outline his explanation.

$\boldsymbol{hf = \phi + \frac{1}{2}mv^2}$ **(3)**

light travels in photons **(3)**

each photon gives all of its energy to one electron **(3)**

if energy is greater than work function, electron is emitted **(3)**

The work function of iron is 4.7 eV.

Calculate the maximum kinetic energy of an emitted electron when ultra violet radiation of wavelength 200 nm is incident on iron.

$\boldsymbol{c = f\lambda}$ **(3)**

$\boldsymbol{f = 1.5 \times 10^{15}}$ **(3)**

$\boldsymbol{hf = \phi + \frac{1}{2}mv^2}$ **(3)**

$\boldsymbol{\frac{1}{2}mv^2 = 2.4 \times 10^{-19}}$ **J** **(4)**