Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2022
Deferred Examinations

Marking Scheme

Physics

Higher Level

Note to teachers and students on the marking schemes for the deferred examinations

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. However, it should be noted that the marking schemes for the deferred examinations may not necessarily be as detailed as the corresponding marking schemes for the main sitting of an examination, which serve to ensure consistency across a large team of examiners.

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 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 between the main sitting and the deferred sitting and from year to year. In the case of the deferred examinations, this means that the level of detail may vary by question, as the marking scheme will only have been finalised for the questions attempted by the candidates who sat these examinations.

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 a senior examiner when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes (whether for the main examinations or the deferred examinations) 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 concerned. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination will not necessarily be the same for the deferred sitting as for the main sitting or from one year to the next.

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.

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.

SECTION A (80 marks)

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

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1. A student carried out a laboratory experiment to verify the principle of conservation of momentum. During the experiment body A, moving at a constant velocity, was made to collide with body B, which was at rest. Both bodies then moved on together with a common velocity. The mass of body A was twice that of body B.

(*i*) Draw a labelled diagram of the experimental arrangement that the student could have used.

runway/air-track with two trolleys/riders **[3]**

means of getting trolleys to stick to each other, e.g. pin and cork **[3]**

means of measuring distance and time, e.g cards and light gates **[3]**

[–1 if no label present on diagram]

The student measured the velocity of the moving body before the collision and the velocity of the combined bodies after the collision.

(*ii*) Describe how the student could have made these measurements.

description of how distance was determined **[3]**

description of how time was determined **[3]**

description of how velocity was calculated, i.e. *v = s/t* **[3]**

(*iii*) What additional steps could the student have taken in order to make these measurements more accurate?

any two additional steps to improve accuracy **[4 + 3]**

(*iv*) Why should body A be moving with a constant velocity before the collision?

so that the velocity measured is the impact velocity / so its velocity on impact is known **[3]**

(*v*) How did the student check this?

measure the initial velocity of body A twice [e.g. compare different sections of tape] **[6]**

(*vi*) The velocity of the combined bodies was found to be 0.18 m s^{-1}. If the experiment had indeed verified the principle of conservation of momentum, what velocity would you expect body A to have had before the collision?

p **= mv / 3 × 0.18 = 0.54** **(3)**

0.54 ÷ 2 = 0.27 m s^{-1} **(3)**

2. In an experiment to measure the specific latent heat of vaporisation of water, steam was added to water that had been cooled to below room temperature.

(*i*) Draw a labelled diagram of the apparatus that the student could have used in the experiment.

means of producing steam **[3]**

means of delivering (dry) steam [e.g. steam trap, lagging of delivery tube] **[3]**

water in calorimeter (with lagging or lid) **[3]**

thermometer in water **[3]**

[–1 if no label present on diagram]

The following readings were made:

Mass of aluminium calorimeter = 25.6 g

Mass of calorimeter and water = 75.3 g

Final mass of calorimeter and water = 76.6 g

Room temperature = 19 °C

Initial temperature of water = 12 °C

Temperature of steam = 100 °C

Final temperature of water = 26 °C

(*ii*) Given that the specific heat capacity of aluminium is 910 J kg^{-1} K^{-1} and the specific heat capacity of water is 4180 J kg^{-1} K^{-1}, calculate the specific latent heat of vaporisation of water.

m_{water} = 49.7 (g) <u>or</u> m_{steam} = 1.3 (g) **[3]**

$\Delta\theta_{water}$ = 14 (°C) <u>or</u> $\Delta\theta_{steam}$ = 74 (°C) **[3]**

(ΔE) = ml **[3]**

(ΔE) = $mc\Delta\theta$ **[3]**

$(25.6 \times 910 \times 14) + (49.7 \times 4180 \times 14) = (1.3 \times l_v) + (1.3 \times 4180 \times 74)$ **[3]**

$l_v = 2.18 \times 10^6$ J kg^{-1} **[3]**

(*iii*) Why did the student use water that that had been cooled to below room temperature?

so that heat lost ≈ heat gained **[4]**

(*iv*) The student decided to repeat the experiment using a greater mass of steam. Discuss one advantage and one disadvantage of using a greater mass of steam.

advantage: less % error [in m_{steam} or in any $\Delta\theta$]

disadvantage: water gets too hot / loss of heat to surroundings **[4 + 2]**

3. In an experiment to measure *f*, the focal length of a concave mirror, a student first found an approximate value for the focal length. Then the student recorded the image distance *v* for different values of the object distance *u*.

The student recorded the data in the following table:

u (cm)	25.0	30.0	35.0	40.0
v (cm)	70.1	44.1	36.4	33.1

(*i*) What is meant by the focal length of a concave mirror?

distance from the focal point/focus **[3]**

to the [back of] the mirror **[3]**

(*ii*) How did the student find an approximate value for the focal length?

measured the image distance **[3]**

for a distant object **[3]**

(*iii*) Why did the student find an approximate value for the focal length?

to make sure the object was not placed inside the focal length **[3]**

(*iv*) Describe how the position of the image was determined.

move screen/mirror/object **[3]**

until sharpest image is formed **[3]**

(*v*) Use the data in the table to calculate the focal length.

$1/u + 1/v = 1/f$ **[6]**

one value calculated for *f* **[3]**

average *f* calculated **[3]**

The student later carried out an experiment to measure the focal length of a converging lens.

(*vi*) Sketch the shape of a converging lens.

correct shape **[3]**

(*vii*) How does the arrangement of the apparatus differ between the two experiments?

screen is on the same side of the mirror as the object **[2]**

screen is on the other side of the lens as the object **[2]**

4. The following is part of a student's report on an experiment to measure the wavelength of monochromatic light with a diffraction grating.

"The apparatus, including a monochromatic light source, was arranged so that a number of bright images could be observed. The position of the central bright image was noted. After this the angular positions of the other images were determined and the formula $n\lambda = d\sin\theta$ was used to find the wavelength of the light."

(*i*) What is meant by the word "monochromatic"?

one colour/wavelength/frequency **[3]**

(*ii*) Describe, with the aid of a labelled diagram, how the apparatus was arranged in this experiment.

diffraction grating **[3]**

screen/spectrometer **[3]**

correct arrangement **[3]**

[–1 if no label present on diagram]

Explain how (*iii*) the value of *d*, and (*iv*) the value of θ for each image, was determined.

(*iii*) read from diffraction grating **[3]**

(*iv*) protractor // spectrometer // meter stick **[3]**

for angle with straight through // subtract zero order angle // correct trigonometry **[3]**

In carrying out this experiment the student wanted to have a large angular separation of the images.

(*v*) Why would the student have wanted this?

less % error **[4]**

(*vi*) State one way in which the student could have achieved a larger angular separation of the images without changing the light source.

move grating and screen apart / decrease *d* **[3]**

(*vii*) The third order image of the monochromatic light source was obtained at an angle of 50°. If the grating being used had 400 lines per mm, calculate the wavelength of the light.

$3\lambda = (1/400000) \times \sin 50°$ **[3]**

$\lambda = 6.38 \times 10^{-7}$ m **[3]**

(*viii*) Draw a diagram of what is observed when a beam of white light is passed through a diffraction grating.

spectrum

multiple spectra

red diffracted most / blue diffracted least

central white order **Any two items [4 + 2]**

[–1 if no diagram present]

5. A student was asked to investigate the variation of the resistance of a metallic conductor with temperature. The student set up a circuit using the appropriate equipment and recorded the value of the resistance, *R*, of the conductor as its temperature, θ, was changed.

The data recorded are shown in the table.

θ (°C)	20	30	40	50	60	70	80
R (Ω)	8.1	8.5	9.0	9.5	10.0	10.4	10.9

(*i*) Draw a labelled diagram of the experimental arrangement used and describe how the data in the table were obtained.

conductor in liquid **[3]**

heat source and thermometer **[3]**

ohmmeter / multimeter (set to read ohms) / ammeter and voltmeter **[3]**

heat water and read thermometer and ohmmeter **[3]**

[–1 if no label present on diagram]

(*ii*) Use the table to draw a suitable graph that shows the relationship between the resistance of the conductor and its temperature.

labelled axes **[3]**

points plotted **[6]**

[–1 for each point missing or incorrectly plotted]

straight line of best fit **[3]**

(*iii*) Describe the relationship between resistance and temperature shown by your graph.

resistance increases [linearly] with temperature **[3]**

(*iv*) Use your graph to find the rate of change of resistance with respect to temperature for the metallic conductor.

slope formula **[2]**

$(dR/d\theta) \approx 0.047\ \Omega\ ^{\circ}C^{-1}$ ***[accept*** **$\Omega\ K^{-1}$** ***for units]*** **[2]**

(*v*) Estimate the resistance of the metallic conductor when its temperature is –10 °C.

$R \approx 6.7\ \Omega$ / answer consistent with graph or $dR/d\theta$ calculation **[3]**

(*vi*) Later the student carried out a similar experiment to measure the variation of resistance with temperature for a thermistor. How would the results of the two experiments differ?

resistance decreases for a thermistor **[3]**

non-linear relationship for a thermistor **[3]**

SECTION B (224 marks)

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

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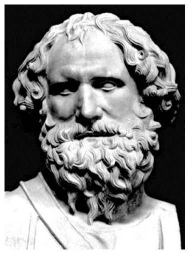
6. Answer any **eight** of the following parts, (*a*), (*b*), (*c*), etc.

(*a*) An athlete weighing 850 N runs up a stairs in 6 seconds. If the vertical height of the stairs is 2.5 m, calculate the average power generated by the athlete.

P = W/t / P = Fs/t / P = Fv **[4]**

***P* = (850 × 2.5) ÷ 6 = 354 W** **[3]**

(*b*) The picture is of the Greek mathematician and physicist Archimedes of Syracuse. State Archimedes' principle.



upthrust/buoyancy

is equal to the weight of displaced fluid/liquid **[4 + 3]**

(*c*) Calculate the length of a pendulum that has a period of one second.

***T* = 2π√(*l/g*)** **[4]**

***l* = 0.248 m** **[3]**

(*d*) A thermocouple thermometer and an alcohol-in-glass thermometer each gave a different reading when placed in the same container of water. Explain why this occurred.

different thermometric properties **[4]**

change differently with temperature changes **[3]**

(*e*) A standing wave is set up in a stretched string that is fixed at each end. Sketch the first two harmonics that are produced when the string is plucked.

first harmonic: node – antinode – node

second harmonic: node – antinode – node – antinode – node **[4 + 3]**

(*f*) What is meant by sound intensity?

power / rate of change of energy **[4]**

per unit area **[3]**

(*g*) Calculate the effective focal length of two thin lenses in contact, one a converging lens of focal length 5 cm and the other a diverging lens of focal length 15 cm.

$1/f_T = 1/f_1 + 1/f_2$ <u>or</u> $P_T = P_1 + P_2$ **[3]**

f_1 = 5 (cm); f_2 = –15 (cm) **[1 + 1]**

f_T = 7.5 cm **[2]**

(*h*) A precaution usually taken when using electrical equipment is to put a fuse in the circuit. Explain the role of a fuse.

breaks the circuit **[4]**

when current is too high **[3]**

(*i*) A solid copper cube of side 5 cm rests on a horizontal table. Find the pressure exerted by the cube on the table.

$P = F/A$ **[2]**

$\rho = m/V$ **[2]**

$W = mg$ **[2]**

P = 8960 × 0.05 × 9.8 = 4390.4 Pa **[1]**

(*j*) What is meant by the *U*-value of a material?

rate of energy transfer **[3]**

through 1 m^2 of a surface **[2]**

when a temperature difference of 1 K across the surface **[2]**

(*k*) How are X-rays produced?

high speed electrons **[4]**

hit a metal **[3]**

(*l*) *a*. Name the metal used as a target in the Cockroft and Walton experiment.

lithium **[7]**

or

b. A light-emitting diode emits light of a particular colour when a current flows. What determines the colour of the emitted light?

material used / energy gap between free electrons and holes **[7]**

7. Define (*i*) displacement, (*ii*) velocity.

(*i*) **distance in a given direction** **[3]**

(*ii*) **rate of change of** **// speed** **[3]**

displacement **// in a given direction** **[3]**

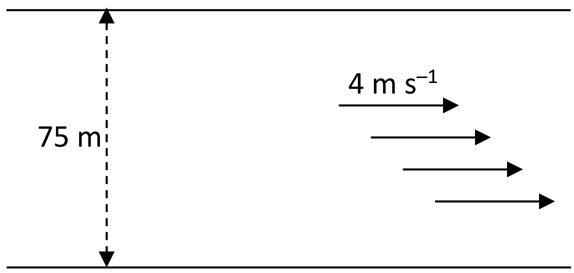
(*iii*) What is a vector quantity?

a quantity with magnitude **[3]**

and direction **[3]**

A swimmer wants to cross a river which is 75 m wide. The banks of the river are parallel.
The river is flowing with a velocity of 4 m s^{-1} parallel to the river banks, as in the diagram.

The swimmer sets out to swim across the river with a speed of 2.5 m s^{-1} perpendicular to the banks of the river.



(*iv*) What is the resultant velocity of the swimmer?

magnitude: $\sqrt{(2.5)^2 + (4)^2} = 4.72$ **m** s^{-1} **[3]**

direction: $\tan^{-1}(4/2.5) = 58°$ **[3]**

(*v*) How long will it take the swimmer to reach the opposite bank of the river?

$t = s/v$ **[3]**

$t = 75/2.5 = 30$ **s** **[3]**

(*vi*) What will be the displacement of the swimmer from his starting position when he has reached the opposite bank?

$s = vt$ **[3]**

$s = 4.72 \times 30 = 141.6$**m** **[3]**

(*vii*) Describe a laboratory experiment to find the resultant of two co-planar forces.

application of two known or measureable forces **[3]**

application of third known or measureable force to counteract first two forces **[3]**

lines drawn to indicate magnitude and direction of the forces **[3]**

find the resultant of the first two forces **[3]**

A car of mass 1000 kg is freely rolling downhill on a road that is at an angle of 10° to the horizontal.

(*viii*) If the frictional force on the car as it moves down the slope is a constant 550 N, calculate the acceleration of the car.

$W\sin10° = mg\sin10° = 1000 \times 9.8 \times \sin10° = 1702$ **[N]** **[3]**

$F = 1702 - 550 = 1152$ **[N]** **[3]**

$F = ma$ **[3]**

$a = 1152 \div 1000 = 1.152$ **m** s^{-2} **[2]**

8. (*i*) What is the Doppler effect?

(apparent) change in frequency **[3]**

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

(*ii*) Explain how the Doppler effect occurs.

as source moves towards observer // as source moves away from observer **[3]**

shorter *λ* // longer *λ* **[3]**

increased *f* // decreased *f* **[3]**

(*iii*) What is meant by the emission line spectrum of an element?

specific frequencies of e.m. radiation emitted by an element **[3]**

(*iv*) How is the emission line spectrum of an element related to the energy levels of the electrons in an atom of that element?

Electron moves to a higher level (when given energy) **[3]**

Electron falls to a lower level **[3]**

$E_2 - E_1 = hf$ **[3]**

(*v*) Describe how you would show the emission line spectrum of hydrogen in the laboratory.

hydrogen vapour lamp [with energy source, e.g. electric current] **[3]**

diffraction grating / prism **[3]**

(*vi*) The wavelength of the red line in the emission line spectrum of hydrogen was measured in the laboratory as 656 nm. Calculate its frequency.

$c = f\lambda$ **[3]**

$f = (3 \times 10^8) \div (656 \times 10^{-9}) = 4.57 \times 10^{14}$ **Hz** **[3]**

In the 1920s, American astronomer Edwin Hubble, pictured, used the Doppler effect to study distant galaxies. He found that most galaxies were moving away from Earth. He also found that the galaxies which were furthest away from Earth were the ones which were moving with the fastest speeds.

A certain galaxy is moving at a speed of 3×10^7 m s^{-1} away from the Earth. Astronomers on Earth analysed the light from this galaxy and measured the frequency of the red line in the hydrogen emission line spectrum.

(*vii*) Calculate the frequency they observed.

$f' = cf/(c \pm u)$ **[3]**

substitution **[3]**

$f' = 4.15 \times 10^{14}$ **Hz** **[3]**

From their observations, astronomers have also calculated that the Sun is orbiting the centre of the Milky Way galaxy with a speed of 220 km s^{-1}. The Sun takes 240 million years to complete one orbit of the galaxy.

(*viii*) Use this data to calculate a value for the radius of the orbit of the Sun about the centre of the galaxy.

$T = 2\pi/\omega$ **[2]**

$T = 7.57 \times 10^{15}$ **s** **[2]**

$v = r\omega$ **[2]**

$r = 2.65 \times 10^{20}$ **m** **[2]**

9. State (*i*) Faraday's law of electromagnetic induction, (*ii*) Lenz's law.

(*i*) emf induced **[3]**

is proportional to the rate of change of [magnetic] flux **[3]**

(*ii*) the direction of the induced current/emf **[3]**

is such that it opposes the change which caused it **[3]**

(*iii*) Describe how you would demonstrate each of these laws in the laboratory.

(*i*) means of changing magnetic flux **[3]**

means of measuring induced emf **[3]**

correct observation **[3]**

(*ii*) suitable apparatus **[3]**

correct observation **[3]**

The diagram shows a square coil of wire of side 20 cm. There are 4 turns of wire in the coil. The coil is placed perpendicular to a magnetic field of flux density 1.5×10^{-3} T.

(*iv*) Calculate the magnetic flux through the coil.

$\Phi = BA$ **[3]**

$\Phi = (1.5 \times 10^{-3}) \times (0.2)^2 = 6 \times 10^{-5}$ **Wb** **[3]**

The coil is then moved out of the magnetic field in a direction parallel to one of the sides of the square.

(*v*) If the speed at which the coil is moved is 2.5 m s^{-1}, calculate the emf induced in the coil.

emf $= -N(d\Phi/dt)$ **[3]**

$t = s/v = 0.2/2.5 = 0.08$ **[s]** **[3]**

emf $= 4 \times (6 \times 10^{-5}/0.08) = 0.003$ **V** **[3]**

The diagram shows a transformer.

The coils A and B are wound on a laminated iron core.

(*vi*) What happens in coil B when an alternating voltage is applied to coil A?

voltage/current **[3]**

(*vii*) What is the purpose of a transformer?

to change the (size of an alternating) voltage **[3]**

(*viii*) Describe the principle of operation of a transformer.

alternating voltage in primary coil **[3]**

changing magnetic field (induced in core) **[3]**

[alternating] voltage induced in secondary coil **[2]**

10. (*a*) The photograph shows a flat-screen television set. Flat-screen displays have replaced cathode ray tubes in most applications.

(*i*) Explain, with the aid of a labelled diagram, the operation of a cathode ray tube.

cathode and anode **[3]**

cathode heated **[3]**

emission of electrons at cathode **[3]**

application of electric/magnetic field (to change direction of electron beam) **[3]**

screen **[3]**

[–1 if no label present on diagram]

(*ii*) State two of the disadvantages of cathode ray tubes that led to their replacement by flat-screen displays.

any two disadvantages [e.g. heat loss, size etc.] **[2 × 3]**

(*b*) The photocell is based on the photoelectric effect.

(*i*) What information does the photoelectric effect give about the nature of light?

quantised/photonic nature of light **[3]**

(*ii*) What effect does the *frequency* of the incident light have on the current flowing in a photocell? Describe how you would show this effect in the laboratory.

no current flows if frequency is below a certain (threshold) frequency **[3]**

e.m. radiation source of varying frequency (incident on photocell) **[3]**

ammeter/galvanometer **[2]**

change in current detected **[2]**

(*iii*) What effect does the *intensity* of the incident light have on the current flowing in a photocell? Describe how you would show this effect in the laboratory.

current increases with intensity [above threshold frequency] **[3]**

e.m. radiation source of varying intensity (e.g. distance incident on photocell) **[3]**

ammeter/galvanometer **[2]**

change in current detected **[2]**

Light of frequency 7.6×10^{14} Hz is incident on a metal that has a work function of 2.1 eV. Calculate (*iv*) the energy of a photon of the incident light, (*v*) the energy of the most energetic electron emitted.

(*iv*) $\boldsymbol{E = hf}$ **[3]**

$\boldsymbol{E = (6.6 \times 10^{-34}) \times (7.6 \times 10^{14}) = 5.04 \times 10^{-19}\ \mathrm{J}}$ **[3]**

(*v*) $\boldsymbol{\Phi = 2.1\ \mathrm{eV} = 3.36 \times 10^{-19}\ [\mathrm{J}]}$ **[3]**

$\boldsymbol{E = 5.04 \times 10^{-19} - 3.36 \times 10^{-19} = 1.68 \times 10^{-19}\ \mathrm{J}}$ **[3]**

11. Define (*i*) potential difference, (*ii*) resistance.

(*i*)	**work**	**// formula**	**[3]**
	per unit charge	**// notation**	**[3]**
(*ii*)	**voltage**	**// formula**	**[3]**
	divided by current	**// notation**	**[3]**

(*iii*) Derive an expression for the total effective resistance of resistors R_1 and R_2 shown in the diagram on the right.

$I_T = I_1 + I_2$ **[3]**

$V/R_T = V/R_1 + V/R_2$ **[3]**

$1/R_T = 1/R_1 + 1/R_2$ **[3]**

An LDR is a light dependent resistor. It can be used in a circuit to monitor the intensity (brightness) of light.

(*iv*) Describe an experiment to show how the resistance of an LDR varies with the intensity of the light falling on it.

apparatus **[3]**

method **[3]**

observation **[3]**

(*v*) Sketch a graph to show the relationship between the resistance of an LDR and the intensity of the light falling on it.

labelled axes **[3]**

correct shape **[3]**

In the circuit diagram above, the resistance of the LDR is 1.1 kΩ when light of a particular intensity falls on it.

(*vi*) Calculate the total resistance of the circuit.

1/1100 + 1/900 = 1/495 **[3]**

495 [Ω] **[3]**

495 + 500 = 995 Ω **[3]**

(*vii*) Calculate the current flowing through the 900 Ω resistor.

12/995 = 0.012 [A] **[3]**

(11/20)(0.012) = 0.0066 A **[3]**

(*viii*) If the resistance of the LDR decreases, explain what happens to the potential difference across the 500 Ω resistor.

potential difference across 500 Ω resistor increases **[3]**

because resistance of parallel section decreases **[2]**

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

(*a*) CERN, based near Geneva, is the European centre for research in particle physics. The photograph shows the particle accelerator in CERN, which is in a 27 km long circular tunnel. The accelerator has been used to find many of the fundamental particles of matter.

Explain what is meant by the following terms:

(*i*) quark (*ii*) lepton

(*iii*) meson (*iv*) baryon

(*i*) elementary/fundamental particle [3]

found in hadrons / feels strong force/ [3]

(*ii*) elementary/fundamental particle [3]

does not feel strong force [3]

(*iii*) quark anti-quark pair [*accept* "two quarks"] [6]

(*iv*) three quarks [6]

(*v*) State the quark composition of the proton and the neutron.

proton: up up down [3]

neutron: up down down [3]

In a particle accelerator, two protons are accelerated to half the speed of light before being allowed to collide. In the collision a single neutral pi meson (π^0) is formed, as in the equation below.

$$p + p \rightarrow p + p + \pi^0$$

(*vi*) Why is it that the pi meson that is formed in the collision must be neutral?

so that charge is conserved [5]

(*vii*) Assuming that the pi meson produced has a negligible speed, and that both protons have an equal speed of *v* after the collision, calculate *v*.

$E = mc^2$ **[6]**

$m_\pi = 264 \times 9.1 \times 10^{-31} = 2.4 \times 10^{-28}$ **kg [3]**

$E_\pi = (2.4 \times 10^{-28}) \times (3.0 \times 10^8)^2 = 2.16 \times 10^{-11}$ **J [3]**

$E_K = ½mv^2 \, / \, (1.67 \times 10^{-27})v^2 = (1.67 \times 10^{-27}) \times (0.5 \times 3.0 \times 10^8)^2 - 2.16 \times 10^{-11}$ **[3]**

$v = 9.8 \times 10^7$ **m s^{-1} [3]**

Anti-matter is composed of particles that have the same mass as particles of ordinary matter but have opposite charge. They can be created in particle accelerator laboratories such as CERN.

(*viii*) Name the scientist who predicted the existence of anti-matter.

Dirac [3]

(*b*) (*i*) Describe an experiment to demonstrate that a current-carrying conductor experiences a force when placed in a magnetic field.

apparatus **[3]**

method **[3]**

observation **[3]**

The diagram shows a moving-coil loudspeaker.

(*ii*) Name the parts A, B and C.

A = cone **[3]**

B = coil **[3]**

C = magnet **[3]**

(*iii*) Explain how the moving-coil loudspeaker emits sound.

current carrying coil experience a force in magnetic field **[3]**

coil moves **[3]**

cone moves **[3]**

The d.c. motor and the moving-coil galvanometer are based on the same principle of operation as the moving-coil loudspeaker.

(*iv*) Draw a labelled diagram of a simple d.c. motor.

magnet, coil, commutator **[3 × 3]**

[-1 if no label present on diagram]

The circuit controlling an electric motor may contain an electromagnetic relay.

(*v*) What is the function of an electromagnetic relay and how does it carry out that function?

current in one circuit switches on current in second circuit **[3]**

electromagnet **[3]**

pivot switch **[3]**

Describe how a moving-coil galvanometer may be arranged so as to function (*vi*) as an ammeter, (*vii*) as a voltmeter.

(*vi*) low resistance **[3]**

in parallel **[3]**

(*vii*) high resistance **[3]**

in series **[2]**

13. Read the following passage and answer the accompanying questions.

Off-shore wind farms are making electricity suppliers look again at high-voltage d.c. transmission to reduce operating costs. Out at sea, turbine blades turn more quickly than on land thanks to faster, more stable winds. This means that power generation shoots up because it is governed by the cube of the airstream's velocity. The power capacity of the largest offshore turbines is currently 5 MW whereas on land it is 3 MW.

To make best use of the energy generated at sea, it must be transmitted back to the mainland in an efficient manner. For this reason the power must be transmitted to land at a very high voltage. Where turbines are more than about 80 kilometres from shore, a.c. transmission is not viable, due to very large energy losses in the transmission system.

The alternative is high-voltage d.c. transmission. This was used in the cross-channel link between Britain and France in the last century. More recently, China has been developing the use of high voltage d.c. to transmit electrical energy between generating stations and cities.

However transmitting electricity at high voltages places greater demands on the reliability of insulating materials used in these electrical transmission systems.

Adapted from *Physics World Focus on Nanotechnology, June 2013*

(*a*) How do a.c. and d.c. differ?

a.c. changes direction **[7]**

(*b*) A wind turbine has a power output of 200 kW when the wind speed is 10 m s^{-1}.
Calculate the power of the turbine when the wind speed increases to 15 m s^{-1}.

$(15 \div 10)^3 = 3.375$ **[4]**

$200 \times 3.375 = 675$ kW **[3]**

(*c*) The average power output of a wind turbine over a period of one year was 300 kW.
Calculate the number of units of electrical energy generated by the turbine in that year.

1 year = 8760 hours **[4]**

300 × 8760 = 2628000 [kW hours] **[3]**

(*d*) The conversion of a.c. to d.c. is required for high-voltage d.c. transmission.
Name the term used to describe this conversion. Draw the electrical circuit symbol for the semiconductor device used in this process.

rectification

correct circuit symbol for a diode **[4 + 3]**

(*e*) The peak a.c. voltage generated by a particular wind turbine is 690 V.
Calculate the rms voltage generated.

reference to $\sqrt{2}$ **[4]**

$690 \div \sqrt{2} = 488$ V **[3]**

(*f*) The average power generated by the wind turbine described in part (*e*) is 1.5 MW.
Calculate the rms current generated.

$P = VI$ **[4]**

$I = (1.5 \times 10^6) \div 488 = 3074$ A **[3]**

(*g*) Explain why a very high voltage is required for the efficient transmission of electricity.

low current

small loss in heat/energy **[4 + 3]**

(*h*) Name a material that is an electrical insulator. State one reason why an insulator is needed in the transmission of electricity.

e.g. plastic

safety **[4 + 3]**

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

(*a*) (*i*) State Hooke's law.

force proportional to **// F = (–)ks** **[2]**

displacement **// notation** **[2]**

The length of the spiral spring in the diagram increases from 50 cm to 56 cm when a body of weight 0.7 N is hung from the spring.

(*ii*) Calculate the elastic constant of the spring.

F = (–)ks **[2]**

0.7 = *k*(0.06) **[2]**

***k* = 11.7 N m^{-1}** **[2]**

When the body at the end of the spring is pulled down by a further short distance and then released, the mass oscillates with simple harmonic motion.

(*iii*) Calculate the period of the simple harmonic motion.

$T = 2\pi/\omega$ **[3]**

$\omega = \sqrt{(k/m)}$ **[3]**

ω **= 12.8 (s^{-1})** **[3]**

***T* = 0.49 s** **[3]**

At what point during its oscillation does the body have (*iv*) maximum velocity, (*v*) maximum acceleration?

(*iv*) at the equilibrium position, i.e. 56 cm **[3]**

(*v*) at a position of maximum amplitude **[3]**

(acceleration due to gravity, g = 9.8 m s^{-2})

(*b*) (*i*) State Snell's law of refraction.

sin *i* is proportional **[3]**

to sin *r* **[3]**

A ray of blue light with a wavelength of 480 nm in air is incident on a rectangular glass block, as shown in the diagram.

(*ii*) Calculate the refractive index of the glass for blue light.

sin 40° ÷ sin 25° / sin i ÷ sin r **[3]**

n = 1.52 **[3]**

(*iii*) Calculate the speed of this light in the glass.

$n = c_1 \div c_2$ **[3]**

$c = 1.97 \times 10^8$ m s^{-1} **[3]**

(*iv*) Calculate the wavelength of this light in the glass.

$\frac{c_1}{\lambda_1} = \frac{c_2}{\lambda_2}$ **or** **$\lambda = \lambda_{air}/n$** **[3]**

λ = 315 nm **[3]**

A ray of red light, incident at the same point on the glass block, takes a different path in the block.

(*v*) Explain why this is happens.

red light has a different refractive index / red light has a different velocity in the block / red light has a different wavelength in the block **[4]**

(*c*) (*i*) What is a capacitor?

a device that stores charge / separates charge **[6]**

(*ii*) Define the unit of capacitance, i.e. the farad.

coulomb per volt **[3]**

A parallel plate capacitor of capacitance 3 μF has plates A and B connected across a 6 V battery, as shown in the diagram on the right.

Calculate the charge on (*iii*) plate A, (*iv*) plate B.

(*iii*) $\boldsymbol{Q = (3 \times 10^{-6}) \times 6 = (+)1.8 \times 10^{-5}}$ **C** **[3]**

(*iv*) $\boldsymbol{Q = -1.8 \times 10^{-5}}$ **C** **[3]**

(*v*) Calculate the energy stored in the capacitor.

$\boldsymbol{E = \frac{1}{2}CV^2 = 5.4 \times 10^{-5}}$ **J** **[3]**

A 2 μF capacitor, with plates X and Y, is now connected in parallel with the first capacitor across the 6 V battery, as shown in the diagram on the left.

Calculate the charge that is now on (*vi*) plate A, (*vii*) plate B, (*viii*) plate X, (*ix*) plate Y.

(*vi*) **[+]**$\boldsymbol{1.8 \times 10^{-5}}$ **C** **[1]**

(*vii*) $\boldsymbol{-1.8 \times 10^{-5}}$ **C** **[1]**

(*viii*) **[+]**$\boldsymbol{1.2 \times 10^{-5}}$ **C** **[2]**

(*ix*) $\boldsymbol{-1.2 \times 10^{-5}}$ **C** **[2]**

(*x*) Calculate the capacitance of a single capacitor which could store as much energy as is stored in the two capacitors connected in parallel across the 6 V battery.

Q = $\boldsymbol{3 \times 10^{-5}}$ **C** **[2]**

5 μF **[2]**

(*d*) (*i*) What is meant by nuclear fission?

the splitting of a large nucleus **[3]**

into two smaller nuclei [with the release of neutrons/energy] **[3]**

[-1 if atom used instead of nucleus]

The equation below gives one of the many reactions in the fission of uranium–235.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Z + ^{89}_{X}Kr + 3Y + \textit{Energy}$$

(*ii*) Is this a spontaneous nuclear reaction or an induced nuclear reaction?

induced **[3]**

(*iii*) What numbers or symbols do X, Y and Z represent in the above equation?

X = 36 **[3]**

Y = n **[3]**

Z = Ba **[3]**

The krypton–89 isotope decays by beta-emission to rubidium. The decay constant for the isotope is $3.67 \times 10^{-3}\ s^{-1}$.

(*iv*) Calculate the number of atoms of krypton–89 in a sample of the isotope that emits 2.0×10^{5} beta particles per second.

$A = \lambda N$ **[3]**

$N = (2.0 \times 10^{5}) \div (3.67 \times 10^{-3}) = 5.45 \times 10^{7}$ **[3]**

(*v*) What is the half-life of krypton–89?

$T_{½} = (\ln 2)/\lambda$ **[2]**

$T_{½} = 188.9$ s **[2]**