Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2016

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. In an experiment to verify the laws of equilibrium, the centre of gravity and the weight of a metre stick were found. The centre of gravity of the stick was at the 50.2 cm mark and its weight was 1.1 N. A number of forces were then applied to the metre stick, as shown in the diagram. The metre stick was horizontal and stationary.

Explain how

(*i*) the centre of gravity was found

balance (horizontally) on a pivot // suspend (horizontally) from a thread **(3)**

(*ii*) the weight of the metre stick was found

newton balance / weighing scales // mass balance & multiply by *g* **(3)**

(*iii*) the upward forces and downward forces were determined.

upward: newton balances // pulleys & (known) weights **(3)**

downward: (known) weights **(3)**

Give one possible reason why the centre of gravity is not at the 50.0 cm mark.

stick worn at one side / stick had a hole in one side / stick not uniform **(4)**

Use the data given to calculate

(*i*) the net force acting on the metre stick

upward force = 3.9 + 4.1 = 8.0 (N) **(2)**

downward force = 2 + 3 + 2 + 1.1 = 8.1 (N) **(2)**

net vertical force = 0.1 N // upward ≈ downward **(2)**

(*ii*) the sum of the moments about the 40 cm mark of the metre stick.

moment = force × displacement **(3)**

clockwise moments = (2 × 0.52) + (1.1 × 0.102) + (3.9 × 0.04) = 1.3082 (N m) **(3)**

anti-clockwise moments = (2 × 0.24) + (4.1 × 0.20) = 1.3 (N m) **(3)**

sum of moments ≈ 0.01 N m // clockwise ≈ anti-clockwise **(3)**

(–1 for use of incorrect axis)

Explain how your calculations verify the laws of equilibrium.

net vertical force ≈ 0 (N) **(3)**

sum of moments about a point ≈ 0 (N m) **(3)**

(0 for answers inconsistent with calculations)

2. A student investigated the variation of f, the fundamental frequency of a stretched string, with its length l. The string was kept at a constant tension of 8.5 N.

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

Indicate on your diagram the measured length of the string.

stretched string, two bridges, tuning fork / signal generator,
newton balance / pulley & (known) weights *(any three)* **(3 × 3)**

length shown between two bridges **(3)**

The following data were recorded.

f (Hz)	256	288	320	341	384	427	480	512
l (cm)	51.3	42.6	39.2	37.7	34.5	30.3	26.0	25.0

Draw a suitable graph to illustrate the relationship between f and l.

values of $^1/_f$ or $^1/_l$ **(3)**

axes labelled **(3)**

points plotted *(–1 for each omitted/incorrect point)* **(3)**

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

State the relationship and explain how the graph verifies it.

$f \propto {}^1/_l$ **(3)**

straight line through origin **(3)**

Use your graph to calculate

(*i*) the length of the string at a frequency of 192 Hz

value read from graph ($^1/_l \approx 1.52$ m^{-1}) **(2)**

value inverted ($l \approx 0.66$ m) **(2)**

(*ii*) the mass per unit length of the string.

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

value for slope from graph **(2)**

$\mu \approx 1.3 \times 10^{-4}$ **kg m^{-1}** **(2)**

3. In an experiment to measure the wavelength of monochromatic light, the angles θ between a central bright image ($n = 0$) and the first and second order images to the left and right were measured.

A source of monochromatic light and a diffraction grating of 500 lines per mm were used.

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

laser	**// vapour lamp**	**(3)**
grating & screen	**// grating & spectrometer**	**(3)**
	(correct arrangements)	
measure *D* from grating to screen	**// measure angle on left, θ_L**	**(3)**
measure *x* from central image to other images	**// measure angle on right, θ_R**	**(3)**
$\tan\theta = {}^{x}/_{D}$	**// $\frac{1}{2}(\theta_L \pm \theta_R)$**	**(3)**

The following data were recorded.

n	2 (left)	1 (left)	1 (right)	2 (right)
θ (degrees)	36.2	17.2	17.1	36.1

Use the data to calculate

(*i*) the wavelength of the light

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

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

$\lambda = 5.9 \times 10^{-7}$ m **(3)**

repeat and average appropriately **(3)**

(*ii*) the maximum number of images that could be observed.

$\theta_{max} = 90°$ **(2)**

$n_{max} = 3$ **(2)**

3 + 3 + 1 = 7 **(2)**

Explain what would happen to the positions of the images if

(*i*) the wavelength of the light was decreased

they would be closer together **(4)**

(*ii*) the diffraction grating was replaced with a diffraction grating of 300 lines per mm.

they would be closer together **(3)**

4. In an experiment to measure the resistivity of nichrome, a student measured the length, resistance and diameter of a sample of nichrome wire of uniform diameter.

The following data were recorded:

resistance of wire	= 29.1 Ω
length of wire	= 95.1 cm
diameter of wire	= 0.21 mm

Describe how the data were collected.

resistance: ohmmeter/multimeter **(3)**

length: metre stick **(3)**

diameter: micrometer **(3)**

How did the student ensure that the wire was of uniform diameter?

measure <u>diameter</u>/<u>thickness</u> at different positions // no kinks **(3)**

Use the data to calculate the resistivity of nichrome.

$\boldsymbol{A = \pi r^2}$ **(2)**

$\boldsymbol{r = \frac{1}{2}d}$ **(2)**

$\boldsymbol{\rho = {}^{RA}/_{l}}$ **(3)**

$\boldsymbol{\rho = 1.06 \times 10^{-6}\ \Omega\ m}$ **(3)**

The student then used a piece of this nichrome wire in an experiment to investigate the variation of the resistance of the piece of wire with its temperature.

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

thermometer and source of heat **(3)**

wire in container of liquid **(3)**

<u>ohmmeter</u>/<u>multimeter</u> connected across the wire **(3)**

The student drew a graph to show the relationship between resistance and temperature.

Draw a sketch of the graph. Describe this relationship.

labelled axes **(3)**

straight line with positive slope and correct intercept **(3)**

linear/proportional relationship // *R* increases with *T* **(3)**

5. (*a*) A cyclist's average power output when climbing a mountain is 280 W. He completes the climb in 18 minutes. How much energy does he use?

E* = *Pt **(4)**

***E* = 302400 J** **(3)**

(*b*) A sprinter starts from rest and accelerates uniformly for 3 seconds until she reaches a velocity of 10 m s^{-1}. She then runs at a constant velocity for 6 seconds before decelerating. Sketch a velocity-time graph of her motion.

labelled axes **(2)**

correct acceleration **(2)**

correct constant velocity **(2)**

correct deceleration **(1)**

(*c*) In your answer book copy the diagram on the right, which shows a light ray incident on the interface between glass and air.
In your diagram, sketch (*i*) the refracted ray, (*ii*) the weak reflected ray.
The critical angle of the glass is 42°.

correct refracted ray **(4)**

correct reflected ray **(3)**

(*d*) What is meant by the polarisation of a wave?

one plane **(4)**

of wave vibration **(3)**

(*e*) The ear canal acts as a cylindrical pipe closed at one end. It is of average length 2.3 cm. The speed of sound in air is 340 m s^{-1}. What is the fundamental frequency of the ear canal?

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

$\lambda = 4l = 0.092$ **(m)** **(2)**

$f = 3696$ **Hz** **(2)**

(*f*) State and define the SI unit of capacitance.

the farad **(4)**

couloumb per volt **(3)**

(*g*) Why is it more economical to transmit electrical energy at high-voltage?

low current **(4)**

less heat lost **(3)**

(*h*) When does the photoelectric effect occur?

when <u>a photon</u>/<u>light</u>/<u>em radiation</u> strikes a surface **(4)**

with a suitable <u>frequency</u>/<u>energy</u> **(3)**

(*i*) The magnets in the Large Hadron Collider (LHC) operate at a temperature of 1.92 K, which is colder than deep space. What is the value of this temperature in degrees Celsius (°C)?

273.15 indicated *(–1 if 273 used)* **(4)**

– 271.23 (°C) *(no marks deducted for omission of units)* **(3)**

(*j*) Experiments in the LHC in 2016 have suggested the existence of pentaquarks, hadrons that consist of five quarks. What terms are used for hadrons that consist of (*i*) two quarks, (*ii*) three quarks?

mesons **(4)**

baryons **(3)**

or

Draw a labelled diagram of an electromagnetic relay.

electromagnet **(4)**

armature **(3)**

6. A mass at the end of a spring obeys Hooke's law. The mass can be made to oscillate vertically, so that it executes <u>simple harmonic motion</u>. Explain the underlined term.

acceleration proportional to displacement **// equation and notation** **(3)**

State Hooke's law.

(restoring) force proportional to displacement **// equation and notation** **(3)**

Use Hooke's law to show that the mass executes simple harmonic motion.

$F = -ks$ **//** $F = ma$ **(3)**

$ma = -ks$ **(3)**

$a = -{}^{k}/_{m}(s)$ **(2)**

A simple pendulum also executes simple harmonic motion. The time taken for each oscillation of a certain simple pendulum on the Earth's surface is 2 s. The weight of its bob is 3.5 N. The bob travels along a curved path. It travels a distance of 18 cm during each oscillation.

Calculate

(*i*) the length of the pendulum

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

$l = 0.99$ **m** **(3)**

(*ii*) the maximum angular displacement of the pendulum.

$s = ¼(0.18) = 0.045$ **(m)** **(3)**

$\theta = {}^{s}/_{r}$ **(3)**

$\theta = 0.045$ **radians** **(3)**

Draw a diagram to show the forces acting on the bob when it is at its maximum displacement.

weight down **(3)**

tension up at angle to the vertical **(3)**

(–1 if no label shown)
(–1 for each additional incorrect force)

Calculate the restoring force at this point.

$F = W\sin\theta$ **(3)**

$F = 0.16$ **N** **(3)**

At what point during its movement does the bob have its greatest angular velocity?

when $\theta = 0$ **/ at the centre of oscillation / at its lowest point** **(3)**

The period of a simple pendulum varies with its height above the surface of the Earth. At what height will the period of a simple pendulum be 2% more than the period of a simple pendulum of the same length at the Earth's surface? Show your work clearly.

$T = 2\pi\sqrt{l/g}$ **(3)**

$g = \frac{Gm}{d^2}$ **(3)**

$T \propto d$ **(3)**

height = 127.4 km **(3)**

(–1 if answer given as radius of orbit: 6498.4 km)

7. At a lecture in Cork in 1843, James Joule, while describing his work on heat and temperature, suggested the principle of conservation of energy. Later in the nineteenth century, the work of Joule and Lord Kelvin led to the invention of the heat pump.

Distinguish between heat and temperature.

heat is a measure of energy **(3)**

temperature is a measure of hotness **(3)**

State the principle of conservation of energy

energy cannot be created or destroyed **(2)**

it can be changed from one form into another **(2)**

As part of his presentation, Joule proposed that the temperature of the water at the bottom of the Niagara Falls would be 0.12 °C greater than that at the top, due to gravitational potential energy being converted into heat energy. Calculate the height of the Niagara Falls.

$\boldsymbol{E = mgh}$ **//** $\boldsymbol{E = mc\Delta\theta}$ **(3)**

$\boldsymbol{mgh = mc\Delta\theta}$ **(3)**

$\boldsymbol{h}$ **= 51.4 m** **(3)**

In reality the increase in temperature will be much smaller. Suggest a reason for this.

energy converted into other forms // energy lost to surroundings **(3)**

In a heat pump, a fluid is used to transfer energy from a cold body to a warmer body.

Describe the operation of a heat pump and explain how a heat pump can be used to reduce the temperature of a cold region, for example the interior of a refrigerator.

pipe containing a fluid **(3)**

fluid changes state on passing through a <u>valve</u>/<u>compressor</u> **(3)**

latent heat associated with fluid changing from liquid to gas **(3)**

loss of <u>temperature</u>/<u>heat</u> in surroundings associated with fluid changing from liquid to gas **(3)**

State two desirable physical properties of the fluid used in a heat pump.

high (specific) latent heat of vaporisation **(3)**

low boiling point / volatile / low molecular mass / little intermolecular forces **(3)**

The fluid in the heat pump of a refrigerator has a specific latent heat of vaporisation of 4.6 MJ kg^{-1}. The internal volume of the refrigerator is 0.6 m^3. The heat pump removes 12 kJ of energy from the air in the refrigerator as the fluid evaporates.

Calculate

(*i*) the mass of fluid that has evaporated

$\boldsymbol{E = ml}$ **(3)**

$\boldsymbol{m}$ **= 0.0026 kg** **(3)**

(*ii*) the fall in temperature of the air in the refrigerator.

$\boldsymbol{\rho = m/V}$ **(3)**

$\boldsymbol{m}$ **= 0.74 (kg)** **(3)**

$\boldsymbol{E = mc\Delta\theta}$ **(2)**

$\boldsymbol{\Delta\theta}$ **= 16.1 °C** **(2)**

8. What is a semiconductor?

resistivity/conductivity // **resistivity** // **conductivity** **(3)**

between that of a conductor and an insulator // **decreases** // **increases with temperature** **(3)**

Distinguish between intrinsic and extrinsic conduction in a semiconductor.

intrinsic: pure semiconductor // **equal number of electrons & holes** **(3)**

extrinsic: doped semiconductor // **unequal number of electrons & holes** **(3)**

Explain how a pure semiconductor can be converted into (*i*) a p-type and (*ii*) an n-type semiconductor.

(i) doped with a group III element / element with fewer outer electrons / boron **(3)**

(ii) doped with a group V element / element with more outer electrons / phosphorus **(3)**

A semiconductor p-n junction acts as a diode.

Describe, with the aid of a labelled diagram, how a depletion layer is formed at the p-n junction.

p-type material connected to n-type material **(4)**

electrons move from n-type to p-type **(4)**

What is a depletion layer?

region with no charge carriers / high resistance **(3)**

Indicate on your diagram the sections of the p-n junction that are positively charged, negatively charged and neutral.

correctly labelled positive region (in n-type side of layer) **(3)**

correctly labelled negative region (in p-type side of layer) **(3)**

correctly labelled neutral regions (on both sides of depletion layer) **(3)**

A diode will be damaged if too large a current flows through it when it is connected in forward bias.

Explain how a diode might be protected from having too large a current flowing through it when it is connected across a battery, as in the diagram.

resistor **(3)**

in series **(3)**

What would be the effect on the current flowing in this diode if the terminals of the battery were reversed?

small/zero current **(3)**

Explain your answer.

diode in reverse bias // **larger resistance/depletion layer** **(3)**

A diode can be used as a rectifier. What is the function of a rectifier?

converts a.c. to d.c. **(3)**

What property of a diode makes it useful in a rectifier circuit?

allows current to flow in one direction only **(3)**

9. Lise Meitner and Marie Curie are the only women scientists to have elements named after them. In the case of Meitner this was for her work on fission and in the case of Curie it was for her discovery of radium and her work on radioactivity. Explain the underlined terms.

fission: **the breaking up of a large nucleus into smaller nuclei** **(3)**

(–1 for "atom" instead of "nucleus")
(–1 for omission of nuclear size)

with the release of energy and neutrons **(3)**

(–1 for omission of neutrons)

radioactivity: **the (spontaneous) disintegration of a nucleus** **(3)**

(–1 for "atom" instead of "nucleus")

with the emission of one or more types of radiation **(3)**

The following is the nuclear equation of a fission reaction explained by Meitner.

$$^{238}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{56}Ba + ^{97}_{36}Kr + 3^{1}_{0}n$$

Calculate the energy released during this reaction.

mass before = 3.9696×10^{-25} (kg) **(3)**

mass after = 3.9667×10^{-25} (kg) **(3)**

loss in mass = 2.9×10^{-28} (kg) **(3)**

$E = mc^2$ **(3)**

$E = 2.6 \times 10^{-11}$ **J** **(3)**

How many of the neutrons emitted in a fission reaction must, on average, cause a further fission so that the reaction is self-sustaining and safe? Explain your answer.

1 **(3)**

>1: uncontrolled reaction **// <1: chain-reaction ending** **(3)**

The neutrons emitted are sometimes passed through a moderator. Explain the function of the moderator.

slows down neutrons **// allows for more fission** **(3)**

Radium–225 is a radioactive isotope that decays into an isotope of actinium.

Write a nuclear equation for the decay of radium–225.

$^{225}_{88}Ra \rightarrow ^{225}_{89}Ac + ^{0}_{-1}e$ **(8 × 1)**

(–3 for each extra species)

Radium–225 has a half-life of 14.9 days.

Calculate the number of radium–225 nuclei in a sample that has an activity of 5600 Bq.

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

$\lambda = 5.38 \times 10^{-7}$ **(s^{-1})** **(3)**

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

$N = 1.04 \times 10^{10}$ **(3)**

10. State Faraday's law of electromagnetic induction.

emf induced is proportional to **// correct equation** **(3)**

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

Describe an experiment to demonstrate this law.

apparatus: magnet / source of magnetic flux, coil/conductor, meter **(3)**

e.g. move magnet, reading on meter **(3)**

e.g. move magnet faster, larger reading **(3)**

Derive an expression for the effective resistance of two resistors in parallel.

labelled diagram showing current splitting **(2)**

$I_T = I_1 + I_2$ **(3)**

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

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

A coil consists of 150 turns of wire and has a total resistance of 200 Ω.

It is connected in series with a 120 V d.c. power supply and a parallel combination of a 200 Ω and a 50 Ω resistor, as shown.

Calculate the current in

(*i*) the coil

R_T **in parallel part = 40 (Ω)** **(3)**

$R_{circuit}$ **= 240 (Ω)** **(3)**

$V = IR$ **(3)**

I **= 0.5 A** **(3)**

(*ii*) the 50 Ω resistor.

$I_{50} = {}^4/_5(I)$ **= 0.4 A** **(3)**

The d.c. supply is then replaced with an a.c. supply.

It takes 3 ms for the magnetic flux cutting the coil to increase by 4.5×10^{-4} Wb.

The average voltage of the a.c. supply during this time period is 120 V.

Calculate

(*i*) the average emf induced in the coil during the 3 ms time period

$E = {}^{d\Phi}/_{dt}$ **(3)**

E **= 0.15 (V)** **(3)**

0.15 × 150 = 22.5 V **(3)**

(*ii*) the average current in the coil during this period.

E_{coil} **= 97.5 (V)** **(3)**

$I = {}^{97.5}/_{240}$ **= 0.406 A** **(3)**

11. (*a*) State the laws of refraction.

incident ray, refracted ray and normal in the same plane **(4)**

$\boldsymbol{n = {}^{\sin i}/_{\sin r}}$ **(3)**

(*b*) Draw a ray diagram to show the formation of a virtual image in a magnifying glass.

object inside focal point of correctly shaped (converging) lens **(3)**

2 correct rays **(2)**

correct image at point of intersection of light rays **(2)**

(*c*) Explain what is meant by the term wavelength.

distance **(4)**

between two <u>crests</u>/<u>troughs</u> **(3)**

(*d*) As part of his investigations into light, Newton dispersed light with a prism. List the colours observed by Newton, in order, starting with the colour that was refracted the least.

correct colours *(5 of: red, orange, yellow, green, blue, indigo, violet)* **(4)**

correct order *(–1 for inverted order)* **(3)**

(*e*) In Young's experiment to demonstrate the wave nature of light he needed two coherent sources of light. How might he have produced these sources?

double slits *(allow "slits" or "grating")* **(7)**

(*f*) Calculate the energy of a photon of green light, which has a wavelength of 510 nm.

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

$\boldsymbol{E = hf}$ **(2)**

$\boldsymbol{E = 3.89 \times 10^{-19}\ \mathrm{J}}$ **(3)**

(*g*) Quantum mechanics is used to explain how electrons in atoms produce line emission spectra. Describe how these spectra are produced.

electrons gain energy to move to higher energy level **(4)**

return (to lower energy level) emitting <u>photon</u>/<u>light</u>/<u>em radiation</u> **(3)**

(*h*) State two differences between photons and electrons.

photons have no mass

photons have no charge

photons are <u>light</u> / <u>electromagnetic radiation</u>

photons are <u>packets</u>/<u>bundles</u> of energy *(any two)* **(4 + 3)**

12. (*a*) State the principle of conservation of momentum.

momentum before = momentum after **(3)**

if there are no external forces **(3)**

A polonium–212 nucleus decays spontaneously while at rest, with the emission of an alpha-particle.

What daughter nucleus is produced during this alpha-decay?

lead–208 **(4 + 3)**

The kinetic energy of the emitted alpha-particle is 8.9 MeV. Calculate its velocity.

$E = 1.426 \times 10^{-12}$ **(J)** **(3)**

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

$v = 2.07 \times 10^7$ **m s**$^{-1}$ **(3)**

Calculate the velocity of the daughter nucleus after the decay.

momentum before = momentum after = 0 **// ratio of masses = 208:4** **(3)**

$v = 4.0 \times 10^5$ **m s**$^{-1}$ **(3)**

(*b*) Define electric field strength.

$E = {}^{F}/_{Q}$ **// force per** **(3)**

notation **// unit charge** **(3)**

In your answer book, sketch the electric field pattern between two oppositely charged parallel plates.

parallel field lines **(2)**

from + to – **(2)**

Draw a diagram to show the forces acting on the drop of oil when it is stationary.

force of weight down **(3)**

equal force up **(3)**

(–1 if no label shown)
(–1 for each additional incorrect force)

The electric field strength between the plates was 3.6×10^4 V m^{-1} when the drop of oil was stationary, and the mass of the drop was 2.4×10^{-15} kg. Calculate the charge of the drop.

$F = Eq$ **//** $F = mg$ **(3)**

$Eq = mg$ **(3)**

$q = 6.53 \times 10^{-19}$ **C** **(3)**

How many excess electrons are on this drop?

4 **(3)**

(–1 if answer not rounded to nearest integer)

(*c*) What is meant by the Doppler effect?

(apparent) change in frequency of a wave **(3)**

due to (relative) motion between source and observer **(3)**

Define centripetal force.

force towards the centre **(2)**

on an object moving in a circle // correct formula **(2)**

A buzzer attached to a string of length 80 cm moves at a speed of 13 m s^{-1} in a vertical circle. The buzzer has a mass of 70 g and emits a note of frequency 1.1 kHz. An observer stands in the plane of motion of the buzzer, as shown in the diagram.

Calculate

(*i*) the maximum and minimum frequency of the note detected by an observer

$f' = {}^{fc}/_{c+u}$ **(3)**

f'_{max} **= 1143.7 Hz** **(3)**

$f' = {}^{fc}/_{c-u}$ **(3)**

f'_{min} **= 1059.5 Hz** **(3)**

(*ii*) the maximum and minimum tension in the string.

$\frac{mv^2}{r}$ **(2)**

mg **(2)**

T_{max} **= 15.5 N,** T_{min} **= 14.1 N** **(2)** (*d*) (*i*) The pair annihilation of an electron and a positron has been investigated for many years at CERN in Switzerland. Two gamma-ray photons are produced during this annihilation.

What is a positron?

positively charged electron **// anti-electron** **(3)**

Why are photons always produced in pairs during pair annihilation?

to conserve momentum **(3)**

Write an equation for this annihilation.

$^{0}_{-1}e + ^{0}_{+1}e \rightarrow 2hf$ // $^{0}_{-1}e + ^{0}_{+1}e \rightarrow 2\gamma$ **(8 × 1)**

(–3 for each extra species)

Calculate the frequency of the gamma-radiation produced in this annihilation.

$E = mc^2$ **(2)**

$E = 8.1 \times 10^{-14}$ **(J)** **(3)**

$f = 1.2 \times 10^{20}$ **Hz** **(3)**

The pair annihilation of a proton and an anti-proton is now being investigated at CERN.

Compare the energy produced in these two annihilations. Explain your answer.

energy from proton annihilation is greater **(3)**

proton mass is greater **(3)**

(*ii*) Electric motors have a huge range of applications in the modern world.
Two types of motor are the d.c. motor and the induction motor.

Draw a labelled diagram of a d.c. motor.

coil; magnet; power supply; carbon brushes; commutator **(6)**

(–1 for each missing item)

Use your diagram to explain why the coil of a d.c. motor rotates when current flows through the coil.

current carrying conductor in magnetic field **(3)**

force on each side **(3)**

rotation **(3)**

Describe how you would demonstrate the principle of operation of an induction motor.

apparatus **(3)**

method **(3)**

observation **(3)**

State one advantage of an induction motor over a d.c. motor

no sparking at brushes **// no need to replace brushes** **(4)**

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