Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2019

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.

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.

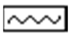
6. For omission of appropriate units (or for incorrect units) in final answers, one mark is deducted, unless otherwise indicated.

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.

9. A zero should only be recorded when the candidate has attempted the question but does not merit marks. If a candidate does not attempt a question (or part of) examiners should record NR.

10. Examiners are expected to annotate parts of the responses as directed at the marking conference. (See below.)

Symbol	Name	Use
✗	Cross	Incorrect element
✓ n	Tick$_n$	Correct element (n marks)
[	Left Bracket	To identify and separate one of several attempts at an answer
	Horizontal wavy line	To be noticed
	Vertical wavy line	Additional page (at bottom of page)
-1	−1	−1
^	^	Missing element

11. Bonus marks at the rate of 10% of the marks obtained will be given to a candidate who answers entirely through Irish and who obtains 75% or less of the total mark available in (i.e. 300 marks or less). In calculating the bonus to be applied decimals are always rounded down, not up ¬ e.g., 4.5 becomes 4; 4.9 becomes 4, etc. See below for when a candidate is awarded more than 300 marks.

Marcanna Breise as ucht freagairt trí Ghaeilge

Léiríonn an tábla thíos an méid marcanna breise ba chóir a bhronnadh ar iarrthóirí a ghnóthaíonn níos mó ná 75% d'iomlán na marcanna.

N.B. Ba chóir marcanna de réir an ghnáthráta a bhronnadh ar iarrthóirí nach ngnóthaíonn níos mó ná 75% d'iomlán na marcanna don scrúdú. Ba chóir freisin an marc bónais sin **a shlánú síos**.

Tábla 400 @ 10%
Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 400 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 300 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
301 - 303	29
304 - 306	28
307 - 310	27
311 - 313	26
314 - 316	25
317 - 320	24
321 - 323	23
324 - 326	22
327 - 330	21
331 - 333	20
334 - 336	19
337 - 340	18
341 - 343	17
344 - 346	16
347 - 350	15

Bunmharc	Marc Bónais
351 - 353	14
354 - 356	13
357 - 360	12
361 - 363	11
364 - 366	10
367 - 370	9
371 - 373	8
374 - 376	7
377 - 380	6
381 - 383	5
384 - 386	4
387 - 390	3
391 - 393	2
394 - 396	1
397 - 400	0

1. In an experiment to determine 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 *s*. The following data were recorded.

s (cm)	30.0	40.0	50.0	60.0	70.0	80.0	90.0
t (ms)	250	285	310	345	380	400	435

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

timer, ball and release mechanism, pressure plate **(3×3)** ***Draw [9]***

Between which points was the distance *s* measured?

bottom of ball and (top of) pressure plate **(3)** ***Which? [3]***

Describe how the time *t* was measured.

timer started when ball released and stopped when it hit plate **(3)** ***Describe [3]***

Draw a suitable graph that can be used to determine the acceleration due to gravity *g*.

***s* (m)**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
t^2 (s^2)	**0.063**	**0.081**	**0.096**	**0.119**	**0.144**	**0.160**	**0.189**

values for t^2 (–1 for each incorrect value) **(3)**

labelled axes **(3)**

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

straight line of good fit **(3)** ***Graph [12]***

Hence determine *g*.

slope formula: $(m =)\frac{y_2-y_1}{x_2-x_1}$/ correct substitution into slope formula **(3)**

slope calculated: $m \approx 5$ **(3)**

acceleration due to gravity calculated: $g \approx 10\ \mathrm{m\ s^{-2}}$ **(3)** ***Determine [9]***

A small, dense ball was used as the object in this experiment. State an advantage of using this type of ball.

less air resistance **(4)** ***State [4]***

2. In an experiment to determine the focal length of a concave mirror a student first found the approximate focal length of the mirror. He then placed an object in front of the mirror and measured the object distance *u* and the corresponding image distance *v*. He repeated this procedure for different values of *u*. The following data were recorded.

u (cm)	20.0	30.0	40.0	50.0
v (cm)	61.0	29.5	24.0	20.5

How did the student find the approximate focal length?

found image of a distant object **(6)** ***How? [6]***

Why did the student find the approximate focal length at the start of the experiment?

to ensure object was placed outside of focal point / so a real image could be formed / image formed on a screen / to compare with later answer **(6)** ***Why? [6]***

Describe, with the aid of a labelled diagram, how the position of the image was found.

concave mirror, screen and object **(3)**

correct arrangement **(3)**

move screen (and/or object and/or mirror) until (sharpest) image is formed **(3)** ***Describe [9]***

State two precautions that should be taken when measuring *v*.

error of parallax, measure to back of mirror, measure to centre of mirror, sharp image formed **(4+2)** ***State two [6]***

Use all of the data to calculate the focal length of the mirror.

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ **(6)**

one correct substitution **(3)**

three values of *f* from: 15.1, 14.9, 15.0, 14.5 (cm) **(3×1)**

correct average: 14.9 cm **(1)** ***Calculate [13]***

3. In an experiment to determine the specific latent heat of fusion of ice, a student first crushed some ice. She then dried the melting ice before adding it to warm water in an insulated copper calorimeter.

The following data were recorded.

Mass of copper calorimeter	= 56.3 g
Mass of calorimeter and water before adding ice	= 108.5 g
Initial temperature of water	= 29.5 °C
Final temperature of water	= 8.0 °C
Mass of calorimeter and water after adding ice	= 122.9 g

Why did the student (*i*) crush the.ice, (*ii*) dry the.ice?

(*i*) **to ensure it was all at the same temperature / to ensure it was all at 0°C / so that it would melt faster / to give a greater surface area** **(3)** ***(i) [3]***

(*ii*) **to ensure that only ice was added to the calorimeter** **(3)** ***(ii) [3]***

How was the ice (*iii*) crushed, (*iv*) dried?

(*iii*) **e.g ice crusher** **(3)** ***(iii) [3]***

(*iv*) **using a towel** **(3)** ***(iv) [3]***

Why did she (*v*) use warm water, (*vi*) use melting ice?

(*v*) **ice would melt more quickly / so that energy lost = energy gained** **(3)** ***(v) [3]***

(*vi*) **to ensure that the ice was at 0°C** **(3)** ***(vi) [3]***

Use the data to calculate the specific latent heat of fusion of ice.

$\Delta\boldsymbol{\theta}_i = \mathbf{8}, \Delta\boldsymbol{\theta}_w = \mathbf{21.5}, \boldsymbol{m}_w = \mathbf{52.2}$ **(3×3)**

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

$(\mathbf{14.4})\boldsymbol{l}_i + (\mathbf{14.4})(\mathbf{4180})(\mathbf{8}) = (\mathbf{56.3})(\mathbf{390})(\mathbf{21.5}) + (\mathbf{52.2})(\mathbf{4180})(\mathbf{21.5})$ **(3)**

$\boldsymbol{l} = \mathbf{3.25} \times \mathbf{10^5}$ **J Kg^{-1}** **(3)** ***Calculate [18]***

Why could using a very large mass of water lead to a less accurate result in this experiment?

smaller change in temperature / greater percentage error **(4)** ***Why? [4]***

(specific heat capacity of water = 4180 J kg^{-1} K^{-1}, specific heat capacity of copper = 390 J kg^{-1} K^{-1})

4. In an experiment to investigate the variation of current *I* with potential difference *V* for a semiconductor diode the following data were recorded.

V (mV)	0	50	100	150	200	250	300
I (mA)	0	0	0	2	5	40	110

Draw a circuit diagram for this experiment.

source of varying voltage, diode, ammeter, voltmeter **(4×3)**

correct arrangement **(3)** ***Draw [15]***

Use the data to draw a graph of current against potential difference.

labelled axes **(3)**

points plotted **(3)**

curve of good fit **(3)** ***Graph [9]***

Use your graph to determine the junction voltage.

≈ 0.2 V **(3)** ***Determine [3]***

What happened in the diode when the junction voltage was exceeded?

depletion layer broke down / low resistance / current flows **(3)** ***What? [3]***

Is Ohm's law obeyed for the diode? Justify your answer.

no **(3)**

not a straight line through the origin **(3)** ***Is? Justify [6]***

The diode is now reversed and data is recorded. State two other changes that are made to the circuit before recording data for a diode in reverse bias.

replace ammeter with a microammeter,

place voltmeter across diode and (micro)ammeter,

remove (protective) resistor if already included [any two] **(2+2)** ***State two [4]***

5. (*a*) A light-year is the distance travelled by light in a vacuum in one year. Calculate this distance in metres.

$s = vt$ **(3)**

$s = (3.00 \times 10^8)(3.15 \times 10^7)$ **(2)**

$s = 9.45 \times 10^{15}$ **(m)** **(2)** ***a [7]***

(*b*) An apple has a weight of 1 N and its volume is 121 cm^3. Calculate the density of the apple.

$W = mg$ / $m = 0.102$ **(3)**

$\rho = \frac{m}{V}$ **(2)**

$\rho = 843$ **kg m^{-3}** **(2)** ***b [7]***

(*c*) A book is decelerating as it moves to the right on a horizontal table. Draw a labelled diagram to show the forces acting on the book as it moves on the table.

force up

(equal) force down

net horizontal force to the left **(3+2+2)** ***c [7]***

(–1 for each incorrect force)

(*d*) What is meant by polarisation of light?

vibrating

in one plane **(4+3)** ***d [7]***

(*e*) What is the thermometric property of (*i*) a mercury thermometer, (*ii*) a thermocouple?

(i) length/height/volume

(ii) emf/voltage **(4+3)** ***e [7]***

(*f*) Sketch a graph to show the relationship between resistance *R* and temperature *T* (in °C) for a metallic conductor.

labelled axes

straight line (–1 if through origin) **(4+3)** ***f [7]***

(*g*) Power *P* is generated in a resistor of resistance *R* when a potential difference *V* is applied across it. Write *P* in terms of *R* and *V*.

$\frac{V^2}{R}$ **(allow 4 marks for VI or I^2R or $V = IR$)** **(7)** ***g [7]***

(*h*) Polonium was discovered by Marie and Pierre Curie in 1898. Polonium–218 has a half-life of 3 minutes. Calculate the activity of a sample of polonium–218 that contains 75000 nuclei.

$\lambda = \frac{\ln 2}{T_{1/2}}$ / $\lambda = 0.00385$ **(3)**

$A = \lambda N$ / $A = (0.00385)(75000)$ **(2)**

$A = 289$ **Bq** **(2)** ***h [7]***

(*i*) Polonium–218 is produced as the daughter nucleus of the alpha-decay of radon–222. Write a nuclear equation for this reaction.

$Rn_{86}^{222} \rightarrow Po_{84}^{218} + He_2^4$ **(7×1)** ***i [7]***

(*j*) Neutrinos are sometimes called ghost particles. Why are they very hard to detect?

very small mass

no charge **(4+3)** ***j Why? [7]***

Describe how a galvanometer can be converted into an ammeter.

small resistance

in parallel **(4+3)** ***j Describe [7]***

6. Satellites, which play an increasing role in the information age, are controlled by the gravitational force. Weather satellites, communications satellites and global positioning satellites (GPS) are used by millions of people every day. Different satellites have different periods and different radii of orbit.

State Newton's law of universal gravitation.

force is proportional to product of masses // $F = G\frac{m_1 m_2}{d^2}$ **(3)**

force is inversely proportional to distance squared **// notation** **(3)** ***State [6]***

What is the relationship between the period *T* and radius of orbit *r* of a satellite?

$T^2 \propto r^3$ **(3)** ***Relationship? [3]***

The METEOSAT 11 weather satellite provides MET Eireann with both visual and infrared images. It is in geostationary orbit above the equator.

Which has a longer wavelength, visible or infrared radiation?

infrared **(3)** ***Which? [3]***

Describe how infrared radiation can be detected in the school laboratory.

heating effect / thermometer **(6)** ***Describe [6]***

What is the period of METEOSAT 11?

24 hours **(6)** ***What? [6]***

Calculate its height above the surface of the Earth.

$T^2 = \frac{4\pi^2 R^3}{Gm}$ / $(86400)^2 = \frac{4\pi^2 R^3}{(6.67\times10^{-11})(6.0\times10^{24})}$ **(3)**

$h = 3.596 \times 10^7$ **m / 36000 km** **(3)** ***Calculate [6]***

(–1 if answer left as R= 4.236 × 10^7 m / 42360 km)

A global positioning satellite orbits the Earth with a speed of 14000 km hr^{-1}.

Calculate (*i*) its radius of orbit,

$v = 3889$ **(m s^{-1})** **(3)**

$v^2 = \frac{Gm}{R}$ / $3889^2 = \frac{(6.67\times10^{-11})(6.0\times10^{24})}{R}$ / $F = G\frac{m_1 m_2}{d^2}$ / $F = \frac{mv^2}{R}$ **(3)**

$R = 2.65 \times 10^7$ **m / 26500 km** **(3)** ***Calculate (i) [9]***

(*ii*) its angular velocity.

$v = r\omega$ / $3889 = (2.65 \times 10^7)\omega$ **(3)**

$\omega = 1.47 \times 10^{-4}$ **(rad) s^{-1}** **(3)** ***Calculate (ii) [6]***

Calculate the minimum time it takes a signal to travel from a global positioning satellite to the Earth.

$v = \frac{s}{t}$ / $(3.00 \times 10^8) = \frac{(2.65\times10^7 - 6.4\times10^6)}{t}$ **(3)**

$t = 0.067$ **s** **(3)** ***Calculate (iv) [6]***

Explain why satellites remain in orbit and do not fall and crash into the Earth.

(horizontal) velocity **(5)** ***Explain [5]***

7. In a thunderstorm different parts of a cloud become positively and negatively charged. There is a large electric field and a large potential difference between different parts of the cloud and between the cloud and the ground.

What is meant by potential difference? State its unit.

work done	**//** $\frac{W}{Q}$	**(3)**	
per unit charge	**// notation**	**(3)**	
volt		**(3)**	***What? State [9]***

Define electric field strength.

force	**//** $\frac{F}{Q}$	**(3)**	
per unit charge	**// notation**	**(3)**	***Define [6]***

Describe how an insulated spherical conductor can be charged positively by induction.

(negatively) charged rod close to it	**(3)**	
earth sphere	**(3)**	
remove earth	**(3)**	***Describe [9]***

A spherical conductor has a diameter of 12 cm. It is charged positively by induction.

Draw the electric field around the charged conductor.

radial field lines		
away from positive charge	**(4+2)**	***Draw [6]***

There is an electric field intensity of 2.3 N C^{-1} at a distance of 5 cm from the surface of this spherical conductor. Calculate the charge on the conductor.

$E = \frac{Q}{4\pi\epsilon d^2}$ / $2.3 = \frac{Q}{4\pi(8.9 \times 10^{-12})(0.11)^2}$ / $E = \frac{F}{Q}$ / $F = \frac{q_1 q_2}{4\pi\epsilon d^2}$	**(3)**	
$Q = 3.1 \times 10^{-12}$ **C**	**(3)**	***Calculate [6]***

Explain how point discharge occurs.

charge accumulates at a point	**(3)**	
air around point is ionised	**(3)**	
opposite charges attracted / like charges repelled	**(6)**	***Explain [12]***

Describe how point discharge can be demonstrated in the laboratory.

charged point	**(3)**	
candle at point	**(3)**	
flame is blown away from the point	**(2)**	***Demonstration [8]***

8. Electrons are emitted from metals during photoelectric emission, thermionic emission and radioactive decay. Distinguish between photoelectric and thermionic emission

photoelectric: light; thermionic: heat **(3+3)** ***Distinguish [6]***

What name is given to electrons emitted during radioactive decay?

beta **(3)** ***Name [3]***

When current is passed through the sodium vapour in a sodium lamp, light is emitted as a line spectrum. What is a line emission spectrum?

(specific) frequencies/colours (of e.m. radiation) emitted by a material **(3)** ***What [3]***

Explain, in terms of the structure of the atom, how this spectrum is produced.

energy given to electron **(3)**

electron changes energy levels **(3)**

photon emitted / light emitted / (e.m.) radiation emitted **(3)** ***Explain [9]***

The graph shows the relationship between the kinetic energy E_k of the electrons emitted during photoemission and the frequency *f* of the incident radiation.

Write down Einstein's photoelectric equation.

$hf = \emptyset + \frac{1}{2}mv^2$ **(3)** ***Write [3]***

What physical quantity is represented by (*i*) point A

threshold frequency **(3)** ***What (i)? [3]***

(*ii*) the slope of the graph?

Planck constant **(3)** ***What (ii)? [3]***

The work function of magnesium is 3.68 eV. Calculate the maximum velocity of the emitted electrons when photons of energy 4.15 eV are incident on magnesium.

$E_k = 0.47$ **(eV) /** 7.5×10^{-20} **(J)** **(3)**

$E_k = \frac{1}{2}mv^2$ **/** $7.5 \times 10^{-20} = \frac{1}{2}(9.1 \times 10^{-31})\,v^2$ **(3)**

$v = 4.1 \times 10^5$ **m s^{-1}** **(3)** ***Calculate [9]***

Electrons are produced in an X-ray tube by thermionic emission. Where in the tube are the electrons produced?

cathode **(3)** ***Where? [3]***

The electrons are then accelerated to high velocities. Some of the electrons have their energy converted into X-rays. What is the minimum wavelength of an X-ray produced in a 50 kV tube?

eV **/** hf **(3)**

$eV = hf$ **/** $(1.6 \times 10^{-19})(50 \times 10^3) = (6.6 \times 10^{-34})f$ **(3)**

$\lambda = 2.5 \times 10^{-11}$ **m** **(3)** ***What (iv)? [9]***

(–1 if answer left as $f = 1.2 \times 10^{19}$ **Hz)**

The kinetic energies of the other electrons are converted into heat energy. State two design features of an X-ray tube that take account of this.

tungsten target, cooling fluid **(3+2)** ***State two [5]***

9. (*a*) Both a moving charge and a conductor carrying an electric current experience a <u>force</u> in a <u>magnetic field</u>. Explain the underlined terms.

force is what causes acceleration **(3)** ***a Explain i [3]***

magnetic field is a region where magnetic forces are felt **(3)** ***a Explain ii[3]***

Describe an experiment to demonstrate that a current-carrying conductor experiences a force in a magnetic field.

power supply, aluminium foil, magnets **(3)**

correct arrangement **(3)**

` **foil moves** **(3)** ***a Describe [9]***

When would a current-carrying conductor in a magnetic field **not** experience a force?

it is parallel to the field **(3)** ***a When? [3]***

(*b*) A straight wire of length 3 cm was placed perpendicular to a magnetic field of uniform magnetic flux density *B*. The force *F* on the wire was measured for a series of values of current *I* flowing in the wire. The following data were recorded.

I (A)	0.5	1.0	1.5	2.0	2.5	3.0	3.5
F (mN)	10	18	31	39	50	59	68

Write down an expression for the force *F* on the current-carrying wire.

$(F =)BIl$ **(3)** ***b Expression [3]***

Plot a graph on graph paper of force against current.

labelled axes **(3)**

points plotted correctly **(3)**

line of good fit **(3)** ***b Graph [9]***

Calculate the slope of graph and use it to calculate the magnetic flux density of the field.

slope: ($m = \frac{y_2 - y_1}{x_2 - x_1}$) = 0.02 **(3)**

$m = Bl$ / $0.02 = B(0.03)$ **(3)**

$B =$ **0.67 T** **(3)** ***b Calculate & use [9]***

(*c*) Starting with the expression for the force that you gave in part (*b*), derive the expression *F* = *qvB* for the force *F* acting on a charge *q* travelling at a velocity *v* perpendicular to a magnetic field of flux density *B*.

$I = \frac{q}{t}$ **and** $v = \frac{l}{t}$ **(3)**

$F = B\left(\frac{q}{t}\right)(vt)$ **(3)**

$F = qvB$ **(3)** ***c Derive [9]***

In a nuclear detector a proton enters a magnetic field of flux density 0.5 T at right angles to the field. The proton initially follows a circular path of radius 2.3 mm. Calculate the speed of the proton on entry.

$F = qvB$ / $F = \frac{mv^2}{r}$ **(3)**

$qvB = \frac{mv^2}{r}$ / $(1.60 \times 10^{-19})(0.5) = \frac{(1.67\times10^{-27})v}{(2.3\times10^{-3})}$ **(3)**

$v = 1.1 \times 10^5$ **m s**$^{-1}$ **(2)** ***c Calculate [8]***

10. Explain the terms diffraction and interference.

diffraction: **the spreading out of a wave** **(3)**

after it passes an obstacle/gap **(3)**

interference: **occurs when two waves meet** **(3)** ***Explain terms [9]***

In 1801 Thomas Young performed an experiment to demonstrate that light is a wave.
He passed monochromatic light through two narrow slits and observed a series of bright and dark fringes on a screen.
Explain, with the aid of a labelled diagram, how a series of bright and dark fringes are produced.

slits **(3)**

diffraction at slits **(3)**

interference **(3)** ***Explain [9]***

How does this experiment demonstrate that light is a wave?

result can only be explained using interference **(3)** ***How? [3]***

The experiment was repeated in the school laboratory.
The slits were 0.5 mm apart and were placed at a distance of 1.25 m from the screen.
The distance across 13 bright fringes on the screen was found to be 1.65 cm. Calculate the wavelength of the monochromatic light.

distance between n equals zero and n equals six $= \mathbf{0.825}$ **cm** **(3)**

$\tan\theta = \frac{O}{A}$ / $\tan\theta = \frac{0.825}{125}$ / $\theta = 0.378$ **(3)**

$n\lambda = d\sin\theta$ / $6\lambda = (0.5 \times 10^{-3})\sin(0.378)$ **(3)**

$\lambda = 5.5 \times 10^{-7}$ **m** **(3)** ***Calculate [12]***

List two adjustment to the apparatus that could be made to increase the distance between the bright fringes?

move screen from slits, decrease distance between slits, increase λ **(2×3)** ***List two [6]***

Young was a polymath with many other interests, including the deciphering of Egyptian hieroglyphs, discovery of the purpose of the ciliary muscle in the eye and the invention of the *Young temperament* which made use of harmonics to tune musical instruments.
When the ciliary muscles contract the lens in the eye becomes thinner. What effect does this have on the power of the lens?

decreases power **(3)** ***What? [3]***

A certain musical instrument can be modelled as a cylindrical pipe that is closed at one end and whose length can be changed. The air column in the pipe vibrates at a frequency of 512 Hz.
Draw diagrams to show the first two harmonics of this instrument.

correct diagram for first harmonic **(3)**

correct diagram for third harmonic **(3)** ***Draw [6]***

The lengths of the pipe at the first two positions of resonance are 16.7 cm and 49.8 cm.
Calculate (*i*) the wavelength of the sound wave,

$\lambda = 2 \times (0.498 - 0.167) = 0.66$ m **(3)** ***Calculate (i) [3]***

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

$c = f\lambda$ / $c = (512)(0.66)$ **(3)**

$c = 339$ m s^{-1} **(2)** ***Calculate (ii) [5]***

11. (*a*) Explain why transmission of electricity using low voltage is not economical.

high current

heat/energy loss **(4+3)** ***a [7]***

(*b*) Name the device used to (*i*) reduce a.c. voltage, (*ii*) convert current from a.c. to d.c.

(*i*) transformer

(*ii*) rectifier/diode **(4+3)** ***b [7]***

(*c*) State Hooke's law.

(restoring) force is proportional to // $F = -ks$ **(4)**

displacement // correct notation **(3)** ***c [7]***

(*d*) A ball of mass 110 g is travelling at a speed of 4 m s^{-1}. It rebounds from a wall and travels in the opposite direction at the same speed. The ball was in contact with the wall for 0.2 seconds. Use Newton's laws of motion to calculate the force exerted by the wall on the ball.

$F = \frac{\Delta(mv)}{\Delta t}$ **(3)**

$F = \frac{(0.11)(4)-(0.11)(-4)}{0.2}$ **(2)**

$F = 4.4\ \text{N}$ **(2)** ***d [7]***

(*e*) A magnifying glass is a basic microscope. Draw a ray diagram to show the formation of an upright image in a magnifying glass.

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

two correct rays through lens **(2)**

correct image **(2)** ***e [7]***

(*f*) A plutonium–239 nucleus undergoes nuclear fission when a neutron collides with it. Xenon–134 and zirconium–103 are produced together with some neutrons. Write a nuclear equation for this fission reaction.

$Pu_{94}^{239} + n_0^1 \rightarrow Xe_{54}^{134} + Zr_{40}^{103} + 3n_0^1$ **(5×1)** ***f Write [5]***

Calculate the energy released in this reaction.

loss in mass = 3.3682×10^{-28} **kg** **(3)**

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

$E = (3.3682 \times 10^{-28})(2.9979 \times 10^8)^2$ **(3)**

$E = 3.0271 \times 10^{-11}$ **J** **(3)** ***f Calculate [12]***

In what form is this energy released?

kinetic energy / heat **(4)** ***f What? [4]***

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

(*a*) State the principle of conversation of energy.

energy cannot be created or destroyed **(3)** ***a State [3]***

(Due to typographical error, award 3 marks to all candidates who attempt Q12 (a))

A mass hanging at the end of a string of length 80 cm is given an initial horizontal velocity of 4 m s^{-1}.

Calculate

(*i*) the velocity of the mass at position B,

$\boldsymbol{h = 0.8 - 0.8\cos 35}$ **/** $\boldsymbol{0.145}$ **(3)**

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

$\boldsymbol{mgh + \frac{1}{2}mv^2 = mgh + \frac{1}{2}mv^2}$ **/** $\boldsymbol{\frac{1}{2}(4)^2 = (9.8)(0.145) + \frac{1}{2}v^2}$ **(3)**

$\boldsymbol{v = 3.63}$ **m s^{-1}** **(3)** ***a Calculate (i) [12]***

(*ii*) its centripetal acceleration at position B.

$\boldsymbol{a = \frac{v^2}{r}}$ **(3)**

$\boldsymbol{a = \frac{3.63^2}{0.8}}$ **(3)**

$\boldsymbol{a = 16.5}$ **m s^{-2} (towards the centre)** **(3)** ***a Calculate (ii) [9]***

Draw a labelled diagram to show the forces acting on the mass when it is at position B.

weight, tension (–1 for each incorrect force) **(2+2)** ***a Draw [4]***

(*b*) A RAM (random access memory) integrated chip contains transistors, in which there are doped semiconductors, and capacitors.

What is a semiconductor?

material with a resistivity between that of a conductor and an insulator

(3) ***b What (i)? [3]***

What is meant by doping a semiconductor?

adding an impurity (to change its conductivity) **(3)** ***b What (ii)? [3]***

How can a semiconductor be doped so that (*i*) its majority charge carriers are electrons,

(*i*) add an element with more outer electrons / add e.g. phosphorus (3) ***b How (i)? [3]***

(*ii)* its majority charge carriers are holes?

(*ii*) add an element with fewer outer electrons/ add e.g. boron **(3)** ***b How (ii)? [3]***

The capacitance of a capacitor in a RAM chip is 90 fF. It operates at a voltage of 1.2 V. Calculate,

(*i*) the energy stored in the capacitor when it is fully charged,

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

$\boldsymbol{E = \frac{1}{2}(90 \times 10^{-15})(1.2)^2}$ **(3)**

$\boldsymbol{E = 6.5 \times 10^{-14}\ \mathrm{J}}$ **(3)** ***b Calculate (i) [9]***

(*ii*) the number of additional electrons that are on the negative plate of the capacitor as a result of it being fully charged.

$\boldsymbol{Q = CV}$ **/** $\boldsymbol{Q = (90 \times 10^{-15})(1.2)}$ **(3)**

$\boldsymbol{Q = 1.08 \times 10^{-13}}$ **(C)** **(2)**

number of additional electrons $\boldsymbol{= \frac{1.08 \times 10^{-13}}{1.6 \times 10^{-19}} = 675000}$ **(2)** ***b Calculate (ii) [7]***

(*c*) As light passes from water into air the <u>critical angle</u> may be exceeded and <u>total internal reflection</u> may occur. Explain the underlined terms.

<u>critical angle:</u> angle of incidence **(3)**

corresponding to an angle of refraction of 90° **(3)**

<u>t.i.r.:</u> angle of incidence > critical angle (and all light is reflected) **(3)**

c Explain terms [9]

A diver is 12 m below the surface in a pool of water. When he looks up he can see a circular window of light on the surface of the water.

Calculate the area of this disc of light.

$\boldsymbol{n = \frac{1}{\sin C}}$ **/** $\boldsymbol{1.33 = \frac{1}{\sin C}}$ **/** $\boldsymbol{C = 48.8°}$ **(3)**

$\boldsymbol{\tan\theta = \frac{r}{d}}$ **/** $\boldsymbol{\tan 48.8° = \frac{r}{12}}$ **/** $\boldsymbol{r = 13.7\ (\mathrm{m})}$ **(3)**

$\boldsymbol{A = \pi r^2}$ **(3)**

$\boldsymbol{A = 590\ \mathrm{m}^2}$ **(3)** ***c Calculate [12]***

Use a labelled diagram to explain why the diver does not appear to be at a depth of 12 m when viewed by an observer outside the pool.

correct refracted ray

correct apparent ray / correct position of image **(4+3)** ***c Diagram [7]***

(*d*) (*i*) The new Swiss 200-franc note honours proton-proton collisions in the Large Hadron Collider (LHC) at CERN.

There are two families of hadrons. Name the two families and distinguish between them.

baryon and meson **(3)**

baryon has three quarks and meson has a quark and an antiquark **(3)**

d i Name and distinguish [6]

Two protons, each with a velocity of 0.9c, travelling in opposite directions collide. A neutral pion (π^0) and two protons remain after the collision.

The single pion produced must be neutral. Explain why.

conservation of charge **(3)**

d i Explain why [3]

Calculate the total kinetic energy of the three particles after the collision.

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

$E_b = (1.6726 \times 10^{-27})((0.9)(2.9979 \times 10^8))^2 /\ E_b = 1.2176 \times 10^{-10}$ **(3)**

$E = mc^2\ /\ E_a = E_b - m_\pi c^2$

$/\ E_a = 1.2176 \times 10^{-10} - (264)(9.1094 \times 10^{-31})(2.9979 \times 10^8)^2$ **(3)**

$E_a = 1.00 \times 10^{-10}$ **J** **(3)**

d i Calculate [12]

The large hadron collider is a circular accelerator.

How are the protons maintained in circular motion?

magnetic fields (provide the centripetal force) **(3)** ***d i How? [3]***

State the principal advantage of a circular accelerator over a linear accelerator

greater energy can be created / longer path available for particles / more compact

(4) ***d i State [4]***

(*ii*) Draw the symbol for a transistor and a diagram of its structure.

symbol **(3)**

correct diagram of structure **(3)**

fully labelled **(3)** ***d ii Draw and diagram [9]***

Transistors and resistors can be used to construct voltage amplifier circuits. Draw a circuit diagram of a voltage amplifier circuit.

transistor, bias resistor, load resistor **(3)**

correct arrangement **(3)** ***d ii Draw [6]***

Label the bias, the load resistor and the input and output voltages.

labelled bias resistor and labelled load resistor **(3)**

labelled input voltage between base and emitter **(3)**

labelled output voltage across load resistor

or between collector, emitter **(3)** ***d ii Labels [9]***

What is the purpose of the bias resistor?

ensures base emitter junction is always forward biased (2) ***d ii Purpose i [2]***

What is the purpose of the load resistor?

converts changes in collector current to

changes in voltage across load **(2)** ***d ii Purpose ii [2]***