Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE 2009

MARKING SCHEME

PHYSICS

ORDINARY LEVEL

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Introduction

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. Marks shown in brackets represent marks awarded for partial answers as indicated in the scheme.

3. Words, expressions or statements separated by a solidus, /, are alternatives which are equally acceptable.

4. 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.

5. The descriptions, methods and definitions in the scheme are **not** exhaustive and alternative valid answers are acceptable. Marks for a description may be obtained form a relevant diagram, depending on the context.

6. The context and the manner in which the question is asked and the nu mber of marks assigned to the answer in the examination paper determines the detail required in any question. Therefore, in any instance, it may vary from year to year.

Section A (120 marks) **Three questions to be answered.**

Question 1 **40 marks**

(i) Draw a labelled diagram of the apparatus you used **6 + 2 × 3**

labelled diagram to show:

falling object/ball	// pendulum bob	//picket fence	6
timer: timer shown in diagram	//stop-watch	// photogate (and timer)	3
stop/start mechanism/ detail	// fixed point / split cork	//calculator/computer	3

NOTE: no labels, 2 deducted marks
all valid methods are acceptable e.g. data logging methods, which fit the scheme

(ii) State what measurements you took during the experiment **2 × 3**

distance	// length (of pendulum)	// selected v versus t /s	3
time	//period (of pendulum)	// slope of graph /t	3

(iii) Describe how you took one of these measurements **3 + 6**

measure length	//time	// time (n) oscillations	// start program / datagate	3
metre stick	// timer	// timing device	// drop picket fence	6

(iv) How did you calculate the value of g from your measurements? **3 × 3**

substitute (for t and s) into the equation

$$g = \frac{2s}{t^2} / s = \frac{1}{2} g t^2 \qquad // \quad g = \frac{4\pi^2 l}{T^2} / T = 2\pi \sqrt{\frac{l}{g}} \qquad 3\times3$$

valid partial answer; e.g. $g = \frac{2s}{t}$ // $g = \frac{4\pi l}{T^2}$ (3)

substitute into the equation/draw a graph (of T^2 versus l) (3)

(v) Give one precaution that you took to get an accurate result **4 or 2**

any valid specific precaution, which has not already been awarded marks
e.g. use the smallest time value recorded for t // swing through small angle 4

any valid general precaution e.g. repeat the experiment a number of times (2)

Question 2 40 marks

A student carried out an experiment to measure the specific latent heat of fusion of ice .

(i) Draw a labelled diagram of the apparatus used in the experiment **4 × 3**

labelled diagram to show:

calorimeter		3
thermometer	// temperature sensor	3
ice		3
insulation / (electronic) balance / stirrer /other detail		3

incorrect experiment, maximum mark 3×3

No labels, deduct 2

(ii) What measurements did the student take in the experiment? **6 + 2 × 3**

mass of calorimeter
mass of calorimeter and warm water
mass of calorimeter and warm water and ice
temperature of water before
temperature of water and melted ice after

	any 3 lines	6+2×3
	any line	(6)
mass and temperature		(2×3)

(iii) How did the student prepare the ice for the experiment? **4 or 2**

crushed / dried / melting ice used	any one correct	4
preparation may be inferred from the diagram		
partial answer; e.g. in the fridge		(2)

(iv) How did the student know the ice was a 0 °C? **6 or 3**

(use) melting (ice)/leave ice at room temperature/take its temperature	6
partial answer;	(3)

(v) Why did the student use warm water in the experiment? **6 or 3**

ice melts quickly / less heat loss / increase accuracy / heat lost balanced by heat gained	6
partial answer; e.g. so that the ice would melt	(3)

Question 3 **40 marks**

A student carried out an experiment to investigate the variation of the fundamental frequency *f* of a stretched string with its length *l*.

(i) Describe, with the aid of a diagram, how the student obtained the data. **4 × 3**

labelled diagram to show

tuning fork	// signal/frequency generator
fork (vibrating) on the wire/bridge/sonometer	// current in wire/(U-) magnet
move the bridge	// move bridge / adjust frequency
until paper/rider falls off / until resonance occurs	
measure the length/frequency/detail	

any 4 lines 4×3

No labels, deduct 2

(ii) Why was the tension in the string kept constant during the experiment? **6 or 3**

frequency also depends on tension / fair test / only one independent variable 6

partial answer (3)

(iii) Copy this table and fill in the last row by calculating $\frac{1}{l}$ for each measurement **6 × 1**

f/Hz	100	150	200	250	300	350	400
l/m	0.5	0.33	0.25	0.2	0.166	0.142	0.125
$\frac{1}{l}$/ m^{-1}	**2.00**	**3.03**	**4.00**	**5.00**	**6.02**	7.04	**8.00**

(iv) Plot a graph on graph paper to show the relationship between the fundamental frequency and the length of the stretched string (put $\frac{1}{l}$ on the X-axis) **4 × 3**

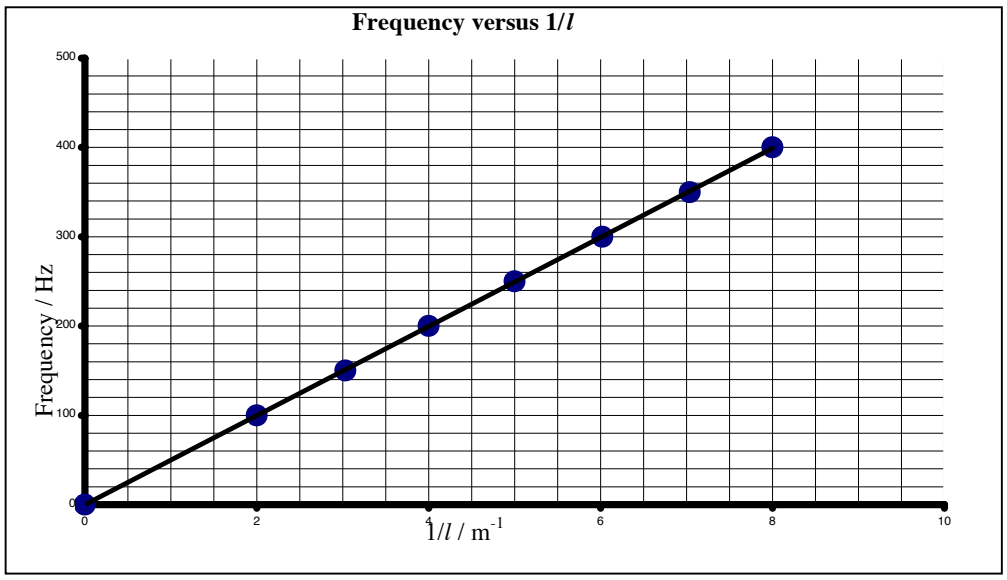
label axes correctly- name/symbol/unit acceptable 3

plot four points correctly 3

plot another three points correctly 3

straight line 3

if graph paper is not used / $\frac{1}{l}$ on the Y-axis maximum mark 3×3



(v) What does your graph tell you about the relationship between the fundamental frequency of a stretched string and its length? **4 or 2**

fundamental frequency is inversely proportional to length / frequency goes up as length goes down / answer consistent with graph 4

partial answer; e.g. proportional / linear (2)

Question 4 40 marks

In an experiment to investigate the variation of the resistance *R* of a thermistor with its temperature *θ*, a student measured the resistance of a thermistor at different temperatures

(i) Draw a labelled diagram of the apparatus used in this experiment ? **4 × 3**

labelled diagram to show:

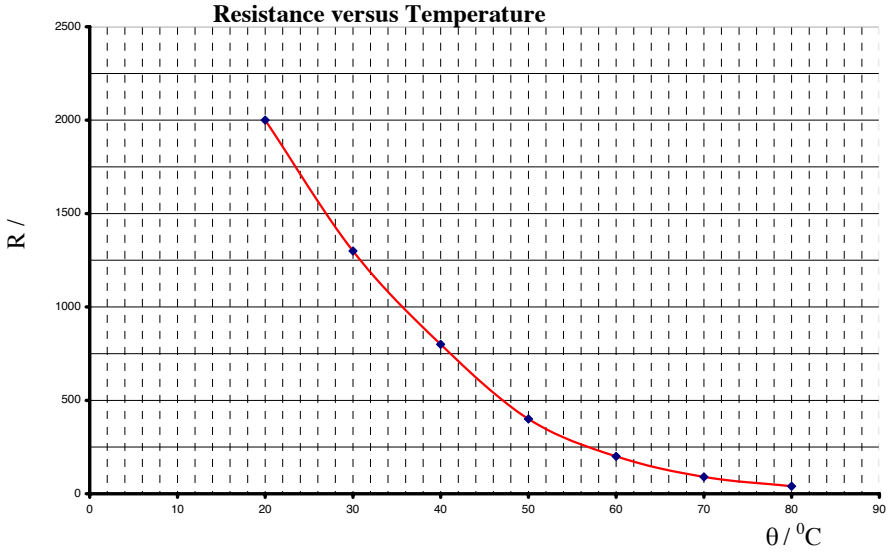
thermistor in waterbath
thermometer // temperature sensor
ohmmeter // datalogger
heat source
detail any 4 lines 4×3

No labels, deduct 2

(ii) How did the student measure the resistance of the thermistor? **6 or 3**

ohmmeter / (digital) multimeter / measure *V* and *I* and hence determine R 6
partial answer; e.g. meter (3)

(iii) Plot a graph on graph paper to show the relationship between resistance *R* and its temperature *θ* (put *θ* on the X-axis) **4 × 3**



label axes correctly, (name / symbol / unit acceptable) 3
plot three points correctly 3
plot another three points correctly 3
(smooth) curve 3
if graph paper is not used, maximum mark 3 × 3
if θ is on the Y-axis, maximum mark 3 × 3

(iv) Use your graph to estimate the temperature of the thermistor when its resistance is 1000 Ω **4 or 2**

35 °C to 36.5 °C / value consistent with the graph 4
partial answer; e.g. evidence of using the graph (2)

(v) What does your graph tell you about the relationship between the resistance of a thermistor and its temperature? **6 or 3**

resistance goes down with increased temperature / is not linear / not directly proportional 6
partial answer; e.g. mention of proportional (3)

SECTION B (280 marks) **Five questions to be answered**

Question 5 **any *eight* parts** **56 marks**

(a) State the principle of conservation of momentum **7 or 4**

momentum before = momentum after // $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ 7

partial answer; e.g. incomplete equation // in a closed system (4)

(b) A man opens a door by applying a 5 N force to the door. If the distance from the point of application of the force to the fulcrum is 120 cm, calculate the moment of the applied force ($M = Fd$) **7 or 4**

M = 5 × 1.2 = 6 (N m) 7

partial answer; e.g. substitutes one quantity correctly into the equation (4)

(c) Which of the following is the unit of energy? **7**

kilogram watt joule ampere

joule 7

(d) Calculate the wavelength of a radio wave whose frequency is 252 kHz **7 or 4**

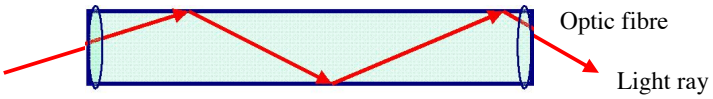
($c = f\lambda$, $c = 3.0 \times 10^8$ m s^{-1})

$(\lambda = \frac{c}{f} = \frac{3.0 \times 10^8}{252 \times 10^3} =) 1.19 \times 10^3$ (m) 7

partial answer; e.g. transposed equation / substitute one quantity in the equation (4)

(e) Draw a diagram to show the path of a ray of light through an optical fibre **7 or 4**

7



partial answer; e.g. incomplete diagram (4)

(f) On what property does the pitch of a musical note depend ? **7 or 4**

frequency / wavelength 7

partial answer; e.g. loudness, pressure, temperature (4)

(g) Name the instrument shown in the diagram? **7 or 4**

(gold leaf) electroscope 7

partial answer; e.g. gold leaf (4)

(h) What are isotopes? **7 or 4**

elements with different mass number 7

partial answer; e.g. mention of atoms / elements (4)

(i) Give one application of the photoelectric effect **7 or 4**

burglar alarms, automatic doors, control of burners in central heating , sound track in films, etc one correct 7

partial answer; e.g. definition (4)

(j) State two properties of X-rays **7 or 4**

electromagnetic waves, have short wavelength, cause ionisation , penetrate materials, no mass, no charge, effect photographic film, diffraction, etc.

two correct 7

one correct (4)

Question 6 56 marks

Define (i) velocity, (ii) friction **2 × 3**

velocity: rate of change of displacement // distance ÷ time in given direction 3

friction: force which resists (relative) motion (between surfaces in contact) 3

A train of mass 30000 kg started from a station and accelerates at 0.5 m s $^{-2}$ to reach its top speed of 50 m s $^{-1}$ and maintained this speed for 90 minutes. As the train approaches the next station the driver applies the brakes uniformly to bring the train to a stop in a distance of 500 m.

(i) Calculate how long it took the train to reach its top speed? **4 or 2**

$v = u + at$

$50 = 0 + 0.5t$

$t = 50 \div 0.5 = 100$ (s) 4

partial answer; e.g. substitutes one quantity correctly into the equation (2)

(ii) Calculate how far it travelled at its top speed? **6 or 3**

$s = ut + \frac{1}{2} at^2$

$s = 50 \times (90 \times 60) = 270000$ (m) 6

partial answer; e.g. substitutes one quantity correctly into the equation (3)

(iii) Calculate the acceleration of the train when the breaks were applied **6 or 3**

$v^2 = u^2 + 2as$

$0 = 50^2 + 2a(500)$

$a = -2500 \div 1000 = (-)\ 2.5$ (m s^{-2}) 6

partial answer; e.g. substitutes one quantity correctly into the equation (3)

(iv) What was the force acting on the train when the brakes were applied? **6 or 3**

$F = ma$

$F = 30000 \times (-)(2.5) = 75000$ (N) $= 75$ (kN) 6

answer consistent with calculated acceleration (6)

partial answer; e.g. substitutes one quantity correctly into the equation (3)

(v) Calculate the kinetic energy lost by the train in stopping **6 or 3**

$E_k = \frac{1}{2}mv^2$

$E_k = \frac{1}{2} \times 30000 \times 50^2 = 37500000$ (J) $= 37.5$ (MJ) 6

partial answer; e.g. substitutes one quantity correctly into the equation (3)

(vi) What happened to the kinetic energy lost by the train? **6 or 3**

converted to other forms of energy / heat / sound / sparks 6

partial answer; e.g. converted (3)

(vii) Name the forces A and B acting on the train shown in the diagram **2 × 2**

A = friction/retardation / resistance to motion 2

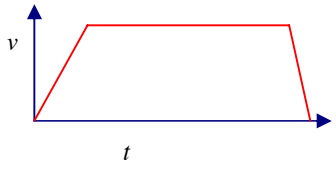
B = weight / force of gravity 2

(viii) What would happen to the train when the force A is equal to force T? **4 or 2**

train will move at constant speed / no acceleration / will not speed up 4

partial answer (2)

(ix) Sketch a velocity-time graph of the train's journey **8 or 6 or 3**



graph showing

v increasing, *v* constant, *v* decreasing 8

one property omitted from graph (6)

partial answer; (3)

Question 7 **56 marks**

In an experiment a beam of <u>monochromatic light</u> passes through a <u>diffraction grating</u> and strikes a screen.

(i) Explain the underlined terms **2(6 or 3)**

light of one colour / one wavelength 6

partial answer; e.g. sodium, laser (3)

piece of glass/plastic with lines / slits engraved 6

partial answer; e.g. reference to slits (3)

marks may be obtained from a diagram

(ii) Describe what's observed on the screen **6 or 3**

(series of) bright dots 6

partial answer (3)

marks may be obtained from a diagram

(iii) Explain, with the aid of a diagram, how this phenomenon occurs **5 + 3 × 3**

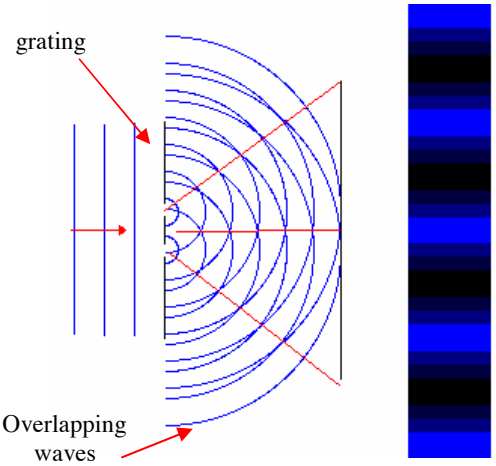


diagram showing

(diffraction) grating 5

waves spread out after passing through the slit 3

interference / constructive /destructive 3

observation e.g. fringes 3

no diagram deduct 3

(iv) What does this experiment tell us about the nature of light? **6 or 3**

(light has a) wave nature / light is a wave 6

partial answer (3)

(v) Which property of light can be determined by taking measurements in this experiment? **6 or 3**

wavelength / frequency 6

partial answer; e.g. velocity/speed (3)

(vi) What measurements must be taken to determine the property you named? **2 (6 or 3)**

angle θ (between bright dots), distance (between slits), n //

distance between bright dots, distance from the, screen to grating, distance between slits, n

two correct 2×6

one correct (6)

Question 8 56 marks

Plugs are used to connect electrical appliances in the home to the 230 volt ESB supply. Modern plugs contain a small fuse which comes with a rating of 1A, 2A, 3A, 5A or 13A. The electrical energy supplied by ESB to the home is measured and charged for in kWh (*kilowatt-hour*).

(i) What is the colour of the wire that should be connected to the fuse in a plug? **6 or 3**

brown 6

red / blue / green-yellow (3)

(ii) What is the function of a fuse? **6 or 3**

prevent too high a current flowing / safety device / prevent overheating / prevent fire 6

partial answer (3)

(iii) Explain how a fuse works **6 + 3**

(thin wire) heats up / breaks /melts

stops flow of current /breaks circuit / if current too high

two correct 6+3

one correct (6)

partial answer (3)

(iv) Name another device with the same function as a fuse **4 or 2**

circuit breaker /trip switch/ RCD/MCB 4

partial answer; e.g. switch, earthing, bonding, other safety device (2)

(v) A coffee maker has a power rating of 800 W. What is the most suitable fuse for the plug of the coffee maker? $P = VI$ **3× 3**

most suitable fuse 5 A 3×3

I = 3.4 (A) // fuse consistent with calculated current (3×3–1)

partial answer; e.g. $800 = 230 \times I$, $230 \div 800$ (3)

(vi) Why would it be dangerous to use a fuse with too high a rating? **6 or 3**

would allow too large a current to flow / device could overheat / danger of fire 6

partial answer (3)

If the coffee maker is used for 150 minutes calculate;

(vii) The number of units of electricity used by the coffee maker. **10 or 7 or 4**

(Work = 0.8 × 2.5) = 2 (kWh) 10

800 × 150 /120000 (7)

Work = (power)(time) /Power = 800 W = 0.8 kW / time = 150 minutes = 2.5 hours (4)

(viii) The cost of the electricity used if each unit of electricity costs 15 cent. **6 or 3**

cost = 2 × 15 = 30 (cent) 6

answer consistent with calculated units in (vii) (6)

partial answer (3)

Question 9 56 marks

A magnetic field exists in the vicinity of a magnet

(i) What is a magnetic field? **2 × 3**

area (where) 3

magnet experiences force / magnet where it effects compass 3

partial answer (3)

marks may be obtained from a diagram

Describe an experiment to show the shape of the magnetic field due to a U-shaped magnet **4 × 3**

apparatus: U-shaped magnet, 3

(plotting) compass / iron filings 3

procedure: place piece of paper/perspex over the magnet and sprinkle the iron filings onto the paper // place a number of compasses near the magnet 3

observation: note the shape of the magnetic field / collection of iron filings near the poles of the magnet 3

marks may be obtained from a diagram

(i) What happens to the compass when the switch is closed? **6 or 3**

(needle) moves / deflects 6

partial answer; e.g. current induced (3)

marks may be obtained from a diagram

(ii) What does this tell you about an electric current? **6 or 3**

it affects a compass, magnetic field, magnetic effect 6

partial answer; e.g. electric current flows in the circuit (3)

(iii) What happens to the compass when the switch is opened? **6 or 3**

(needle) moves / returns to original position 6

partial answer; e.g. no current flows (3)

The wire is then placed between the poles of a U-shaped magnet as shown in the diagram

(iv) Describe what happens to the wire when a current flows through it **6 or 3**

wire moves / wire gets hot 6

partial answer (3)

(v) What would happen if the current flowed in the opposite direction? **6 or 3**

wire moves in opposite direction / magnetic field reverses 6

partial answer. (3)

(vi) Name two devices that are based on this effect **2 × 4**

(electric) motor, (moving coil) speaker, galvanometer etc any two 2×4

Question 10 56 marks

Radioactive elements are unstable and decay with the release of radiation

How would you detect radiation? **6 or 3**

GM tube, solid state detector, cloud chamber, ionisation tube, ZnS screen scintillation counter, gold leaf electroscope, photographi c film, etc. one correct 6

partial answer (3)

Name the three types of radiation **3 × 2**

alpha / α 2

beta / β 2

gamma / γ 2

(i) Which radiation is negatively charged? **2**

beta / β 2

(ii) Which radiation has the shortest range? **2**

alpha / α 2

(iii) Which radiation is not affected by electric fields? **2**

gamma / γ 2

Nuclear fission occurs in a nuclear reactor

(iv) What is nuclear fission? **2 × 3**

splitting (of large) nucleus) 3

into (two) smaller nuclei / with release of energy / release of neutrons 3

partial answer; e.g. definition of fusion (3)

(v) What is the role of neutrons in nuclear fission? **6 or 3**

split nucleus, makes nucleus unstable, causes fission one correct 6

partial answer; e.g. neutrons fired at/hit nucleus (3)

(vi) Name a fuel used in a nuclear reactor **6 or 3**

plutonium / P, (enriched) uranium / U, thorium / Th one correct 6

partial answer; e.g. named reactor part (3)

(vii) In a nuclear reactor how can the fission be controlled or stopped? **6 or 3**

correct reference to (control/boron) rods // refers to slowing down neutrons 6

partial answer (3)

(viii) How is the energy produced in a nuclear reactor used to generate electricity? **6 + 3**

(energy produced) converted to heat /(this is used to) generates steam 6

(which) drives generator /turbine 3

partial answer (3)

(ix) Give one advantage and one disadvantage of a nuclear reactor as a source of energy **5 or 3**

advantage; abundant fuel / cheap fuel / no greenhouse gases / no global warming , etc.

disadvantage; risk of nuclear contamination / fallout / difficulty of dealing with waste / dangerous, etc.

advantage and disadvantage for fission or fusion reactor both correct 5

advantage and disadvantage one correct (3)

Question 11 56 marks

Read this passage and answer the questions below.

Why do stars and the lights of distant objects twinkle?

The twinkling of stars, also known as stellar scintillation, is due to atmospheric turbulence. The turbulence of the air is caused by heat changing the density and thus the refractive index of moving pockets of air in the earth's atmosphere. These moving pockets of air act like lenses, refracting light in random directions and causing the stars to "twinkle" - it looks as though the star moves a bit, and our eyes interprets this as twinkling.

Heat rising from buildings in towns ensures the air is always turbulent around them. We don't usually notice its effect on the appearance of nearby lights, because the turbulence is small by comparison with the size of the lights. On the other hand, lights fro m a distant town appear so small that the effect of turbulence on them has a significant impact, which we see as twinkling.

The same phenomenon, incidentally, allows one to tell the difference between stars and planets in the night sky. Planets do not usu ally twinkle, because they are closer to us; they appear big enough that the twinkling is not noticeable. The point -like images of the immensely distant stars are affected by turbulent air far more than the planets.

Stars closer to the horizon appear to twinkle more than stars that are overhead - because the light of stars near the horizon has to travel through more air than the light of stars overhead and so is subject to more refraction.
(Adapted from 'Why don't Spiders stick to their Webs? And other ev eryday mysteries of Science')

(a) What causes the twinkling of stars? **7 or 4**
atmospheric turbulence // refraction 7
partial answer (4)

(b) Give another name for the twinkling of stars **7 or 4**
stellar scintillation 7
partial answer (4)

(c) What is meant by the refraction of light? **7 or 4**
change in direction (as it passes from medium to another) 7
partial answer (4)

(d) Name two properties of air that are affected by atmospheric turbulence **7 or 4**
refractive index, density, temperature two correct 7
one correct (4)

(e) Why is the air turbulent in towns? **7 or 4**
heat rising from buildings 7
partial answer (4)

(f) How can you tell the difference between a planet and a star in the night sky ? **7 or 4**
planets do not twinkle (stars do) / stars twinkle (planets do not) 7
partial answer; e.g. reverse order (4)

(g) Why do stars close to the horizon twinkle more? **7 or 4**
the light (of stars near the horizon) has to travel through more air // refraction is more noticeable // more refraction 7
partial answer (4)

(h) A star emits light, what is the source of this energy? **7 or 4**
nuclear / fusion 7
partial answer; e.g. mistakes planet for star and refers to the sun (4)

Question 12 56 marks

Part (a)

Define pressure **2 × 3**

force 3

per unit area 3

$P = \frac{F}{A}$ (2×3)

partial answer; e.g. area (3)

Describe an experiment to show that the pressure in a liquid increases with depth **4 × 3**

apparatus: (tall) container, liquid, tubing and funnel // (tall) container, liquid 3

detector e.g. pressure sensor, manometer // holes at different levels 3

procedure: connect the tubing to the funnel and the detector. Insert the funnel into the liquid and note the pressure. Repeat for different depths and note pressure at each depth // fill container above the holes 3

observation/conclusion: note the pressure increases as the depth increases 3

marks may be obtained from a diagram

partial answer (3)

A diver is swimming at a depth of 5m. He then dives deeper until he reached a depth of 30 m. Calculate the increase in pressure on the diver at this new depth **10 or 7 or 4**

Pressure at 30 m**:** ($p = \varrho gh = (10^3)(9.8)(30) =$) 2.94×10^5 (Pa)

Pressure at 5 m**:** ($p = \varrho gh = (10^3)(9.8)(5) =$) 0.49×10^5 (Pa)

Increase in pressure at 30 m**: =** $2.94 \times 10^5 - 0.49 \times 10^5 = 2.45 \times 10^5$ (Pa) 10

$(10^3)(9.8)(30)$ / $(10^3)(9.8)(5)$ / $(10^3)(9.8)(35)$ (7)

partial answer; e.g. correct substitution of one quantity into the equation (4)

Part (b)

What is meant by the temperature of a body? **6 or 3**

(measure of) hotness /coldness 6

partial answer; e.g. heat (3)

Name two scales that are used to measure temperature **2 × 3**

Celsius, Fahrenheit, Kelvin two correct 2×3

one correct (3)

Give the boiling point of water on each of these scales **3**

100 (°C), 212 °F, 373 K two correct 3

one correct (2)

The diagram shows a laboratory thermometer, what is its thermometric property? **3**

length / definition of thermometric property 3

Name one other type of thermometer and give it's thermometric of property **2 × 3**

thermometer	thermistor	thermocouple	constant volume gas	liquid crystal
thermometric property	resistance	emf / V	pressure	colour

3

3

Why is there a need for a standard thermometer? **4 or 2**

because different thermometric properties // thermometers respond differently // give different results // to ensure a consistent measure // for calibration 4

partial answer (2)

Part (c)

A p-n junction (diode) is formed by <u>doping</u> adjacent layers of a <u>semiconductor</u>, and a depletion layer is formed at the junction **6 + 3**

doping: addition of impurity (to semiconductor) / changes its conductivity

semiconductor: material with (resistivity) between that of conductors and insulators

two correct 6+3

one correct (6)

partial answer; e.g. p-type / n-type (3)

How does the depletion layer form? **6 or 3**

holes and electrons recombine 6

partial answer; e.g. reference to holes and electrons (3)

The diagram shows two diodes connected to two bulbs A and B, a 6 V d.c. supply and a switch

What is observed when the switch is closed? **6 or 3**

diode A lights // B does not light 6

partial answer (3)

Explain why this happens **7 or 4**

A is forward biased // B is reverse biased // depletion layer removed in A / depletion layer increases in B 7

partial answer (4)

Part (d)

The diagram shows a simple cathode ray tube. Thermionic emission occurs at plate A

(i) What is thermionic emission? **2 × 3**

emission of electrons 3

from the hot surface / from a hot metal 3

partial answer (3)

(ii) What are cathode rays? **2 × 3**

(stream of) high speed 3

electrons 3

partial answer (3)

(iii) Why is there a high voltage between A and B? **2 × 3**

to accelerate / attract 3

(the beam of) electrons 3

partial answer (3)

(iv) What happens to the cathode rays when they hit the screen C? **6 or 3**

converted to light // bright dot (on screen) 6

partial answer (3)

(v) Give a use for a cathode ray tube **4 or 2**

TV/computer/screen/oscilloscope, X-rays, etc. 4

partial answer (2)