



6 Mark Questions (mix of all sections)

Q1.An experiment can be performed to determine whether a particular component is an ohmic conductor.

(a) State what is meant by an ohmic conductor.

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(1)

(b) (i) Draw a suitable circuit diagram for such an experiment.

(2)

(ii) For the circuit diagram you have drawn, describe a suitable experiment. Your account should include details of:

- what measurements you would take
- how you would use your measurements
- how you would reach a conclusion.

The quality of written communication will be assessed in your answer.

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Q2.Discuss the formation of stationary waves on a string or rope. Your account should include:

- a labelled diagram of a stationary wave
- the conditions necessary for stationary waves to form
- a definition of the terms node and antinode
- an explanation of how nodes and antinodes form.

The quality of written communication will be assessed in your answer.

(Total 6 marks)

- Q4.** (a) Light has a dual wave-particle nature. State and outline a piece of evidence for the wave nature of light and a piece of evidence for its particle nature. For each piece of evidence, outline a characteristic feature that has been observed or measured and give a short explanation of its relevance to your answer. Details of experiments are not required.

The quality of your written communication will be assessed in your answer.

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- Q5.** (a) A student wishes to investigate how the resistance of a thermistor changes with temperature.
- (i) Draw a labelled diagram of a suitable circuit that would enable the student to measure the resistance of the thermistor.

(2)

- (ii) Describe the procedure the student would follow in order to obtain accurate and reliable measurements of the resistance of the thermistor at different temperatures.

The quality of your written communication will be assessed in this question.

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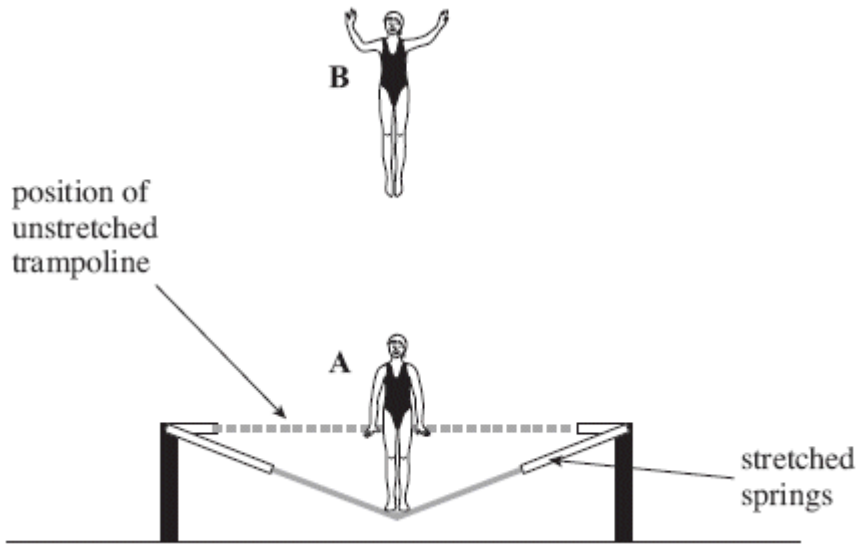
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Q6. The figure below shows a gymnast trampolining.



- (e) On her next jump the gymnast decides to reach a height above position **B**. Describe and explain, in terms of energy and work, the transformations that occur as she ascends from her lowest position **A** until she reaches her new position above **B**.

The quality of your written communication will be assessed in this question.

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Q7. Electrons with a range of kinetic energies strike atoms of a particular element which are in their *ground state*. As a result of these collisions photons of various frequencies are emitted by some of the atoms.

- (a) Explain what is meant by the ground state of an atom and describe the process that is taking place in the atoms emitting photons.

The quality of your written communication will be assessed in this question.

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Q8. A student wishes to collect data so he can plot the I - V curve for a semiconductor diode.

- (a) (i) Draw a suitable diagram of the circuit that would enable the student to collect this data.

(3)

- (ii) Describe the procedure the student would follow in order to obtain an I - V curve for the semiconductor diode.

The quality of your written communication will be assessed in this question.

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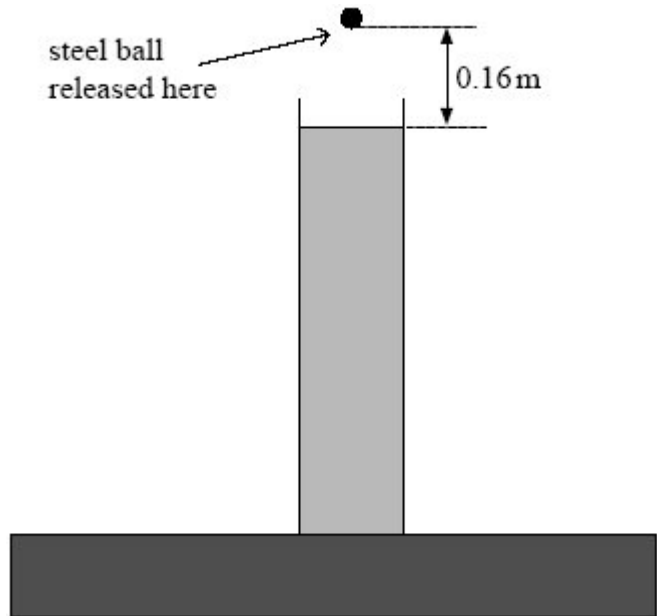
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(6)

Q9. A steel ball is released from rest above a cylinder of liquid, as shown in **Figure 1**. The ball

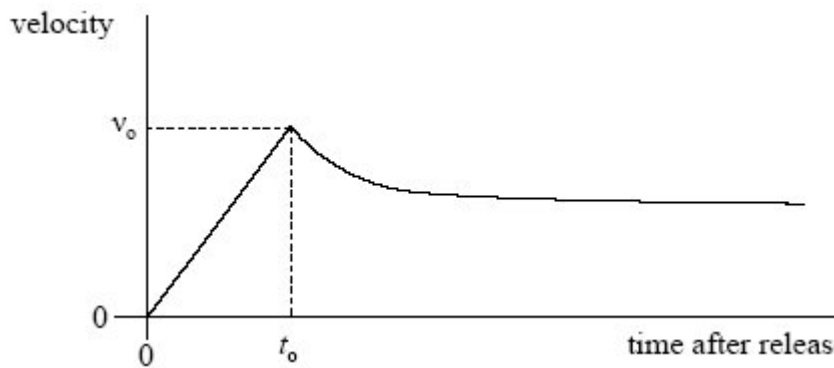
descends vertically in the air then in the liquid until it reaches the bottom of the cylinder.

Figure 1



(b) **Figure 2** below shows how the velocity of the ball changed after it was released.

Figure 2



Describe and explain how the acceleration of the ball changed after it entered the liquid until it reached the bottom of the cylinder.

The quality of your written answer will be assessed in this question.

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(6)
(Total 11 marks)

Q10. (a) When monochromatic light is incident on a metal plate, electrons are emitted only when the frequency of light exceeds a certain frequency. Explain in terms of energy, why this threshold frequency exists and why a photon theory of light provides a better explanation of the photoelectric effect than a wave theory of light.
The quality of your written answer will be assessed in this question.

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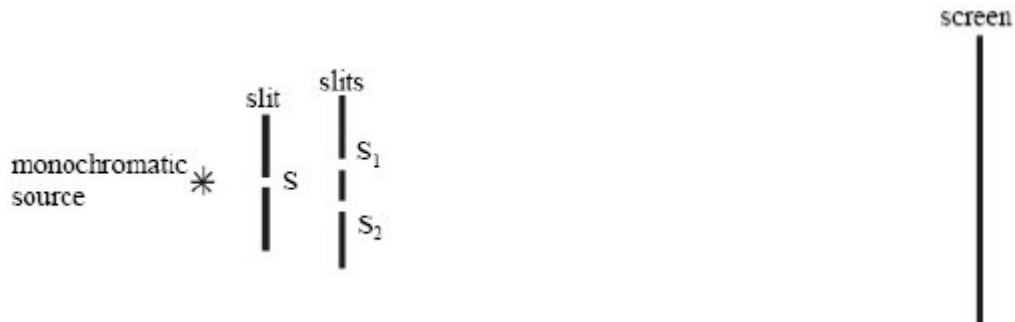
Q11. (a) State **two** requirements for two light sources to be coherent.

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(2)

(b)

Figure 1



Young's fringes are produced on the screen from the monochromatic source by the arrangement shown in **Figure 1**.

Explain how this arrangement produces interference fringes on the screen. In your answer, explain why slit S should be narrow and why slits S_1 and S_2 act as coherent sources.

The quality of your written answer will be assessed in this question.

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(6)

Q12. (a) The discovery of photoelectricity and subsequent investigations led to the wave theory of light being replaced by the photon theory. State one feature of

photoelectricity that could not be explained using the wave theory of light and describe how it is explained using photon theory.
The quality of your written answer will be assessed in this question.

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Q13. Electromagnetic waves and electrons have properties of both particles and waves. Explain what evidence there is to support this statement. Experimental details are not required.

You may be awarded marks for the quality of written communication in your answer.

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(Total 6 marks)

Q14.(a) Hadrons and leptons are two groups of particles.
Write an account of how particles are placed into one or other of these two groups.
Your account should include the following:

- how the type of interaction is used to classify the particles
- examples of each type of particle
- details of any similarities between the two groups
- details of how **one** group may be further sub-divided.

The quality of your written communication will be assessed in your answer.

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Q15. A fluorescent light tube contains mercury vapour at low pressure. The tube is coated on the inside, and contains two electrodes.

(a) Explain why the mercury vapour is at a low pressure.

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(1)

(b) Explain the purpose of the coating on the inside of the tube.

You may be awarded marks for the quality of written communication in your answer.

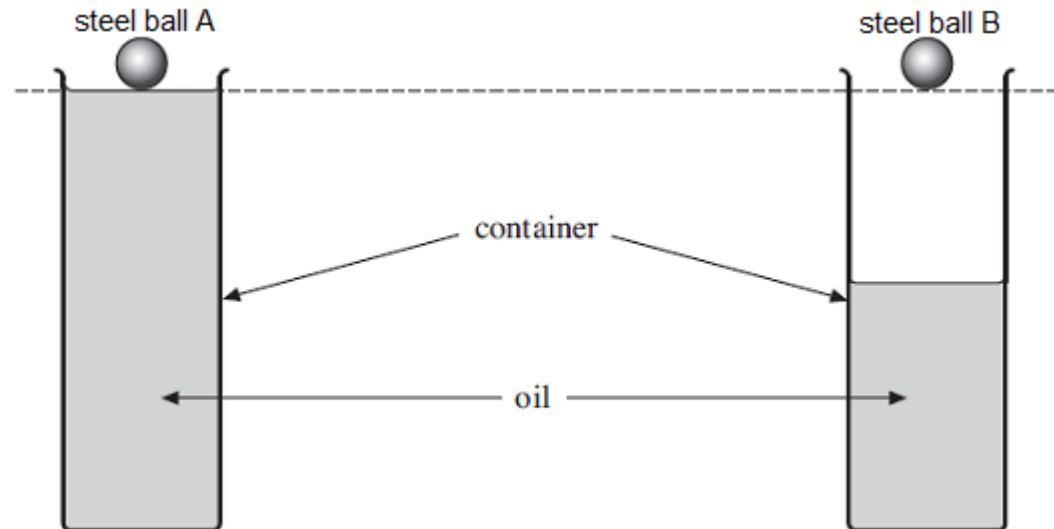
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(3)
(Total 4 marks)

Q16.

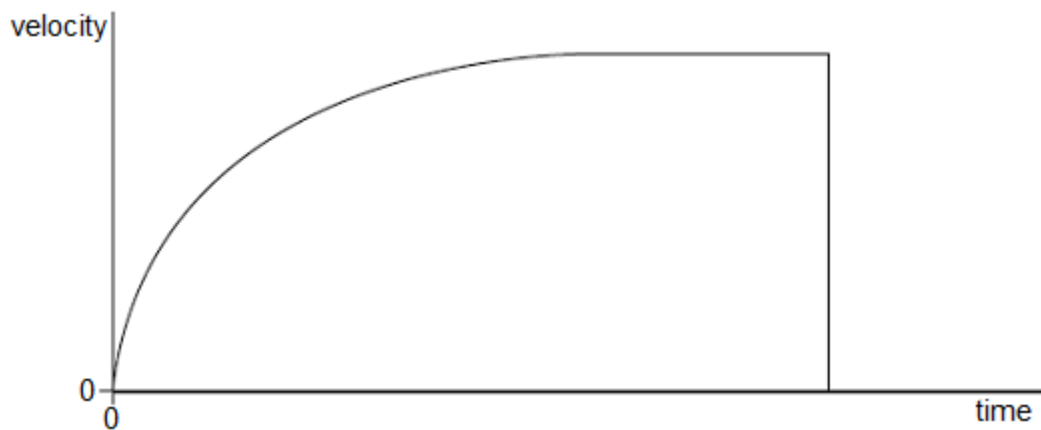
(b) **Figure 1** shows two identical steel balls dropped from rest into containers of oil.

Figure 1



(i) **Figure 2** shows the velocity-time graph for steel ball A.

Figure 2



Explain the shape of the graph in **Figure 2**. Your account should include

- how the velocity and acceleration of the steel ball vary with time
- reference to how Newton's First and Second laws of motion apply in this situation.

The quality of written communication will be assessed in your answer.

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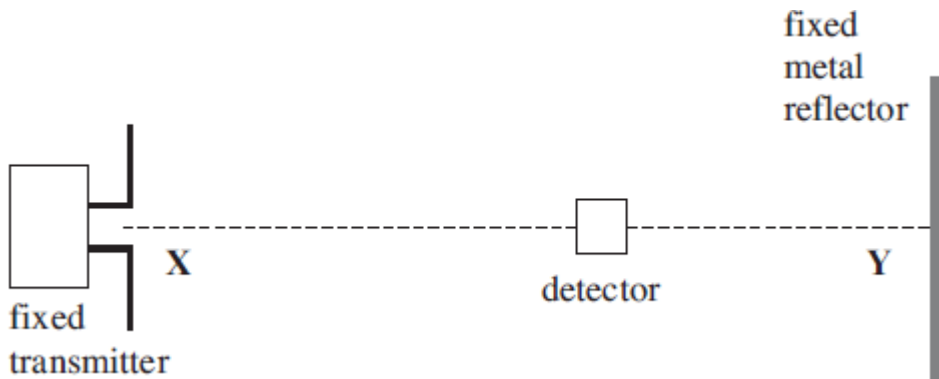
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Q17.In his investigation of radio waves, Hertz created stationary waves by using a large flat metal sheet to reflect radio waves as shown in the diagram below.



- (a) Explain why stationary waves are formed in this arrangement and describe how the wavelength of the radio waves can be determined by moving a suitable detector along **XY**.

The quality of your written communication will be assessed in your answer.

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Q18. (a) Line spectra were observed before they could be explained by theory. We now know that photons of characteristic frequency are emitted when the vapour of an element is bombarded by energetic electrons. The spectrum of the light emitted contains lines, each of a definite wavelength.

Explain how

- the bombarding electrons cause the atoms of the vapour to emit photons
- the existence of a spectrum consisting of lines of a definite frequency supports the view that atoms have discrete energy levels.

The quality of your written communication will be assessed in this question.

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M1.(a) a component with constant resistance OR $V \propto I$ ✓

1

- (b) (i) circuit using correct symbols with means of varying current / voltage ✓
correct voltmeter and ammeter ✓

*ignore symbol for component
unless it is a variable resistor*

2

- (ii) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**
The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Candidate draws an appropriate circuit diagram with correctly positioned ammeter and voltmeters. Candidate has a means of varying the current. Sets current to different values and measures pd. Mentions wide range. Has a sensible way of varying current (e.g. variable resistor / potential divider). Plots a graph of pd against current. Relates constant gradient to a constant resistance.

Level 5 / 6

meaning of line through origin

reverse current readings

suitable range with suggested values

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Candidate draws an appropriate circuit diagram with correctly positioned ammeter and voltmeters. Candidate has a means of varying the current. Varies current and measures pd. Plots a graph of pd against current. Relates constant gradient to a constant resistance.

Level 3 / 4

Draw best fit line or state R constant

*Relate **straight** line on graph to ohmic conductor*

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate measures resistance at least twice to see if constant. Has some means of varying current.

Level 1 / 2

Take several readings of V and I and plot graph or calculate R

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

method for varying current
current varied in regular steps
pd and current measure
resistance calculated
graph drawn
significance of gradient of the graph discussed

6

(c) (i) a material with zero resistivity / resistance ✓
not negligible

1

(ii) material becomes superconducting at / below critical temperature ✓
accept reverse argument

1

(iii) any correct usage e.g. powerful magnets, mri, maglev trains / bullet train / (high power) transmission lines / particle accelerators / LHC ✓

1

[12]

M2.Good / Excellent

The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

can say disturbance, amplitude or displacement

Mentions:

- (1) waves (meet when) travelling in opposite directions / cross/ wave meets a reflected wave / etc

- (2) same wavelength (or frequency)
- (3) node – point of minimum or no disturbance
- (4) antinode – point of maximum disturbance / maximum displacement/amplitude occurs
- (5) node - two waves (always) cancel / destructive interference / 180° phase difference (between displacements of the two waves at the node)
- (6) antinode – reinforcement / constructive interference occurs / (displacements) in phase
- (7) mention of superposition of the two waves

5 marks: points (1) **AND** (2) with three points from (3), (4), (5), (6) or (7)

for 6 marks: points (1) to (6) must be seen

labelled diagram can provide supporting evidence but labels: 'node' / 'antinode' by themselves cannot replace points 3 and 4

5 / 6

Modest

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Mentions any 3 of the 7 points.

4 marks: (1) **OR** (2) **AND** three others.

3 / 4

Limited

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

One relevant point

OR a relevant, labelled diagram

2 marks: two points OR one point and a relevant labelled diagram

1 / 2

[6]

M3. (a) **The candidate's writing should be legible and the spelling, punctuation and**

grammar should be sufficiently accurate for the meaning to be clear.

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate states that the power supply is connected to the input of the oscilloscope. The time base is switched off and the y gain adjusted until a complete vertical line is seen on the screen. The length of the line is measured and this is converted to peak to peak voltage using the calibration. The peak voltage is divided by root two to get the rms voltage and this is compared with the stated value. The time base is now switched on and adjusted until a minimum of one cycle is seen on the screen. The length of one cycle is measured and this is converted to time using the time base setting. Frequency is the reciprocal of this time.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate states that the power supply is connected to the input of the oscilloscope. The y gain adjusted. The length of the line/height of peak is measured. The peak voltage is divided by root two to get the rms voltage. The time base is now switched on and adjusted until a minimum of one cycle is seen on the screen. The length of one cycle is measured and this is converted to time using the time base setting.

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate states that the power supply is connected to the input of the oscilloscope. The length of the line/height of peak is measured. The time base is now switched on and adjusted until a minimum of one cycle is seen on the screen. The length of one cycle is measured and this is converted to time.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

- power supply connected to oscilloscope input
- time base initially switched off
- y gain adjusted to get as long a line as possible
- length of line used to find peak to peak voltage
- rms voltage found
- time base switched on and adjusted to get several cycles on the screen
- use the time base setting to find period
- use period to find frequency
- compare vales with stated values

6

(b) (i) (use of $P = IV$)

$$I = 24/12 = 2.0 \text{ (A)} \checkmark$$

1

(ii) peak current = $\sqrt{2} \times 2.0 = 2.8 \text{ (A)} \checkmark$

1

(iii) peak power = $\sqrt{2} \times 12 \times \sqrt{2} \times 2.0 \checkmark = 48 \text{ (W)} \checkmark$

2

[10]

M4. (a) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate provides a comprehensive and coherent answer that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light and a stated property such as photoelectricity that can only be explained in terms of the particle nature of light. In each case, a relevant specific observational feature should be referred to and should be accompanied by a coherent explanation of the observation. Both explanations should be relevant and logical.

For full marks, the candidate may show some appreciation as to why the specific feature of either the named wave property cannot be explained using the particle nature of light or the named particle property cannot be explained using the wave nature of light.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

*The candidate provides a logical and coherent explanation that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light **and** a stated property such as photoelectricity that can only be explained in terms of the particle nature of light.*

For 4 marks, the candidate should be able to refer to a relevant specific observational feature of each property, at least one of which should be followed by an adequate explanation of the observation. Candidates who fail to refer to a relevant specific observational feature for one of the properties may be able to score 3 marks by providing an adequate explanation of the observational feature referred to.

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate provides some relevant information relating to two relevant stated properties for 1 mark. Their answer may lack coherence and may well introduce irrelevant or incorrect physics ideas in their explanation.

Points that can be used to support the explanation:

Wave-like nature property

- property is either interference **or** diffraction
- observational feature is either the bright and dark fringes of a double slit interference pattern or of the single slit diffraction pattern (or the spectra of a diffraction grating)
- explanation of bright or dark fringes (or explanation of diffraction grating spectra) in terms of path or phase difference
- particle/corpuscular theory predicts two bright fringes for double slits or a single bright fringe for single slit or no diffraction for a diffraction grating

Particle-like nature

- property is photoelectricity
- observational feature is the existence of the threshold frequency for the incident light **or** instant emission of electrons from the metal surface
- explanation of above using the photon theory including reference to photon energy hf , the work function of the metal and '1 photon being absorbed by 1 electron'
- wave theory predicts emission at all light frequencies **or** delayed emission for (very) low intensity

6

(b) (i) $m (= m_0 (1 - v^2 / c^2)^{-0.5} = 9.11 \times 10^{-31} (1 - 0.890^2)^{-0.5}$

$(= 1.998 \times 10^{-30} \text{ kg}) = 2.0(00) \times 10^{-30} \text{ kg} \checkmark$

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{2.0(0) \times 10^{-30} \times 0.89(0) \times 3.0(0) \times 10^8} \checkmark$$

$(= 1.2(4) \times 10^{-12} \text{ m})$

2

(ii) $E_{Ph} = \left(hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{1.24 \times 10^{-12}} \right) = 1.6(0) \times 10^{-13} \text{ J} \checkmark$

1

$$\begin{aligned}
 \text{(iii)} \quad E_k &= (m - m_0) c^2 \\
 &= (1.998 \times 10^{-30} - 9.11 \times 10^{-31}) \times (3.0 \times 10^8)^2 \\
 &= 9.78 \times 10^{-14} \text{ J} \quad \checkmark \quad 3 \text{ sf only} \quad \checkmark
 \end{aligned}$$

2

[11]

- M5.** (a) (i) **working** circuit including power supply and thermistor (correct symbol) **(1)**

voltmeter and ammeter or ohm meter **(1)**

2

- (ii) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate states that the thermistor is connected in a suitable circuit with voltmeter and ammeter or ohmmeter.

The candidate gives details of how the thermistor is heated in a beaker of water **or** a water bath and a thermometer is used to measure the temperature at small regular intervals.

The candidate states that the resistance is found at various temperatures either directly with an ohmmeter or by dividing voltage by current. The candidate may mention that the water must be stirred to ensure that the thermistor is at the temperature measured by the thermometer.

The candidate may give some indication of the range of temperatures to be used.

The candidate may refer to repetition of whole experiment.

The candidate may plot a graph of resistance against temperature.

The candidate may use a digital thermometer.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate states that the thermistor is connected in a suitable circuit with voltmeter and ammeter or ohmmeter. The candidate gives details of how the thermistor is heated in a beaker of water and a thermometer is used to measure the temperature.

The candidate states that the resistance is found at various temperatures either directly with an ohmmeter or by dividing voltage by current.

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary.

The form and style of writing may be only partly appropriate.

The candidate changes temperature at least once and measures V and I or R.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

Max 6

- (b) (i) $pd = 6.0 - 1.6 = 4.4$ (V) **(1)** 1
- (ii) $current = 4.4/1200 = 3.7 \times 10^{-3}$ (A) **(1)** (not 3.6) 1
- (iii) $resistance = 1.6/3.7 \times 10^{-3} = 440$ or 430 (Ω) **(1)**
2 sfs **(1)** 2
- (c) less current now flows or terminal pd/voltage lower **(1)**
(or voltage across cell/external circuit is lower)
(hence) pd/voltage across resistor will decrease **(1)** 2

[14]

M6. (a) $(\Delta E_p = mg\Delta h) = 55 \times 9.8(1) \times 4.2$ **(1)**
 $= 2300$ (J) **(1)** (2266.1)

2

(b) (i) $(E_k = 3.2/4.2 \times 2264$ or uses suitable kinematics equation)
 $= 1700$ (J) **(1)** (= 1724.8 = 1720)

1

ecf (a)

(ii) $(E_k = +\frac{1}{2} mv^2 = 1724.8)$ $v = \sqrt{\frac{2 \times 1724.8}{55}} = \sqrt{62.72}$
ecf (b) (i)

or use of $v^2 = 2as$ **(1)**

$= 7.9$ m s⁻¹ **(1)** (= 7.9196)

2

(c) one arrow, vertical, upward pointing, starts on soles of feet **(1)**

1

(d) (use of $\alpha = \frac{\Delta v}{\Delta t}$ gives) $= \frac{7.920}{0.26}$ **(1)**
or ecf (b) (ii)/0.26

$= 30$ (m s⁻²) **(1)** (30.46)

or use $\alpha = \frac{2s}{t^2}$ of or $\alpha = \frac{v^2}{2s}$ **(1)**

allow incorrect values of s here

$= 29.6$ or 31.4 respectively **(1)**

2

(e) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Candidate must state that:

- (elastic potential) energy is transformed to **kinetic or** trampoline does work (on gymnast)
- (KE) is transformed into (gravitational) **potential** energy
- (the gymnast) must 'jump'/bend knees/do work/'use' chemical energy/supply energy (to increase height)

For 6 marks, must also state that (the gymnast) must overcome resistive forces (drag/heat loss/reference to energy 'lost' in trampoline, etc)

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Candidate must state **one** from:

- chemical energy (transferred) to elastic, kinetic or gravitational energy
- PE (from trampoline) to KE (of gymnast)
- KE (gymnast) to (G)PE (gymnast)

and one of the following:

- work is done by the trampoline (on the gymnast)
- that work is done on the trampoline (by the gymnast)
- work done against resistive forces
- (additional) energy input required (to achieve additional height)

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

Candidate must

- give **one** relevant energy gain or loss in the system **or** state that energy is input to reach greater height

For two marks, a relevant energy transformation must be given **or** one further marking point:

- (to reach the same height) the gymnast must do work in order to replace the energy wasted as the springs and the trampoline (rubber) unload (contract)
- to reach a greater height, the gymnast must do additional work by (bending and) extending her legs (jumping) as the trampoline moves upwards
- the additional downward force keeps the trampoline extended for longer, thus increasing the impulse
- correct reference to law of energy conservation

max 6

[14]

- M7.** (a) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

QWC	descriptor	mark range
good-excellent	Uses accurately appropriate grammar, spelling, punctuation and legibility. Uses the most appropriate form and style of writing to give an explanation or to present an argument in a well structured piece of extended writing. [May include formulae or equations]. Answer refers to at least 5 of the relevant points listed below.	5-6
modest-adequate	Only a few errors. Some structure to answer, style acceptable, arguments or explanations partially supported by evidence or examples. Answer refers to at least 3 of the relevant points listed below.	3-4

poor-limited	Several significant errors. Answer lacking structure, arguments not supported by evidence and contains limited information. Answer refers to no more than 2 of the relevant points.	1-2
incorrect, inappropriate or no response	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	0

The explanation expected in a competent answer should include a coherent selection of the following physics ideas.

electron in atoms can only occupy certain (discrete) energy levels **(1)**

the ground state is the lowest energy state an electron/atom can occupy **(1)**

electrons collide with (orbital) electrons **(1)**

giving the electrons the energy necessary to move to a higher level **(1)**

electrons later return to a lower level/ground state losing energy **(1)**

by emitting photons of a characteristic/different/discrete/certain/
varying frequencies **or** $\Delta E = hf$ **or** frequency depends on energy
difference **(1)**

(b) (i) the 5.5 eV electron does not have enough energy to excite
an (orbital) electron/atom **(1)**

the 9.0 eV electron provide enough energy to excite an (orbital)
electron/atom **(1)**

(ii) energy = $9.0 \times 1.6 \times 10^{-19}$ **(1)** = 1.44×10^{-18} (J) **(1)**

(iii) $E = 1.44 \times 10^{-18} - 1.6 \times 10^{-19} = 1.28 \times 10^{-18}$ **(1)** (J)

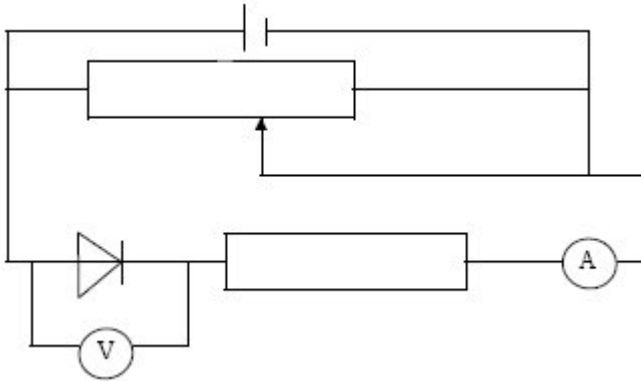
$6.63 \times 10^{-34} \times f = 1.28 \times 10^{-18}$ **(1)**

$f = 1.28 \times 10^{-18} / 6.63 \times 10^{-34} = 1.9 \times 10^{15}$ Hz **(1)**

7

[13]

M8. (a) (i)



suitable variable input (variable power supply or variable resistor) **(1)**

protective resistor **and** diode **forward** biased **(1)**

correct current **and** pd measuring devices **(1)**

3

(ii) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

QWC	descriptor	mark range
good-excellent	Uses accurately appropriate grammar, spelling, punctuation and legibility. Uses the most appropriate form and style of writing to give an explanation or to present an argument in a well structured piece of extended writing. [May include bullet points and/or formulae or equations]. Answer refers to at least 5 of the relevant points listed below.	5-6
modest-adequate	Only a few errors. Some structure to answer, style acceptable, arguments or explanations partially supported by evidence or examples. Answer refers to at least 3 of the relevant points listed below.	3-4
poor-limited	Several significant errors. Answer lacking structure, arguments not supported by evidence and contains limited information. Answer refers to no more than 2 of the relevant points.	1-2
incorrect, inappropriate or no	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	0

response		
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The explanation expected in a competent answer should include a coherent selection of the following physics ideas.

connect circuit up **(1)**

measure current (I) and pd/voltage (V) **(1)**

vary resistance/voltage **(1)**

obtain a range of results **(1)**

reverse connections to power supply (and repeat) **(1)**

plot a graph (of pd against current) **(1)**

mention of significance of 0.6V **or** disconnect between readings **or** change range on meters when doing reverse bias **(1)**

(b) (i) (use of $I = V/R$)

$$I = 12/8 \text{ (1)} = 1.5 \text{ A (1)}$$

(ii) $I = (12 - 0.65 \text{ (1)})/4 = 2.8 \text{ A (1)}$ sig figs **(1)**

5

[14]

M9. (a) (i) ($u = 0$, $s = 0.16 \text{ m}$, $a = 9.8(1) \text{ m s}^{-2}$)
(rearranging $s = ut + \frac{1}{2} at^2$ with $u = 0$ gives)

$$t = \frac{2s}{a} \text{ or } v^2 = u^2 + 2gs \text{ or } 0.16 = 1/2 \times 9.81 t^2$$

$$\text{or } t_0 = \sqrt{\frac{(2 \times 0.16)}{9.8(1)}} \text{ (1) = 0.1804 or 0.1806 or 0.181 etc (1)}$$

(s) **2 sf only (1)**

(ii) $(v_0 = u + at_0 =) 0 + 9.81 \times 0.18$ ecf (a) (i) or $v^2 = 2 \times 9.81 \times 0.16$ **(1)**
 $= 1.8$ or $1.77 \text{ (m s}^{-1}\text{)}$ **(1)**

5

- (b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

QWC	descriptor	mark range
good-excellent	The candidate provides a correct description of the motion of the ball including its deceleration in the fluid decreasing and becoming zero (or attaining constant velocity). They should give a comprehensive and coherent explanation which includes nearly all the necessary principles in a logical order. In their explanation, the candidate should refer to the forces including their directions acting on the ball, why the resistive force decreases and why the acceleration becomes zero.	5-6
modest-adequate	The description should refer to the ball decelerating in the fluid until it becomes zero or attains constant velocity . Their explanation should be fairly coherent although it may not be comprehensive and may focus only on the forces acting when the ball attains constant velocity - balanced forces - or on the reason for the initial deceleration.	3-4
poor-limited	The candidate knows that the ball decelerates (acceleration with direction) or is acted on by an upward force (as well as the force of gravity). Their explanation of why the ball attains constant velocity may be absent. May be sketchy and lacks key considerations. They may not appreciate that the two forces are equal and opposite when the ball is moving at constant velocity.	1-2
incorrect, inappropriate or no response	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	0

The explanation expected in a competent answer should include a coherent selection of the following physics ideas.

The ball decelerates/slows down in the fluid **(1)** if acceleration is used the direction must be specified

- because a force due to fluid friction/resistance/viscosity acts (upwards) on the ball **(1)**

- (and) the force due to the fluid is greater than the weight of the ball **(1)**
- resistive force is upwards **(1)**
- resistive force decreases **(1)**

The deceleration decreases (to zero) **(1)**

- because the force due to fluid friction/resistance/viscosity decreases as the ball's speed decreases **(1)**
- until it is equal (and opposite) to the weight of the ball **(1)** (or the resultant force is zero)
- gradient of graph gives the acceleration and the ball moves at constant/terminal velocity/ $a = 0$ **(1)**

[11]

M10. (a) The marking scheme for this part of the question includes an overall assessment for the quality of written communication. There are no discrete marks for the assessment of written communication but the quality of written communication will be one of the criteria used to assign the answer to one of three levels.

Level	Descriptor	Mark range
	an answer will be expected to meet most of the criteria in the level descriptor	
Good 3	<ul style="list-style-type: none"> — answer supported by appropriate range of relevant points — good use of information or ideas about physics, going beyond those given in the question — argument well structured with minimal repetition or irrelevant points — accurate and clear expression of ideas with only minor errors of spelling, punctuation and grammar 	6-7
Modest 2	<ul style="list-style-type: none"> — answer partially supported by relevant points — good use of information or ideas about physics given in the question but limited beyond this — the argument shows some attempt at structure — the ideas are expressed with reasonable clarity but with a few errors of spelling, punctuation and grammar 	3-5

Limited 1	<ul style="list-style-type: none"> - valid points but not clearly linked to an argument structure - limited use of information or ideas about physics 	1-2
0	<ul style="list-style-type: none"> - unstructured - errors in spelling, punctuation and grammar or lack of fluency - incorrect, inappropriate or no response 	0

physics points:

- the energy of each photon/the light increases with frequency **(1)**
- electrons need a minimum amount of energy to leave the metal **(1)**
- the amount of energy required is equal to the work function **(1)**
- (this suggests) the electrons are given energy in one discrete event or one electron interacts with one photon **(1)**
- (so the) light energy is not spread out it is concentrated (into quanta) **(1)**
- the electron does not build up energy over time or photoelectricity occurs immediately light falls on the metal **(1)**

(b) (i) $E = hf = 6.63 \times 10^{-34} \times 2.10 \times 10^{15} = 1.39 \times 10^{-18} \text{ (J) (1)}$

(ii) $\phi = hf - E_k \text{ (1)}$
 $= 1.39 \times 10^{-18} - 6.20 \times 10^{-19}$
 $= 7.72 \times 10^{-19} \text{ J (1)}$

5

[12]

- M11.** (a) same wavelength or frequency **(1)**
same phase or constant phase difference **(1)**

2

- (b) The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question.

Level	Descriptor	Mark range
	an answer will be expected to meet most of the criteria in the level descriptor	
Good 3	<ul style="list-style-type: none"> – answer includes a good attempt at the explanations required – answer makes good use of physics ideas including knowledge beyond that given in the question – explanation well structured with minimal repetition or irrelevant points and uses appropriate scientific language – accurate and logical expression of ideas with only minor/occasional errors of grammar, punctuation and spelling 	5-6
Modest 2	<ul style="list-style-type: none"> – answer includes some attempts at the explanations required – answer makes use of physics ideas referred to in the question but is limited to these – explanation has some structure but may not be complete – explanation has reasonable clarity but has a few errors of grammar and/or punctuation and spelling 	3-4
Limited 1	<ul style="list-style-type: none"> – answer includes some valid ideas but these are not organised in a logical or clear explanation – answer lacks structure – several errors in grammar, punctuation and spelling 	1-2
0	– incorrect, inappropriate or no response	0

the explanations expected in a competent answer should include a coherent selection of the following physics ideas:

- narrow single slit gives wide diffraction
- to ensure that both S_1 and S_2 are illuminated
- slit S acts as a point source
- narrow single slit ensures it provides coherent sources of light at S_1 and S_2
- S_1 and S_2 are illuminated by same source giving same wavelength
- paths to S_1 and S_2 are of constant length giving constant phase difference or SS_1 and SS_2 so waves are in phase

- light is diffracted as it passes through S_1 and S_2 and the diffracted waves overlap and interfere
- where the path lengths from S_1 and S_2 to the screen differ by whole numbers, n of wavelengths, constructive interference occurs producing a bright fringe on the screen
- where the path lengths differ by $(n + \frac{1}{2})$ wavelengths, destructive interference occurs producing a dark fringe on the screen

- (c) graph to show: maxima of similar intensity to central maximum **(1)**
 (or some decrease in intensity outwards from centre)
 all fringes same width as central fringe **(1)**

2

[10]

M12. (a) **one feature** (1 mark for one of the following)

- there is a threshold (minimum) frequency (of light) for photoelectric emission from a given metal
- photoelectric emission is instant

explanation

- light consists of photons (or wavepackets) **(1)**
- energy of a photon = hf where f is the light frequency **(1)**
- work function ϕ of metal is the minimum amount of energy it needs to escape **(1)**
- 1 electron absorbs 1 photon and gains energy hf **(1)**
- electron can escape if energy gained $hf > \phi$ **(1)**

6

- (b) (i) an electron requires 2.2 eV of energy to escape from the metal surface **(1)**

(ii) photon frequency, $f (= c/\lambda = \frac{3.0 \times 10^8}{5.2 \times 10^{-7}}) = 5.77 \times 10^{14} \text{ J (1)}$

photon frequency ($= hf$) $= 6.63 \times 10^{-34} \times 5.77 \times 10^{14} = 3.83 \times 10^{-19} \text{ J (1)}$

$E_{k \text{ max}} (= hf - \phi) = 3.83 \times 10^{-19} - (2.2 \times 1.6 \times 10^{-19}) \text{ (1)}$
 $= 3.1 \times 10^{-20} \text{ J (1)}$

5

[11]

M13. electrons diffract [or high energy electron scattering] (1)
 showing wave behaviour (1)

electrons are deflected in electric or magnetic fields (1)
 showing particle behaviour (1)

interference of electromagnetic waves (1)
 showing wave behaviour (1)

photoelectric effect (1)
 showing particle behaviour (1)

max 6
 QWC 2

[6]

M14.(a) The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.
 The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Top Band

*Both have rest mass
Mention electromagnetic interaction Correct quark structure of mesons and baryons
Both hadrons and leptons interact/decay through weak interaction
For 6 marks must have last two points*

Candidate gives correct examples of hadrons and leptons. Identifies the differences between hadrons and leptons (hadrons affected by strong nuclear reaction and are made of quarks). Leptons are fundamental and do not experience the strong nuclear reaction. Hadrons are divided into baryons and mesons. Baryons three quarks, mesons quark anti-quark pair. Similarities between groups all experience weak interaction and if charged the electromagnetic interaction. All have rest mass.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Middle band

*Only hadrons experience strong nuclear interaction (need this to get in middle band)
Hadrons are mesons or baryons. Examples of each*

Candidate gives correct examples of hadrons and leptons. Identifies one difference between hadrons and leptons (e.g. hadrons affected by strong nuclear reaction or are made of quarks). Leptons are fundamental. Hadrons are divided into baryons and mesons.

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

Lower band

1 or 2 correct facts about hadrons leptons eg Leptons are fundamental / hadrons made of quarks

Identifies two correct properties of hadrons and leptons.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

example of hadron and lepton
mention of strong interaction
mention of quark structure hadrons
leptons are fundamental
identify baryons and mesons
gives quark structure of baryons and mesons
similarities e.g. all have rest mass
all affected by weak interaction
if charged both experience electromagnetic interaction

6

- (b) (i) a correct example of particle e.g. electron
and correct example of antiparticle e.g. positron ✓

Allow correct symbols
Allow antielectron for positron
Also allow pi zero and gamma

1

- (ii) correct difference e.g. opposite charge/other named quantum number ✓
must be consistent with (i)

1

[8]

- M15.** (a) there must be a large distance between collisions to allow electrons to gain enough energy **(1)**
[or the vapour must not completely absorb the electrons]

1

- (b) the mercury vapour emits ultra violet (radiation) **(1)**
the coating absorbs electromagnetic radiation/light from the mercury **(1)**
emits longer wavelengths/lower frequencies in the visible region **(1)**

max 3
QWC 2

[4]

- M16.(a)** $\text{vol} = \frac{4}{3} \pi 0.011^3 = (5.5753) 5.6 \times 10^{-6} \text{ (m}^3\text{)} \checkmark$
($m = \rho V$)
($= 8100 \times 5.575 \times 10^{-6} =$) 0.045 (kg) ✓ ecf from first part
Allow use of $g = 10$
0.36 kg , 3.5 N from use of diameter rather than radius (max 3 from 4)

candidate's mass x g ($W = 0.045160 \times 9.81 = 0.44302 = 0.44 \text{ N}$) ✓

any 2sf ✓

4

- (b) (i) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Mentions **all** of the following:

- velocity (or speed) increases and then becomes constant (terminal velocity)
- acceleration reduces to zero
- forces become equal / balanced
- weight (allow 'gravity') and drag / friction correctly identified

For 6 marks: In addition to the above, two of the following:

- drag force increases with speed
- (weight /downward force initially) greater than drag / friction etc
- resultant force causes acceleration
- Resultant force = $W - \text{drag}$
- acceleration = gradient
- acceleration is maximum (9.81) at the beginning

5-6

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Mentions the **two** following points:

- velocity (or speed) increases **OR** velocity (or speed) becomes constant / terminal velocity reached
- acceleration decreases **OR** acceleration becomes zero

AND

for 3 marks: mentions **one** more valid point from the 4 above or from the 7 below:

for 4 marks: at least two additional points with at least one from the 'Forces' list

- acceleration = gradient
- acceleration is maximum (9.81) at the beginning

Forces

- weight greater than drag (before terminal velocity)
- there is a resultant force downwards (before terminal velocity)
- forces become equal / balanced / drag = weight
- drag force increases with speed.
- Resultant force = $W - \text{drag}$

Poor QWC may result in award of the lower mark within a band.

3-4

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

Max 3 for mention of deceleration or increasing acceleration

One valid point from list below

For two marks: **Two** valid points

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

Mention of the points below may influence the mark given within each category:

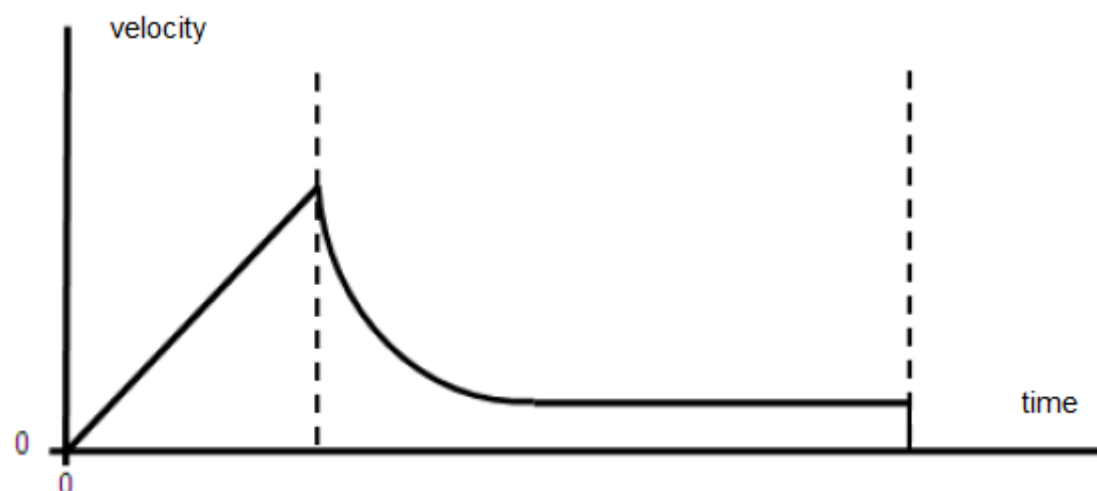
- velocity increases
- velocity becomes constant (terminal velocity)
- acceleration is maximum (9.81) at the beginning
- acceleration decreases (to zero)
- weight greater than drag (before terminal velocity)
- there is a resultant force downwards (before terminal velocity)
- forces become equal / balanced / drag = weight
- drag force increases with speed.
- resultant force = $W - \text{drag}$
- acceleration = gradient

valid point explaining why rapid decrease in velocity occurs when ball hits bottom of container. E.g. resultant upward force (decelerates the ball)

Several serious misconceptions may reduce a 2 mark answer to 1

1-2

(ii)



straight line with positive gradient from origin to first dotted line ✓

3rd mark: Allow lines that become straight with a constant negative gradient after a curve.

*Vertical line at the end is not necessary.
End of line must be between start of 'e' in 'time' and end of 'w'
in 'when'.*

descending line (curved or straight but non-vertical) starting from a point on first dotted line (must not have negative velocity at any point) and the line may then become horizontal ✓

curved line descending from first dotted line which is a continuation of the initial line (the gradient must be decreasing initially (a curve) and the line may then become horizontal

AND extending up to second dotted line (with positive non-zero velocity)

AND no **incorrect** continuation of line beyond second time line ✓

Allow correct lines beyond the second time line: continuous zero velocity or falling below x axis and rising back to x axis (bouncing) but not reaching a higher speed than descent

OR

straight line with positive gradient from origin to first dotted line ✓

straight line with positive gradient from origin to first dotted line

AND ascending curved line with positive gradient decreasing, starting from a point on first dotted line (continuation of first line) ✓

extending up to second dotted line

AND no incorrect continuation of line beyond second time line ✓

3

[13]

M17.(a) Quality of written communication:

Good – Excellent

The candidate provides a comprehensive, coherent and logical explanation which recognises what a stationary wave is and that the conditions for the formation of a stationary wave are present. They should know that nodes and antinodes are formed at alternate positions along XY which are equally spaced with nodes every half wavelength. They should know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible.

Their answer should be well-presented in terms of spelling, punctuation and grammar.

For top band,

explanation = at least b and e

description = at least f, g,h

(5-6 marks)

Modest – Adequate

The candidate provides a logical explanation which recognises what a stationary wave is and what some of the conditions for the formation of a stationary wave are. They may know that nodes and antinodes are formed at alternate positions along XY with nodes every half-

wavelength. They may know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible. Their answer should be well-presented in terms of spelling, punctuation and grammar.

For middle band ,

explanation = at least any two of a-e

description = at least any two of f-i

(3-4 marks)

Poor to Limited

The candidate may recognise that the reflector reflects radio waves which then form a stationary wave pattern with the incident waves. They may be unaware what the conditions for the formation of a stationary wave are and their understanding of nodes and antinodes may be poor. They may have some awareness that the stationary wave causes the detector signal to vary with position along XY and that the wavelength can be determined from this variation although they might not be able to link the wavelength to the changes of detector position correctly.

Their answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation.

For lowest band,

Any 2 points , must be 1 of each for 2 marks

The explanations expected in a good answer should include most of the following physics ideas

Explanation of stationary wave formation;-

a. *radio waves from the transmitter are reflected back towards the transmitter ✓*

b. *reflected and incident waves pass through each other ✓*

c. *both waves have same frequency (and speed) and amplitude ✓*

d. *superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓*

e. *equally spaced nodes and antinodes formed along XY ✓*

Description of measurement of wavelength;-

f. *Detector signal is zero (or least) along XY at nodes ✓*

g. *distance between adjacent nodes is $\frac{1}{2}\lambda$ ✓*

h. *move detector along XY to measure distance between adjacent nodes and double to give the wavelength ✓*

i. *measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓*

6
(1-2 marks)

(b) Speed of radio waves (obtained by Hertz) is the same as

the speed of light ✓

Speed of electromagnetic waves (calculated or predicted by Maxwell) is the same as the speed of light (or of radio waves) so radio waves are electromagnetic waves ✓

2
(Total 8 marks)

M18. (a) The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate provides a comprehensive and coherent description which includes a clear explanation of constant energy level differences and how electrons can be excited by electron collisions. The link between the energy of a photon and its frequency should be clear. The description should include a clear explanation of the reason atoms of a given element emit photons of a characteristic frequency **or** there is a clear link between constant energy differences and photon frequency/wavelength (eg $E=hf$).

The candidate should relate the energy **difference** between levels to the energy of emitted photons and state the energy difference is fixed/constant.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate provides an explanation of energy levels and how excitation takes place by electron collision with

atomic/orbital electrons. The candidate explains how an orbital/atomic electron loses energy by emitting a photon.

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary.

The form and style of writing may be only partly appropriate. Some mention of energy levels and the idea of excitation of electron. Talk about excitation of atom instead of electron limits the mark to 1.

Incorrect, inappropriate or no response: 0 marks

No answer or answer refers to unrelated, incorrect or inappropriate physics.

The explanation expected in a competent answer should include a coherent account of the significance of discrete energy levels and how the bombardment of atoms by electrons can lead to excitation and the subsequent emission of photons of a characteristic frequency.

electrons bombard atoms of vapour and give energy to electrons in atom

electrons move to a higher energy level

electrons are excited

excited electrons move down to lower energy levels losing energy by emitting photons

photons have energy hf

photons of characteristic frequencies emitted from atoms of a particular element

this is because atoms have discrete energy levels which are associated with particular energy values

max 6

- (b) (i) energy required to (completely) remove an electron from atom/hydrogen ✓✓
ground state/lowest energy level ✓✓

2

(ii) $13.6 \times 1.6 \times 10^{-19} \checkmark = 2.18 \times 10^{-18} \text{ (J)} \checkmark$ 3 sfs \checkmark

3

[11]