Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE 2009

MARKING SCHEME

PHYSICS

HIGHER LEVEL

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General Guidelines

In considering this marking scheme the following points should be noted.

1. In many instances only key words are given – words that must appear in the correct context in the candidate's answer in order to merit the assigned marks.

2. 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 conjun ction 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 whic h 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, one mark is deducted, when indicated

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

SECTION A (120 marks)

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

Question 1

In an experiment to measure the acceleration due to gravity, the time *t* for an object to fall from rest through a distance *s* was measured. The procedure was repeated for a series of values of the distance *s*. The table shows the recorded data.

s/m	0.30	0.50	0.70	0.90	1.10	1.30	1.50
t/s	0.247	0.310	0.377	0.435	0.473	0.514	0.540
t^2/s^2	0.0610	0.0961	0.1421	0.1892	0.2237	0.2642	0.2916

Draw a labelled diagram of the apparatus used in the experiment .
timer, ball, release mechanism, pressure plate/trap door (any two items for 3 marks) 3+2+1
(–1 if release mechanism not labelled)

Indicate the distance *s* on your diagram.
(perpendicular) distance indicated between bottom of ball and top of pressure plate
(any correct answer) 3

Describe how the time interval *t* was measured.
timer starts when ball leaves release mechanism 3
timer stops when ball hits pressure plate/trap door/ impact switch 3

15

Calculate a value for the acceleration due to gravity by drawing a suitable graph based on the recorded data.

at least 6 correct values for t^2	**(–1 per each incorrect value)**	3
axes correctly labelled		3
at least 6 points correctly plotted		3
straight line with a good distribution	**(–1 for poor distribution)**	3
correct slope method		3
slope = 5.02 // 0.198 (≈ 0.20)		3
g = (10.04 ± 0.20) m s^{-2}	**(–1 for omission of or incorrect unit)**	3

21

Give two ways of minimising the effect of air resistance in the expe riment.

small(object)/ smooth(object)/ no draughts/ in vacuum/ distances relatively short
heavy (object) / dense / spherical/ aerodynamic 2+2

4

Question 2

A student was asked to measure the focal length of a converging lens. The student measured the image distance *v* for each of three different object distances *u*. The student recorded the following data.

u/cm	20.0	30.0	40.0
v/cm	65.2	33.3	25.1

Describe how the image distance was measured.

object, (converging) lens, screen /search pin **(for any two items, 3 marks)** 2×3
sharp image (state/imply) // no parallax (between image and search pin) 3
measure (distance) from image/screen to (centre of) lens 3

12

Give two precautions that should be taken when measuring the image distance.

measure from the centre of the lens (to the screen) / measure perpendicular distance / avoid parallax error / check zero error in metre rule **(any two precautions)** 2×3

6

Use all of the data to calculate the focal length of the converging lens.

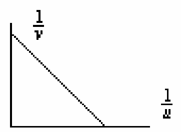
$^1/u + ^1/v = ^1/f$ 3
correct substitution (once) 3
f = 15.3 cm, 15.8 cm, 15.4 cm 3+2+1
f_{ave} = (15.5 ± 0.4) cm **(–1 for omission of or incorrect unit)**

15

Alternative (graphical method):

$1/u$	0.050	0.033	0.025
$1/v$	0.0153	0.0300	0.0398

inverse values for u and for v 2× 3
plot points 3
read intercept(s) 3
f = (15.87 ± 0.40) cm 3 (–1 for omission of or incorrect unit)



What difficulty would arise if the student placed the object 10 cm from the lens?

object inside focal point/length / virtual image / image cannot be formed on a screen / difficult to locate image (by no parallax method) (any *one*) 7

7

Question 3

A student investigated the variation of the fundamental frequency f of a stretched string with its tension T. The following is an extract of the student's account of the experiment.

> **"I fixed the length of the string at 40 cm. I set a tuning fork of frequency 256 Hz vibrating and placed it by the string. I adjusted the tension of the string until resonance occurred. I recorded the tension in the string. I repeated the experiment using different tuning forks."**

The following data were recorded.

f/Hz	256	288	320	341	384	480	512
T/N	2.4	3.3	3.9	4.3	5.7	8.5	9.8

How was the tension measured? How did the student know that resona nce occurred?

a newton balance/scales // weight of pan+contents **(–1 if no reference to 'newton' / 'weight')** 3

(paper) rider jumped / (string) vibration at maximum amplitude / loudest sound / beats 3

6

Draw a suitable graph to show the relationship betw een the fundamental frequency of a stretched string and its tension.

six correct values for $\sqrt{T}$ / f^2 **(–1 per each incorrect value)** 2×3

both axes correctly labelled 3

six points correctly plotted **(–1 per each incorrect value)** 3

straight line with a good fit **(–1 for poor distribution)** 3

State this relationship and explain how your graph verifies it.

f is proportional to square root of T // $f \propto \sqrt{T}$ // $f^2 \propto T$ 3

straight line (graph) through the origin 3

21

Use your graph to

(i) estimate the fundamental frequency of the string when its tension is 11 N;

$\sqrt{T} = 3.32$ 3

$f = (542.24 \pm 10.00)$ Hz **(–1 for omission of or incorrect unit)** 3

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

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

formula squared correctly (state/imply) 2

mass per unit length (μ) = 5.86×10^{-5} kg m^{-1} 2

(–1 for omission of or incorrect unit)

13

Question 4

In an experiment to measure the resistivity of nichrome, the resistance, the diameter and appropriate length of a sample of nichrome wire were measured.

The following data were recorded:

resistance of wire	**= 7.9 Ω**
length of wire	**= 54.6 cm**
average diameter of wire	**= 0.31 mm**

Describe the procedure used in measuring the length of the sample of wire.

<u>straighten</u>/<u>taut</u> wire 3
measure (the distance) between the points for which the resistance was measured 3

6

Describe the steps involved in finding the average diameter of the wire.

(zero) <u>micrometer</u> / <u>digital callipers</u> **(–1 if *digital* not indicated)** 3
place wire between jaws (state/imply) 3
[tighten (jaws) and] take reading 3
repeat at different points on wire 3
get average diameter

15

Use the data to calculate the resistivity of nichrome.

Formula:	$\rho = \frac{R\pi d^2}{4l}$	2×3
Substitution:	$\rho = \frac{(7.9)(3.14)(0.31\times10^{-3})^2}{4(0.546)}$	2×3
Answer:	$\rho = 1.092\times10^{-6}\ \Omega\text{m}$	3

$A = \pi r^2$ 3
$A = 7.55 \times 10^{-8}$ 3
$\rho = \frac{RA}{l}$ 3
correct substitution 3
$\rho = 1.09(2) \times 10^{-6}\ \Omega$ m 3
(–1 for omission of or incorrect unit)

15

The experiment was repeated on a warmer day. What effect did this have on the measurements?

resistance increased / length increased (or wire expands) / diameter increased
(any *one*) 4

4

SECTION B (280 marks)

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

Question 5.

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

(a) State Boyle's law.

pressure is inversely proportional to volume // $P \propto \frac{1}{V}$ // PV = constant (= k) 4

fixed mass of gas at constant temperature 3

(b) The moon orbits the earth. What is the relationship between the period of the moon and the radius of its orbit?

$T \propto$ // $T^2 \propto$ // period squared is proportional to // 4

$\sqrt{R^3}$ // R^3 // radius cubed 3

$T^2 = \frac{4\pi^2 R^3}{GM}$ 7 marks

(c) Why is it necessary to have a standard thermometer?

different thermometers have different thermometric properties 4
give different readings (at the same temperature) 3

(d) The sound intensity level at a concert increases from 85 dB to 94 dB when the concert begins. By what factor has the sound intensity increased?

if sound intensity doubles → intensity level increases by 3 dB 4
(a factor of) 8 / 2^3 3

(e) Draw a ray diagram to show the formation of an image in a convex mirror.

two correct reflected rays 4
image behind the mirror 3

(f) Define electric field strength.

$E = F/q$ // force 4
correct notation // per unit charge 3

(g) When will an RCD (residual current device) disconnect a circuit?

(when magnitude of the) current flowing in differs // leakage of current 4
from that flowing out // to earth (ground) 3

(h) What is the average emf induced in a coil of 20 turns when the magnetic flux cutting it decreases from 2.3 Wb to 1.4 Wb in 0.4 s?

$E = (-)N\left(\frac{\Delta\phi}{\Delta t}\right)$ / $E = (-)\frac{20(0.9)}{0.4}$ 4

E = 45 V 3

(i) How are X-rays produced?

<u>accelerated</u> / <u>fast moving</u> electrons 4
strike <u>a (heavy) metal (target)</u> / <u>anode</u> 3

(j) Arrange the fundamental forces of nature in increasing order of strength.

name the four forces 4×1
in correct order (gravitational, weak, electromagnetic, strong) 3

(–1 if order reversed)

<u>or</u> **Draw the truth table for the AND gate.**

correct input combinations 4
correct output 3

(Statement: '*High output only when A AND B are both high*' ... 4 marks)

56

Question 6

State Newton's laws of motion.

- body <u>at rest</u>/<u>moves with constant velocity</u> unless external force acts 3
- force proportional to // $F \propto$ 3
  rate of change of momentum // $\frac{\Delta p}{\Delta t}$ 3
  ($F = m\,a$ .... 3 marks)
- action and reaction are equal and opposite 3

12

Show that $F = m\,a$ is a special case of Newton's second law .

$F \propto \frac{mv - mu}{t}$ 3

$F \propto ma$ 3

$F = kma$ 3

$k = 1$ 1

10

A skateboarder with a total mass of 70 kg starts from rest at the top of a ramp and accelerates down it. The ramp is 25 m long and is at an angle of 20° to the horizontal. The skateboarder has a velocity of 12.2 m s^{-1} at the bottom of the ramp.
Calculate :

(i) the average acceleration of the skateboarder on the ramp.

$v^2 = u^2 + 2as$ // $(12.2)^2 = 0 + 2a(25)$ 3

$a = 2.977$ m s^{-2} (≈ 2.98 m s^{-2}) **(–1 for omission of or incorrect unit)** 3

(ii) the component of the skateboarder's weight that is parallel to the ramp.

$(W =)$ $mg\sin\theta$ / $mg\cos\theta$ / $mg\sin 20$ / $mg\cos 70$ 3

$(W =)$ 234.63 N **(–1 for omission of g)** 3
(–1 for omission of or incorrect unit)

(iii) **the force of friction acting on the skateboarder on the ramp.**

$F_r = 234.63 - 70(2.977)$ // $F_r = 234.63 - 208.38$ N 3

$F_r = 26.25$ N

18

The skateboarder then maintains a speed of 10.5 m s^{-1} until he enters a circular ramp of radius 10 m. What is the initial centripetal force acting on him?

$F = \frac{mv^2}{r}$ // $F = \frac{70(10.5)^2}{10}$ 3

$F = 771.75$ N **[–1 for omission of or incorrect unit if not already penalised in (ii)]** 3

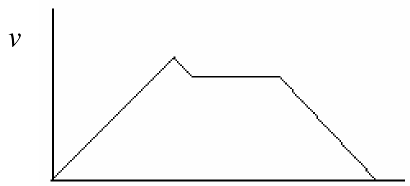
What is the maximum height that the skateboarder can reach?

$v^2 = u^2 + 2as$ // $u^2 = 2gs$ // $E_k = E_p$ // $\frac{1}{2}mv^2 = mgh$ // $h = \frac{u^2}{2g}$ 3

$0 = (10.5)^2 + 2(-9.8)h$ // $h = \frac{(10.5)^2}{2(9.8)}$ // $h = 5.63$ m **(–1 for omission of or incorrect unit)** 3

12

Sketch a velocity-time graph to illustrate his motion.



any line/curve from origin 3
correct graph shape 1

(–1 if no spike)

4

Question 7

When light shines on a compact disc it acts as a diffraction grating causing diffraction and dispersion of the light. Explain the underlined terms.

spreading (out) of a wave 3
when it passes through a gap / by an obstacle 3

splitting (up of white) light 3
into (its constituent / different) colours 3

12

Derive the diffraction grating formula.

diagram showing grating, two rays, angle θ indicated 3
(for constructive interference) path difference = $n\lambda$ 3
path difference = $d \sin\theta$ 3
$n\lambda = d \sin\theta$ 3

12

An interference pattern is formed on a screen when green light from a laser passes normally through a diffraction grating. The grating has 80 lines per mm and the distance from the grating to the screen is 90 cm. The distance between the third order images is 23.8 cm.

Calculate

(i) the wavelength of the green light;

$d = \frac{1}{80000}(m)$ // $d = 1.25\times10^{-5}(m)$ 3
($\sin\theta$ // $\tan\theta$ // θ in radian =) $\frac{23.8}{90}$ // $\frac{11.9}{90}$ // 0.264 // 0.132 3
correct substitution into formula 3
$\lambda = (551 \pm 5)$ nm **(–1 for omission of or incorrect unit)** 3

(ii) the maximum number of images that are formed on the screen.

(For maximum number:) $\theta \rightarrow 90^\circ$ // $n\lambda = d$ 3
$n = 22.7$ 3
(number of images = 22 + 22 + 1 = 45): accept: 22 // 44 // 45 3

21

The laser is replaced with a source of white light and a series of spectra are formed on the screen.

Explain

(i) how the diffraction grating produces a spectrum;

different colours 3
(have) different wavelengths/frequencies 3
constructive interference occurs / bright images formed at different θ 3

(ii) why a spectrum is not formed at the central (zero order) image.

at central image θ = 0 // constructive interference occurs for all
f / λ / colours // path difference zero // 'all colours meet', (state/imply) 2

11

Question 8

What is a photon?

packet/bundle/quantum 3

of (light) energy/electromagnetic radiation 3

6

An investigation was carried out to establish the relationship between the current flowing in a photocell and the frequency of the light incident on it. The graph illustrates the relationship.

Draw a labelled diagram of the structure of a photocell.

(wire) anode / electrode 3

(cylindrical) cathode / electrode 3

vacuum 3

(glass) casing 3

(–1 for each missing label) **12**

Using the graph, calculate the work function of the metal.

$\phi = h f_0$ // $\phi = (6.6\times10^{-34})(5.2\times10^{14})$ 3

$\phi = 3.432\times10^{-19}$ J **(–1 for omission of or incorrect unit)** 3

What is the maximum speed of an emitted electron when light of wavelength 550 nm is incident on the photocell?

any correct format of formula, e.g. $hf = \phi + \frac{1}{2}mv^2$ // $\frac{hc}{\lambda} = W + E_k$,etc 3

(1 mark per correct component)

correct substitution // $\frac{(6.6\times10^{-34})(3\times10^{8})}{550\times10^{-9}} = (3.432\times10^{-19}) + \frac{1}{2}(9.1\times10^{-31})v^2$ 3

(1 mark per correct component substitution)

$v = 1.922\times10^{5}$ m s^{-1} **(–1 for omission of or incorrect unit)** 3

Explain why a current does not flow in the photocell when the frequency of the light is less than 5.2 × 10^{14} Hz.

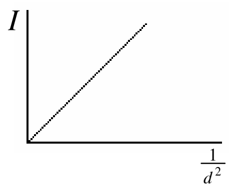
frequency less than 3

threshold frequency 3

21

The relationship between the current flowing in a photocell and the intensity of the light incident on the photocell was then investigated. Readings were taken and a graph was drawn to show the relationship.

Draw a sketch of the graph obtained. How was the intensity of the light varied?



(or intensity)

labelled axes 3

correct shape 3

vary distance from light source to photocell 5

What conclusion about the nature of light can be drawn from these investigations?

light is made up of <u>photons</u> / <u>bundles of energy</u>
// light has a corpuscular nature // light has not got a wave nature 6

17

Question 9

Define (i) potential difference, (ii) capacitance.

(i) work per	// equation (e.g. $V = \frac{W}{q}$)	3
unit charge	// correct notation	3
(ii) charge per	// equation (e.g. $C = \frac{q}{V}$)	3
unit volt	// correct notation	3
		12

Describe an experiment to demonstrate that a capacitor stores energy.

apparatus: capacitor, p.s.u., (bulb)	3
charge capacitor (C) // connect capacitor across p.s.u.	3
discharge C (through bulb)	4
(bulb) <u>flashes</u>/<u>lights</u>	4
	14

The ability of a capacitor to store energy is the basis of a defibrillator. During a heart attack the chambers of the heart fail to pump blood because their muscle fibres contract and relax randomly. To save the victim, the heart muscle must be shocked to re-establish its normal rhythm. A defibrillator is used to shock the heart muscle.

A 64 μF capacitor in a defibrillator is charged to a potential difference of 2500 V. The capacitor is discharged through electrodes attached to the chest of a heart attack victim.

Calculate

(i) the charge stored on each plate of the capacitor;

$q = CV$ / $q = (64 \times 10^{-6})(2500)$ 3

$q = 0.16$ C 3

(–1 for omission of or incorrect unit)

(ii) the energy stored in the capacitor;

$E = \frac{1}{2}CV^2$ 3

correct substitution // $E = \frac{1}{2}(64 \times 10^{-6})(2500)^2$ 3

$E = 200$ J **(–1 for omission of or incorrect unit)** 3

(iii) the average current that flows through the victim when the capacitor discharges in a time of 10 ms;

$I = \frac{q}{t}$ 3

correct substitution 3

$I = 16$ A **(–1 for omission of or incorrect unit)** 3

(iv) the average power generated as the capacitor discharges.

$(P =)\ \frac{W}{t}$ / $\frac{E}{t}$ / $\frac{200}{10 \times 10^{-3}}$ 3

$P = 20000$ W **(–1 for omission of or incorrect unit)** 3

30

Question 10 (a)

In 1932 Cockcroft and Walton succeeded in splitting lithium nuclei by bombarding them with artificially accelerated protons using a linear accelerator. Each time a lithium nucleus was split a pair of alpha particles was produced.

How were the protons accelerated? How were the alpha particles detected?

high voltage 4
scintillations / flashes of light / zinc sulphide (or phosphor) screen 4

$\boxed{8}$

Write a nuclear equation to represent the splitting of a lithium nucleus by a proton.

$${}^{7}_{3}Li + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$$

(1 mark per each correct component) 4×3

Calculate the energy released in this reaction.

loss in mass = $\underline{(1.33186\times 10^{-26}) - (1.32894 \times 10^{-26})}$ / $\underline{2.92 \times 10^{-29}}$ 3
$E = mc^2$ 3
$E = \underline{(2.92 \times 10^{-29})(2.9979 \times 10^{8})^2 \text{ J}}$ / $\underline{2.6 \times 10^{-12} \text{ J}}$ 3

(–1 for omission of or incorrect unit)

$\boxed{21}$

Most of the accelerated protons did not split a lithium nucleus. Explain why.

atom mostly empty space 3
protons <u>did not collide with lithium nucleus</u> / <u>passed straight through</u> 3

$\boxed{6}$

Cockcroft and Walton's apparatus is now displayed at CERN in Switzerland, where very high energy protons are used in the Large Hadron Collider. In the Large Hadron Collider, two beams of protons are accelerated to high energies in a circular accelerator. The two beams of protons then collide producing new particles. Each proton in the beams has a kinetic energy of 2.0 GeV.

Explain why new particles are formed.

kinetic energy of protons // energy converted 3
changed into mass // into mass 3

[e.g. 'mass/energy conservation' ... 2 × 3]

$\boxed{6}$

What is the maximum net mass of the new particles created per collision?

total energy = 4 GeV **(–1 if only 2 GeV used in calculations)** 3

$m = \frac{E}{c^2}$ // $m = \frac{(4\times 10^9)(1.6\times 10^{-19})}{(2.9979\times 10^8)^2}$ // $m = \frac{6.4\times 10^{-10}}{8.9874\times 10^{16}}$ 3

$m = 7.121\times 10^{-27}$ kg **(–1 for omission of or incorrect unit)** 3

What is the advantage of using circular particle accelerators in particle physics?

take up less space // greater (particle) <u>speeds</u> / <u>energy</u> 6

$\boxed{15}$

Question 10 (b)

What is electromagnetic induction? Who invented the induction coil?

emf induced	3
(when) conductor cuts magnetic flux	3
Callan	3
	9

What is the function of an induction coil?

changes low voltage dc	3
to high voltage dc **(-1 if d.c. omitted)**	3
	6

In an induction coil, a primary coil with a few turns of thick wire and a secondary coil with many turns of thin wire are wrapped on the same soft -iron core.
Why is there a large number of turns in the secondary coil?

emf (induced) proportional // $E \propto$	3
to number of turns // $(-)N\frac{\Delta\phi}{\Delta t}$	3
(*'to get a large voltage'*, **3 marks)**	

Explain why the primary coil has thick wire.

(thick wire) has low resistance // greater efficiency	3
large current (flows) // reduced <u>heating</u>/<u>energy</u> losses	3

Why are both coils wrapped on the same soft -iron core?

greater <u>flux linkage</u>/<u>efficiency</u> // less energy losses	3
	15

List two other types of electromagnetic waves with energy less than that of light waves.

microwaves, infra red	2×3

Give one property that is common to all types of electromagnetic waves.

same speed / travel through vacuum // can be <u>polarised</u> / <u>reflected</u> / <u>diffracted</u> etc.	2
	8

The telephone used to transmit the messages to Dublin contained a moving -coil loudspeaker. Describe, with the aid of a labelled diagram, how a loudspeaker operates.

Diagram showing: cone, magnet, coil **(–1 per each missing label)**	3×3
coil in magnetic field	3
changing current (in coil)	3
force on coil / coil vibrates	3
	18

Question 11

(*a*) **What is the maximum energy that can fall on an area of 8 m^2 in one hour if the solar constant is 1350 W m^{-2}?**

$1350 \times 8 \times 3600$	**(–1 if *hour* not converted to *second*)**	4
$E_{max} = 3.9 \times 10^7$ J	**(–1 for omission of or incorrect unit)**	3

(*b*) **Why is the bottom of a flat-plate collector blackened?**

good absorber 4
of heat/energy/radiation 3

(*c*) **How much energy is required to raise the temperature of 500 litres of water from 20 °C to 50 °C?**

$m = \rho V$ // $m = (10^3)(500 \times 10^{-3})$ // $m = 500$ (kg) 4
$E = mc\Delta\theta$ // $E = (500)(4200)(30)$ // $E = 6.3 \times 10^7$ (J) 3

(*d*) **The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation.
Explain why.**

more energy released/absorbed (per kg in the heat exchanger) 4
during change of state 3

(*e*) **Name the three ways that heat could be lost from a vacuum-tube solar collector.**

conduction, convection, radiation 3+3+1

(*f*) **How is the sun's energy trapped in a vacuum-tube solar collector?**

silvered walls prevent radiation 4
evacuated walls prevent conduction and convection 3
(marks reversible)

(*g*) **Describe, in terms of heat transfer, the operation of a heat pump.**

energy taken from <u>body</u>/<u>place</u> (making it colder) 4
to another <u>body</u>/<u>place</u> (making it hotter) 3

(*h*) **Give an advantage of a geothermal heating system over a solar heating system.**

geothermal system functions all the time // constant 4
solar heating system works only during daytime // varies 3

56

Question 12

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

Question 12 (*a*)

State Hooke's law.

(restoring) force proportional to // $F = (-)kx$ 3

extension / displacement // correct notation 3

6

When a sphere of mass 500 g is attached to a spring of length 300 mm, the length of the spring increases to 330 mm. Calculate the spring constant.

$F = mg$ // $F = (0.5)(g)$ 3

$k = \frac{F}{x}$ // $k = \frac{0.5g}{0.030}$ 3

$k = 163.3 \text{ N m}^{-1}$ **(–1 for omission of or incorrect unit)** 3

9

The sphere is then pulled down until the spring's length has increased to 350 mm and is then released.

Describe the motion of the sphere when it is released.

acceleration proportional to 2

displacement 2

('It <u>executes</u>/<u>performs</u> simple <u>harmonic motion</u> / <u>S.H.M</u>.' ... **4 marks**)

4

What is the maximum acceleration of the sphere?

$(F =)\ ma = kx$	$a = -\omega^2 x$	3
$a = \frac{(163.3)(0.02)}{0.5}$	$\omega^2 = \frac{k}{m}$ / $\omega^2 = \frac{163.3}{0.5}$	3

$a = 6.532 \text{ m s}^{-2}$ 3

(–1 for omission of or incorrect unit)

9

Question 12 (b)

A semiconductor diode is formed when small quantities of phosphorus and boron are added to adjacent layers of a crystal of silicon to increase its conduction.

Explain how the presence of phosphorus and boron makes the silicon a better conductor.

more electrons available (as charge carriers when phosphorus is added)	3
more (+) holes (as charge carriers when boron is added)	3
	6

What happens at the boundary of the two adjacent layers?

electron and holes cross (junction)	// electrons move/migrate	3
no free charge carriers /depletion layer formed	// from n-type to p-type (region)	3
junction voltage (created)	// junction voltage / depletion layer formed	3
		9

Describe what happens at the boundary when the semiconductor diode is
(i) forward biased, (ii) reverse biased.

(i) width of depletion reduced / (diode) conducts / conduction

(ii) width of depletion layer increased / no conduction **(any order, once correct)** 6 + 3

9

Give a use of a semiconductor diode.

rectifier (any valid use) 4

4

Question 12 (c)

Information is transmitted over long distances using optical fib res in which a ray of light is guided along a fibre. Each fibre consists of a core of high quality glass with a refractive index of 1.55 and is coated with glass of a lower refractive index.

Explain, with the aid of a labelled diagram, how a ray of lig ht is guided along a fibre.

Diagram:

showing light ray in glass fibre	3
showing ray being reflected at least once	3
(–1 if no label)	
reference to <u>critical angle</u>/ <u>total internal reflection</u>	3
	9

Why is each fibre coated with glass of lower refractive index?

ray travelling from denser to rarer medium // so that total internal reflection oc curs	3
<u>total internal reflection occur s</u> / <u>$i > i_c$</u> // no light escapes	3
	6

What is the speed of the light as it passes through the fibre?

$n = \frac{c_{air}}{c_{glass}}$ // $c_{glass} = \frac{3.0\times10^8}{1.55}$	4
$c_{glass} = 1.94\times10^8\ \mathrm{m\,s^{-1}}$ **(no penalty for units)**	3
	7

Light passing through optical fibres must travel through an enormous length of glass. Impurities in the glass reduce the power transmitted by half every 2 km. The initial power being transmitted by the light is 10 W. What is the power being transmitted by the light after it has travelled 8 km through the fibre?

$(½)^4$ // $\frac{1}{16}$ // $(10 \div 16)$	3
$(P =)\ 0.625$ (W) $[= \frac{5}{8}$(W)$]$	3
	6

Question 12 (d)

Smoke detectors use a very small quantity of the element americium -241. Alpha particles are produced by the americium-241 in a smoke detector.

(i) Give the structure of an alpha particle.

2 protons and 2 neutrons // helium nucleus // ${}^{4}_{2}He$ // He^{++} 3

(ii)

(iii) How are the alpha particles produced?

(americium) is <u>radioactive</u> / <u>unstable</u> /<u>disintegrates</u> /<u>undergoes α-decay</u> 6

(iii) Why do these alpha particles not pose a health risk?

very short range / poor penetrators / neutralised (to form helium)
trapped within smoke detector **(any one reason)** 4

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Americium-241 has a decay constant of 5.1 × 10^{-11} s^{-1}. Calculate its half life in years.

$\lambda T_{\frac{1}{2}} = 0.693$ 3

$T_{\frac{1}{2}} = \frac{0.693}{5.1\times10^{-11}}$ 3

$T_{\frac{1}{2}} = (1.36\times10^{10}\text{ s} = 1.573\times10^{5}\text{ days} =)\ 430.6\text{ years}$ **(–1 if answer not in years)** 3

9

Explain why americium-241 does not exist naturally.

not a member of a decay series / half life is short (w.r.t. age of universe - state/imply) / any reference to <u>*synthetic/artificial*</u> / no natural parent **(any *one*)** 6

6