

**A-LEVEL PHYSICS
EXAMINATION
PREPARATION
BOOK 1**



PAPER 1

**A LEVEL PHYSICS
MOCK EXAMINATION (WINTER SERIES)
EXAMINATION PREPARATION BOOK
STUDENT BOOK**

NAME	
PHYSICS CLASS	
MODULE TEACHER	
ALPS GRADE	

REVISION TRACKER

EXAMINATION	MARK	GRADE
EXAM 1		
EXAM 2		



In the following booklet there are **two examination** papers based on the Physics Paper 1.

These questions are here to ensure you are fully prepared for your A-Level examinations.

These questions are additional to the work which you must do on your A-Level course.

To gain the highest grade possible in your A-Level mock examinations it is recommended that you complete these questions in your spare time.

This will both familiarise yourself with both the concepts found in the A-Level syllabus and the examination technique found in examinations.

The mark scheme to the questions is attached in a further booklet for you to use independently.

To thoroughly prepare yourself for a full examination on Physics Paper 1, it is suggested that you complete each practice examination in timed examination conditions.

Physics Paper 1 has a maximum time of **2 hours**.

Consider this when completing the paper.

Good luck for your examinations and thank you for your hard work.

IMPORTANT NOTE

The information needed to answer these problems are found in the preparatory reading notes and the student class book.

This booklet may be used as a learning resource in addition to the resources in the lesson. If you require any further assistance, please ask.

This booklet may also be used as a revision resource for intervention, internal assessments and external assessments.

Please keep this in your student file.



GRADE BOUNDARIES

Please use this grade boundaries to estimate your A-Level grade.

A* = 64
A = 53
B = 45
C = 37
D = 29
E = 21
U = 0

These will be the grade boundaries for your terminal assessment in Physics Paper 1 in the mock examination period.

**PRACTICE EXAMINATION 1****Section A**Answer **all** questions in this section.**0 1**

A common type of smoke detector contains a very small amount of americium-241, ${}^{241}_{95}\text{Am}$

0 1. **1**

Determine the number of each type of nucleon in one americium-241 nucleus.

[2 marks]

type of nucleon _____ number _____

type of nucleon _____ number _____

0 1. **2**

Americium-241 is produced in nuclear reactors through the decay of plutonium, ${}^{241}_{94}\text{Pu}$

State the decay process responsible for the production of americium-241. Explain your answer.

[2 marks]



0 1 . 3 An americium-241 nucleus decays into nuclide X by emitting an alpha particle.

Write an equation for the decay of the nucleus and determine the proton number and nucleon number of X.

[3 marks]

nucleon number _____

proton number _____

0 1 . 4 The alpha radiation produced by americium-241 causes the ionisation of nitrogen and oxygen molecules in the smoke detector.

State what is meant by ionisation.

[1 mark]

0 1 . 5 A friend who has not studied physics suggests that a smoke detector containing radioactive material should not be sold.

Use your knowledge of physics to explain why a smoke detector containing americium-241 does not provide any risk to the user.

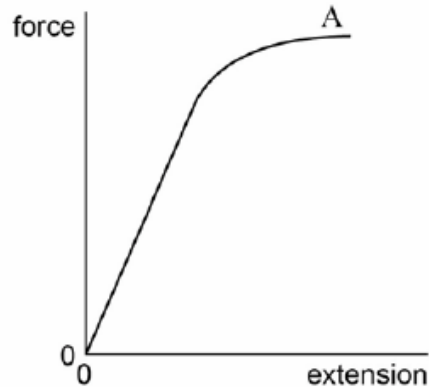
[2 marks]



0 2

A student adds a series of masses to a vertical metal wire of circular cross-section and measures the extension of the wire produced. **Figure 1** is a force–extension graph of the data.

Figure 1



0 2

1

Mark on **Figure 1** the point P, the limit beyond which Hooke's law is no longer obeyed.

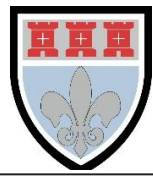
[1 mark]

0 2

2

Outline how the student can use these results and other measurements to determine the Young modulus of the wire.

[3 marks]



- 0 2** . **3** When the wire has been extended to A, the masses are removed one by one and the extension re-measured.

Draw on **Figure 1** the shape of the graph that the student will obtain.

[1 mark]

- 0 2** . **4** Explain why the graph has the shape you have drawn.

[2 marks]

- 0 2** . **5** The metal wire is used to make a cable of diameter 6.0 mm. The Young modulus of metal of the cable is 2.0×10^{11} Pa.

Calculate the force necessary to produce a strain of 0.20% in the cable.

[3 marks]

force = _____ kN

- 0 2** . **6** The cable is used in a crane to lift a mass of 600 kg.

Determine the maximum acceleration with which the mass can be lifted if the strain in the cable is not to exceed 0.20%.

[3 marks]

acceleration = _____ m s^{-2}



0 2 . 7 An engineer redesigns the crane to lift a 1200 kg load at the same maximum acceleration.

Discuss the changes that could be made to the cable of the crane to achieve this, without exceeding 0.20% strain.

[3 marks]

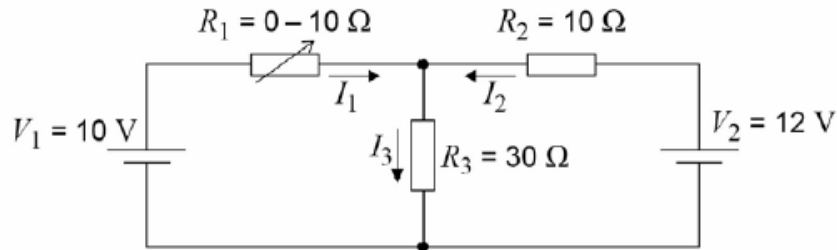
Turn to page 8 for the next question



0 3

The cells in the circuit shown in **Figure 2** have zero internal resistance. Currents are in the directions shown by the arrows.

Figure 2



R_1 is a variable resistor with a resistance that varies between 0 and 10 Ω .

0 3

. 1

Write down the relationship between currents I_1 , I_2 and I_3 .

[1 mark]

0 3

. 2

R_1 is adjusted until it has a value of 0 Ω .

State the potential difference across R_3 .

[1 mark]

potential difference = _____ V

0 3

. 3

Determine the current I_2 .

[2 marks]

current = _____ A



0 3 . 4

State and explain what happens to the potential difference across R_2 as the resistance of R_1 is gradually increased from zero.

[3 marks]

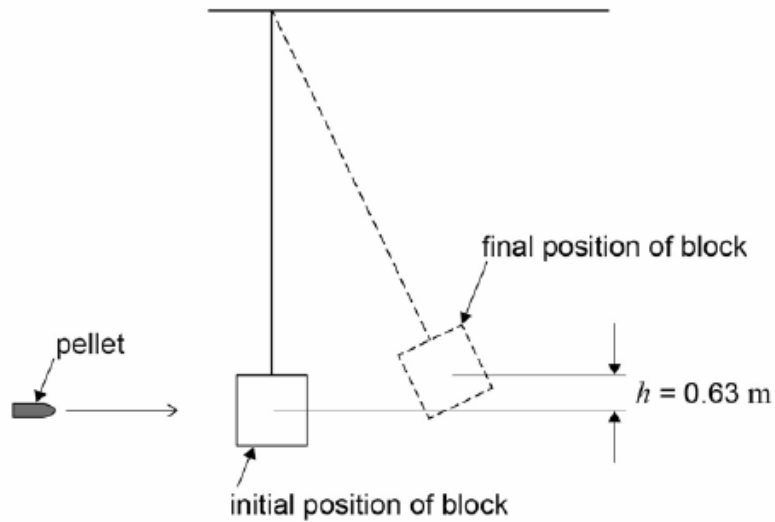
Turn over for the next question



0 4

The speed of an air rifle pellet is measured by firing it into a wooden block suspended from a rigid support. The wooden block can swing freely at the end of a light inextensible string as shown in **Figure 3**.

Figure 3



A pellet of mass 8.80 g strikes a stationary wooden block and is completely embedded in it. The centre of mass of the block rises by 0.63 m. The wooden block has a mass of 450 g.

0 4

. 1

Determine the speed of the pellet when it strikes the wooden block.

[4 marks]

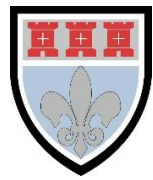
speed = _____ m s^{-1}



0 5 . 1

Describe the structure of a step-index optical fibre outlining the purpose of the core and the cladding.

[3 marks]



0 5 . 2

A signal is to be transmitted along an optical fibre of length 1200 m. The signal consists of a square pulse of white light and this is transmitted along the centre of a fibre. The maximum and minimum wavelengths of the light are shown in **Table 1**.

Table 1

Colour	Refractive index of fibre	Wavelength / nm
Blue	1.467	425
Red	1.459	660

Explain how the difference in refractive index results in a change in the pulse of white light by the time it leaves the fibre.

[2 marks]

0 5 . 3

Discuss **two** changes that could be made to reduce the effect described in part 5.2.

[2 marks]



0 6

Read through the following passage and answer the questions that follow it.

Measuring the speed of sound in air

After the wave nature of sound had been identified, many attempts were made to measure its speed in air. The earliest known attempt was made by the French scientist Gassendi in the 17th century. The procedure involved timing the interval between seeing the flash of a gun and hearing the bang from some distance away. Gassendi assumed that, compared with the speed of sound, the speed of light is infinite. The value he obtained for the speed of sound was 480 m s^{-1} . He also realised that the speed of sound does not depend on frequency.

A much better value of 350 m s^{-1} was obtained by the Italian physicists Borelli and Viviani using the same procedure. In 1740 another Italian, Bianconi, showed that sound travels faster when the temperature of the air is greater.

In 1738 a value of 332 m s^{-1} was obtained by scientists in Paris. This is remarkably close to the currently accepted value considering the measuring equipment available to the scientists at that time. Since 1986 the accepted value has been 331.29 m s^{-1} at 0°C .

0 6

. 1

Suggest an experiment that will demonstrate the wave nature of sound (line 1).

[1 mark]



0 6 . 2

Using Gassendi's value for the speed of sound (line 6), calculate the time between seeing the flash of a gun and hearing its bang over a distance of 2.5 km.

[1 mark]

time = _____ s

0 6 . 3

Explain why it was necessary to assume that 'compared with the speed of sound, the speed of light is infinite' (line 5).

[1 mark]

0 6 . 4

Explain **one** observation that could have led Gassendi to conclude that 'the speed of sound does not depend on frequency' (line 7).

[2 marks]

Question 6 continues on the next page



- 0 6 . 5 Explain how the value obtained by Borelli and Viviani was 'much better' than that obtained by Gassendi (line 8).

[1 mark]

- 0 6 . 6 The speed of sound c in dry air is given by

$$c = k\sqrt{(\theta + 273.15)}$$

where θ is the temperature in $^{\circ}\text{C}$, and k is a constant.

Calculate a value for k using data from the passage.

[2 marks]

$$k = \text{_____} \text{ m s}^{-1} \text{ K}^{-1/2}$$

- 0 6 . 7 State the steps taken by the scientific community for the value of a quantity to be 'accepted' (line 13).

[2 marks]

END OF SECTION A



Section B

Each of Questions 7 to 31 is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response.

Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD WRONG METHODS

If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

0 7

The nucleus of ${}^9_4\text{Be}$ captures a proton and emits an α particle. What is the product nucleus?

[1 mark]

A ${}^{10}_6\text{C}$

B ${}^7_3\text{Li}$

C ${}^6_3\text{Li}$

D ${}^6_2\text{He}$

0 8

When comparing X-rays with UV radiation, which statement is correct?

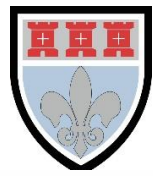
[1 mark]

A X-rays have a lower frequency.

B X-rays travel faster in a vacuum.

C X-rays do not show diffraction and interference effects.

D Using the same element, photoelectrons emitted using X-rays have the greater maximum kinetic energy.



0 9

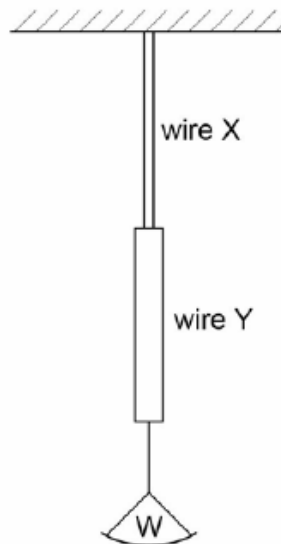
Monochromatic radiation from a source of light (source A) is shone on to a metallic surface and electrons are emitted from the surface. When a second source (source B) is used no electrons are emitted from the metallic surface. Which property of the radiation from source A must be greater than that from source B?

[1 mark]

- A amplitude
- B frequency
- C intensity
- D wavelength

1 0

Two vertical copper wires X and Y of equal length are joined as shown. Y has a greater diameter than X. A weight W is hung from the lower end of Y.



Which of the following is correct?

[1 mark]

- A The strain in X is the same as that in Y.
- B The stress in Y is greater than that in X.
- C The tension in Y is the same as that in X.
- D The elastic energy stored in X is less than that stored in Y.



1 1

An electron has a kinetic energy E and a de Broglie wavelength λ . The kinetic energy is increased to $4E$. What is the new de Broglie wavelength?

[1 mark]

A $\frac{\lambda}{4}$

B $\frac{\lambda}{2}$

C λ

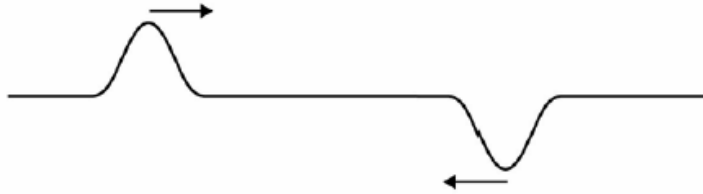
D 4λ

Turn over for the next question



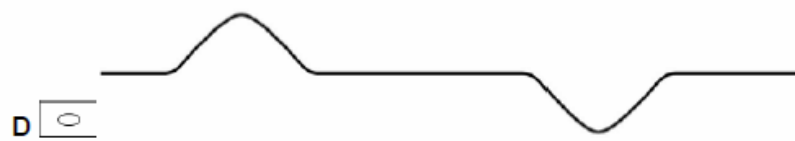
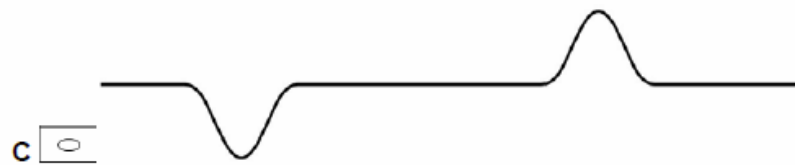
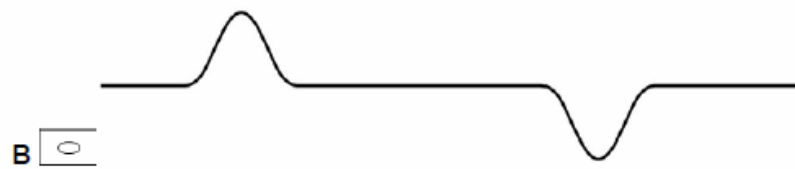
1 2

The diagram shows two pulses on a string travelling towards each other.



Which of the following diagrams shows the shape of the string when the pulses have passed through each other?

[1 mark]





1 3

Monochromatic light may be characterised by its speed, frequency and wavelength. Which of the following quantities change when monochromatic light passes from air into glass?

[1 mark]

- A Speed only.
- B Speed and wavelength only.
- C Speed and frequency only.
- D Wavelength and frequency only.

1 4

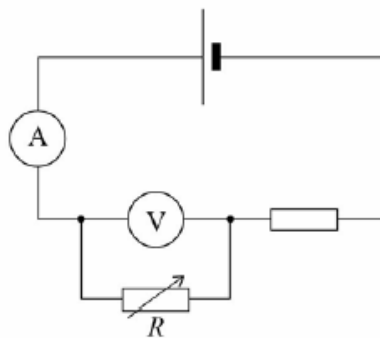
In a photoelectric experiment, light is incident on the metal surface of a photocell. Increasing the intensity of the illumination at the surface leads to an increase in the

[1 mark]

- A work function
- B minimum frequency at which electrons are emitted
- C current through the photocell
- D speed of the electrons

1 5

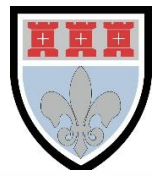
In the circuit shown in the diagram the cell has negligible internal resistance.



What happens to the reading of both meters when the resistance of R is decreased?

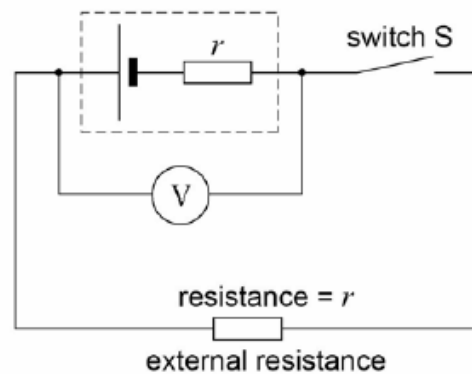
[1 mark]

	Reading of ammeter	Reading of voltmeter	
A	increases	increases	<input type="checkbox"/>
B	increases	decreases	<input type="checkbox"/>
C	decreases	increases	<input type="checkbox"/>
D	unchanged	decreases	<input type="checkbox"/>



1 6

In the circuit shown, V is a voltmeter with a very high resistance. The internal resistance of the cell, r , is equal to the external resistance in the circuit.



Which of the following is not equal to the emf of the cell?

- [1 mark]
- A** the reading of the voltmeter when the Switch S is open
- B** the chemical energy changed to electrical energy when unit charge passes through the cell
- C** twice the reading of the voltmeter when the switch S is closed
- D** the electrical energy produced when unit current passes through the cell

1 7

Monochromatic light of wavelength 490 nm falls normally on a diffraction grating that has 6×10^5 lines per metre. Which one of the following is correct?

- [1 mark]
- A** The first order is observed at angle of diffraction of 17° .
- B** The second order is observed at angle of diffraction of 34° .
- C** The third and higher orders are not produced.
- D** A grating with more lines per metre could produce more orders.



1 8

An electron collides with a neutral atom and ionizes it. Which of the following describes the particles present after the collision?

[1 mark]

- A An electron and an excited atom.
- B An excited atom containing an excess electron.
- C Two electrons and a positive ion.
- D Two electrons and a neutral atom in the ground state.

1 9

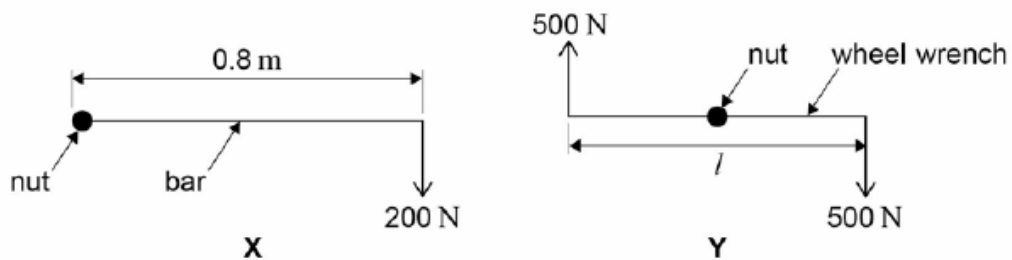
Two forces of 6 N and 10 N act at a point. Which of the following could **not** be the magnitude of the result?

[1 mark]

- A 16 N
- B 8 N
- C 5 N
- D 3 N

2 0

A car wheel nut can be loosened by applying a force of 200 N on the end of a bar of length 0.8 m as in X. A car mechanic is capable of applying forces of 500 N simultaneously in opposite directions on the ends of a wheel wrench as in Y.



What is the minimum length l of the wrench which would be needed for him to loosen the nut?

[1 mark]

- A 0.16 m
- B 0.32 m
- C 0.48 m
- D 0.64 m

**2 1**

A ballbearing **X** of mass $2m$ is projected vertically upwards with speed u . A ballbearing **Y** of mass m is projected at 30° to the horizontal with speed $2u$ at the same time. Air resistance is negligible. Which of the following statements is correct?

[1 mark]

- A** The horizontal component of **Y**'s velocity is u .
B The maximum height reached by **Y** is half that reached by **X**.
C **X** and **Y** reach the ground at the same time.
D **X** reaches the ground first.

2 2

What is the relationship between the distance y travelled by an object falling freely from rest and the time x the object has been falling?

[1 mark]

- A** y is proportional to x^2
B y is proportional to \sqrt{x}
C y is proportional to $\frac{1}{x}$
D y is proportional to $\frac{1}{x^2}$

2 3

A car exerts a driving force of 500 N when travelling at a constant speed of 72 km h^{-1} on a level track. What is the work done in 5 minutes?

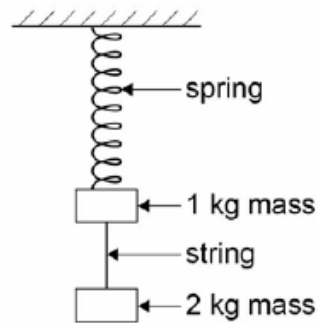
[1 mark]

- A** $3.0 \times 10^6\text{ J}$
B $2.0 \times 10^6\text{ J}$
C $2.0 \times 10^5\text{ J}$
D $1.1 \times 10^5\text{ J}$



2 4

Two masses hang at rest from a spring, as shown in the diagram. The string separating the masses is burned through.



Which of the following gives the accelerations of the two masses as the string breaks?

acceleration of free fall = g

[1 mark]

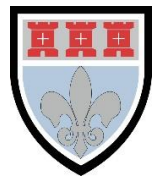
	acceleration of 1 kg mass upwards in m s^{-2}	acceleration of 2 kg mass downwards in m s^{-2}	
A	$3g$	$1g$	<input type="checkbox"/>
B	$2g$	$2g$	<input type="checkbox"/>
C	$2g$	$1g$	<input type="checkbox"/>
D	$1g$	$1g$	<input type="checkbox"/>

2 5

An object falls freely from rest. After falling a distance d its velocity is v . What is its velocity after it has fallen a distance $2d$?

[1 mark]

- A** $2v$
- B** $4v$
- C** $2v^2$
- D** $\sqrt{2}v$

**2 6**

An electric motor of input power 100 W raises a mass of 10 kg vertically at a steady speed of 0.5 m s^{-1} . What is the efficiency of the system?

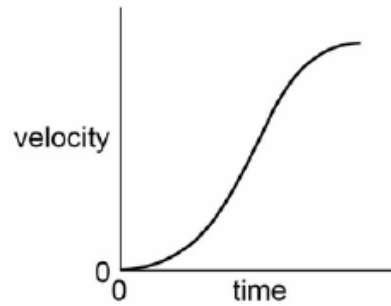
[1 mark]

- A** 5%
- B** 12%
- C** 50%
- D** 100%



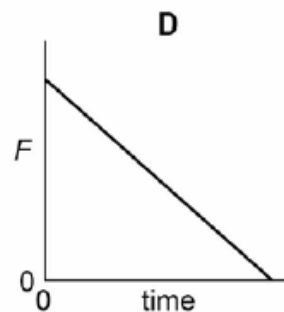
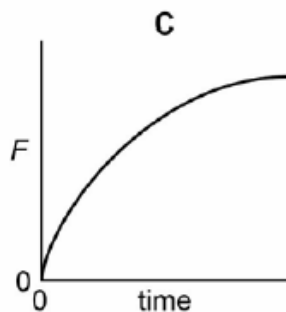
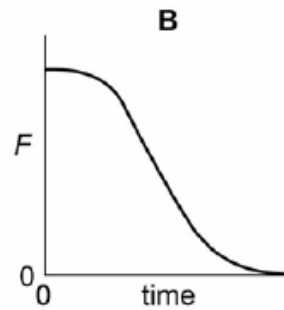
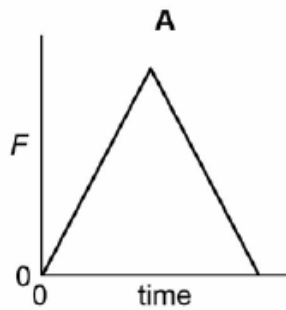
2 7

The velocity of a vehicle varies with time as shown by the following graph.



Which graph below represents how the resultant force F on the car varies during the same time?

[1 mark]



- A
- B
- C
- D



2 8

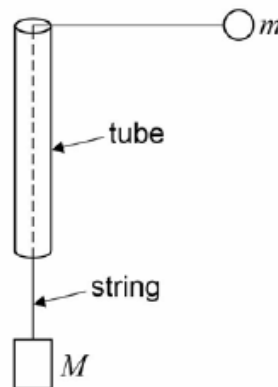
Which one of the following provides direct experimental evidence that light is a transverse wave motion rather than a longitudinal wave motion?

[1 mark]

- A** Two light waves that are coherent can be made to interfere.
- B** Light can be diffracted.
- C** Light can be polarised.
- D** The intensity of light from a point source falls off inversely as the square of the distance from the source.

2 9

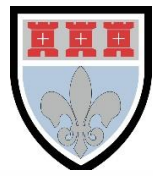
A string passes through a smooth thin tube. Masses m and M are attached to the ends of the string. The tube is moved so that the mass m travels in a horizontal circle of constant radius r and at constant speed v .



Which of the following expressions is equal to M ?

[1 mark]

- A** $\frac{mv^2}{2r}$
- B** mv^2rg
- C** $\frac{mv^2}{rg}$
- D** $\frac{mv^2g}{r}$

**3 0**

The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same which of the following is also doubled?

[1 mark]

- A** The time period.
- B** The total energy.
- C** The maximum velocity.
- D** The maximum acceleration.

3 1

A particle oscillates with undamped simple harmonic motion.

The acceleration of the particle

[1 mark]

- A** is always in the opposite direction to its velocity.
- B** decreases as the potential energy increases.
- C** is proportional to the frequency.
- D** is least when the speed is greatest.

END OF QUESTIONS



MARK SCHEME

Question	Answers	Additional Comments/Guidance	Mark
01.1	95 protons ✓ 241 – 95 = 146 neutrons ✓		1 1
01.2	Beta minus decay. ✓ There is no change in the number of nucleons. The number of protons increases by 1. ✓	Marks can be given for a correct equation Ignore omitted antineutrino.	1 1
01.3	${}_{95}^{241}\text{Am} \rightarrow {}_Z^A\text{X} + {}_2^4\alpha$ ✓ Nucleon number = A = 241 – 4 = 237 ✓ Proton number = Z = 95 – 2 = 93 ✓		1 1 1
01.4	Ionisation is the removal (or addition) of electrons from (to) an atom or molecule ✓		1
01.5	Only a small quantity of material is needed ✓ The particles it emits do not travel more than a few centimetres ✓	Alternative for 2 nd mark: Would be stopped before reaching the outside of the detector	1 1
02.1	P at the end of linear section ✓		1
02.2	Measure original length and diameter ✓ Determine gradient of linear section to obtain F/extension ✓ $E = \frac{F}{e} \times \frac{\text{length}}{\pi \left(\frac{d}{2}\right)^2}$ ✓	Alternative: Convert to stress–strain graph and determine gradient.	1 1 1
02.3	Line from A Parallel to straight section of original Ending at horizontal axis ✓		1
02.4	Plastic deformation has produced permanent extension/re-alignment of bonds in material hence intercept non-zero ✓ Gradient is same because after extension identical forces between bonds ✓		1 1



02.5	0.2% is a strain of 0.002 Stress = $2.0 \times 10^{11} \times 0.002 = 4 \times 10^8 \checkmark$ Force = $\frac{\pi(6 \times 10^{-3})^2}{4} \times 4 \times 10^8 \checkmark$ = 11.3 kN \checkmark		1 1 1
02.6	Maximum force = 11300 N Weight of mass = $600 \times 9.81 = 5886 \text{ N} \checkmark$ Accelerating force must be less than $11300 - 5886 = 5423 \text{ N} \checkmark$ $a (= F/m = 5423/600)$ = $9.0 \text{ m s}^{-2} \checkmark$		1 1 1
02.7	To lift double the load at the same acceleration, would require double the force, \checkmark To produce the same strain either use: <ul style="list-style-type: none"> • double the diameter of wire – so the stress stays the same and therefore the strain is the same for the same wire, \checkmark • a wire with double the Young modulus – so that double the stress produces the same strain for the same diameter. \checkmark 	The first mark is for discussing the effect on the force The other two are for discussing the two alternative methods of keeping the strain the same	1 1 1
03.1	$I_3 = I_1 + I_2 \checkmark$		1
03.2	10 V \checkmark		1
03.3	$I_2 = (12 - 10) / 10 \checkmark$ = 0.2 A \checkmark	Allow ce for 10 V The first mark is for the pd The second is for the final answer	1 1
03.4	pd across R2 increases As R1 increases, pd across R1 increases as $pd = I_1 R_1 \checkmark$ pd across R3 = 10 V – pd across R1 Therefore pd across R3 decreases \checkmark pd across R2 = 12 – pd across R3 Therefore pd across R2 increases \checkmark	First mark is for identifying that pd across R1 increases (from zero). Second mark is for identifying that pd across R3 must decrease Third mark is for identifying that this means pd across R2 must increase	1 1 1
04.1	Max GPE of block = $Mgh = 0.46 \times 9.81 \times 0.63 = 2.84 \text{ J} \checkmark$ Initial KE of block = $\frac{1}{2} Mv^2 = 2.84 \text{ J}$ Initial speed of block $v^2 = (2 \times 2.84)/0.46$ $v = 3.51 \text{ ms}^{-1} \checkmark$	The first mark is for working out the GPE of the block The second mark is for working out the speed of the block initially The third mark is for working out the momentum of the block (and therefore pellet)	1 1



	<p>momentum lost by pellet = momentum gained by block $= Mv = 0.46 \times 3.51 = 1.61 \text{ kg m s}^{-1} \checkmark$</p> <p>Speed of pellet = $1.58 / m = 1.58 / 8.8 \times 10^{-3}$ $= 180 \text{ ms}^{-1} \text{ (183)} \checkmark$</p>	<p>The final mark is for the speed of the pellet</p> <p>At each step the mark is for the method rather than the calculated answer</p> <p>Allow one consequential error in the final answer</p>	<p>1</p> <p>1</p>
04.2	<p>As pellet rebounds, change in momentum of pellet greater and therefore the change in momentum of the block is greater \checkmark</p> <p>Initial speed of block is greater \checkmark</p> <p>(Mass stays the same)</p> <p>Initial KE of block greater \checkmark</p> <p>Therefore height reached by steel block is greater than with wooden block \checkmark</p>	Ignore any discussion of air resistance	<p>1</p> <p>1</p> <p>1</p> <p>1</p>
04.3	<p>Calculation of steel method will need to assume that collision is elastic so that change of momentum can be calculated \checkmark</p> <p>This is unlikely due to deformation of bullet, production of sound etc. \checkmark</p> <p>And therefore steel method unlikely to produce accurate results.</p>		<p>1</p> <p>1</p>
05.1	<p>Core is transmission medium for em waves to progress (by total internal reflection) \checkmark</p> <p>Cladding provides lower refractive index so that total internal reflection takes place \checkmark</p> <p>And offers protection of boundary from scratching which could lead to light leaving the core. \checkmark</p>	Allow credit for points scored on a clear labelled diagram.	<p>1</p> <p>1</p> <p>1</p>
05.2	<p>Blue travels slower than red due to the greater refractive index</p> <p>Red reaches end before blue, leading to material pulse broadening \checkmark</p> <p>Alternative calculations for first mark</p> <p>Time for blue = $d/v = d/(c/n)$ $= 1200 / (3 \times 10^8 / 1.467) = 5.87 \times 10^{-6} \text{ s}$</p> <p>Time for red = $d/v = d/(c/n)$ $= 1200 / (3 \times 10^8 / 1.459) = 5.84 \times 10^{-6} \text{ s}$</p> <p>Time difference = $5.87 \times 10^{-6} - 5.84 \times 10^{-6} = 3(.2) \times 10^{-8} \text{ s} \checkmark$</p>	<p>The first mark is for discussion of refractive index or for calculation of time difference.</p> <p>The second mark is for the link to material pulse broadening</p>	<p>1</p> <p>1</p>



05.3	Discussions to include: Use of monochromatic source so speed of pulse constant Use of shorter repeaters so that the pulse is reformed before significant pulse broadening has taken place. Use of monomode fibre to reduce multipath dispersion ✓ ✓	Answer must make clear that candidate understands the distinction between modal and material broadening.	2
06.1	Suitable experiment eg diffraction through a door/out of a pipe ✓		1
06.2	Using $c = d/t$ $t = 2\ 500/480 = 5.2\ s$ ✓		1
06.3	(Measured time is difference between time taken by light and time taken by sound) Calculation assumes that light takes no time to reach observer, ie speed is infinite ✓	Do not allow "could not know speed of light"	1
06.4	Sound from gun is a mixture of frequencies. ✓ All the sound reaches observer at the same time, ✓	Alternative for 1 st mark '(so speed is independent of frequency) the sound of the gun is similar when close and far away'	1 1
06.5	More accurate, as it is closer to the accepted value. ✓		1
06.6	When $\theta = 0\ ^\circ C$ $c = 331.29\ m\ s^{-1}$ Therefore $331.29 = k\ \sqrt{273.15}$ ✓ $k = 20.045$ ✓		1 1
06.7	The method and value are published ✓ other scientists repeat the experiment using the same method ✓		1 1

Keys to Objective Test Questions (each correct answer is worth 1 mark)													
Q	7	8	9	10	11	12	13	14	15	16	17	18	19
A	C	B	B	C	B	C	B	C	B	D	A	C	D
Q	20	21	22	23	24	25	26	27	28	29	30	31	
A	B	C	A	C	C	D	C	C	C	C	C	D	



PRACTICE EXAMINATION 2

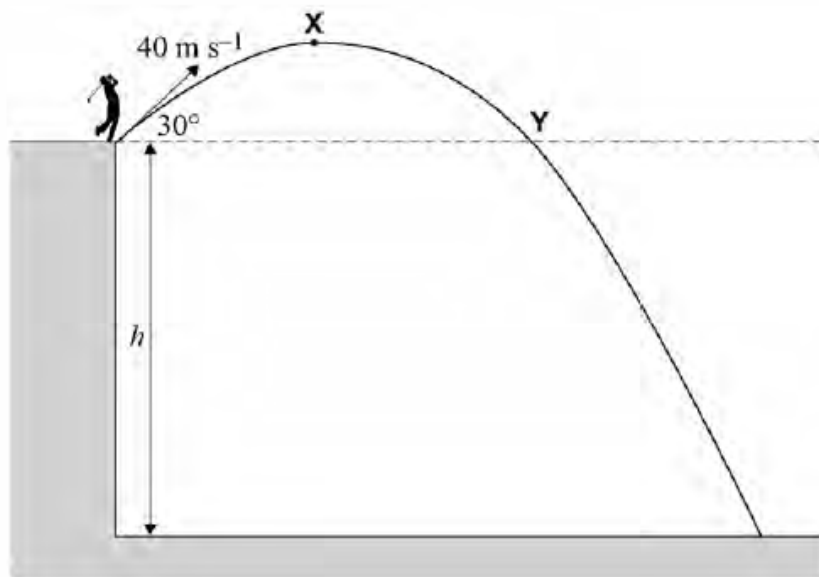
Section A

Answer **all** questions in this section.

0 1

Figure 1 shows a golfer hitting a ball from the top of a cliff. The ball follows the path shown. The ball is hit with an initial velocity of 40 m s^{-1} at an angle of 30° above the horizontal, as shown. Assume that there is no air resistance.

Figure 1



0 1

. 1

Calculate the initial vertical component of velocity of the ball.

[1 mark]

initial vertical component of velocity = _____ m s^{-1}

0 1

. 2

Draw on the diagram an arrow to show the direction of the force acting on the ball when it is at point **X**, the highest point of the flight. Label this arrow **F**.

[1 mark]



0 1 . 3 At point **Y** the ball is level with its initial position.

Show that the time taken to reach **Y** is about 4 s.

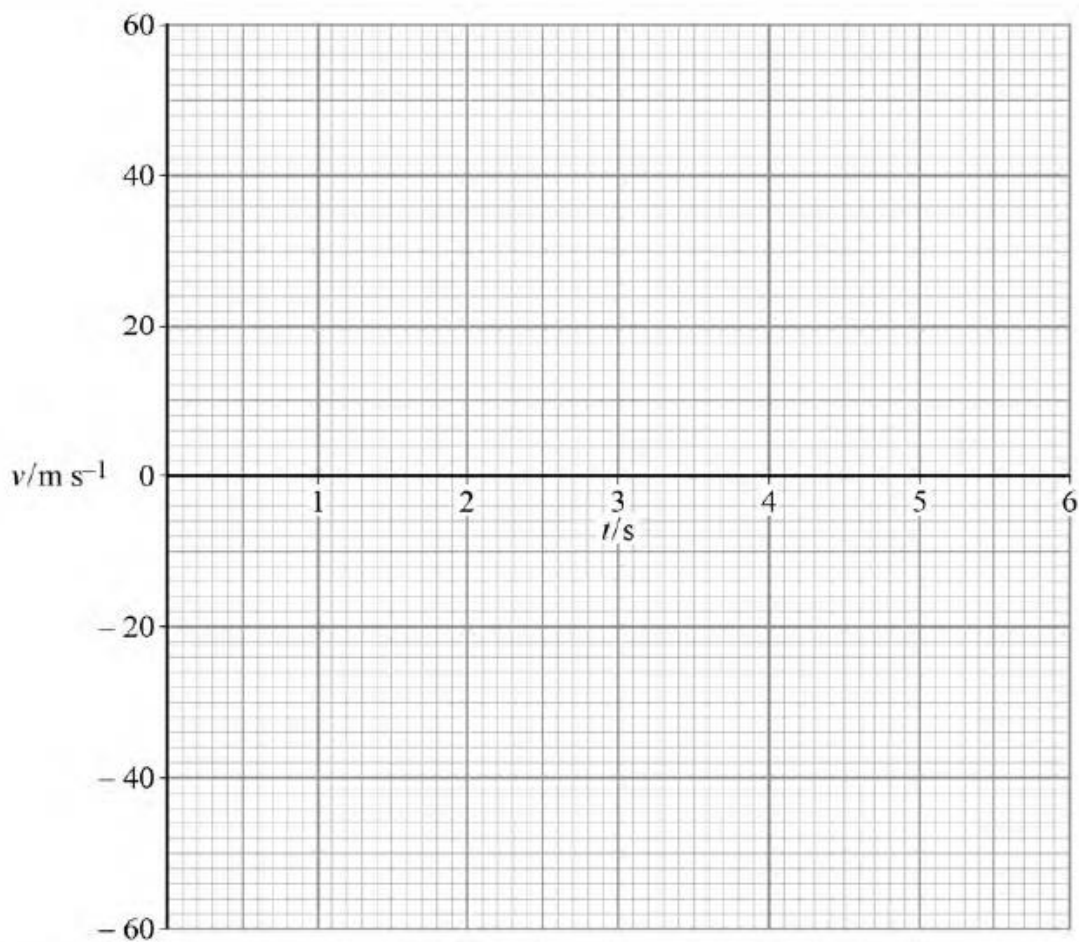
[2 marks]

0 1 . 4 The total time of flight of the ball is 6.0 s.

Show on **Figure 2** how v , the vertical component of the velocity, changes throughout the whole 6.0 s.

[3 marks]

Figure 2



Question 1 continues on the next page



0 1 . 5 Calculate the height h of the cliff.

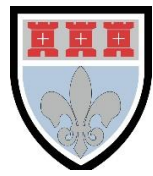
[3 marks]

height = _____ m

0 1 . 6 In practice, the air resistance affects the path of the ball.

Draw on **Figure 1** the path the ball takes when air resistance is taken into account.

[2 marks]



0 2 . 1 Distinguish between longitudinal and transverse waves.

[2 marks]

0 2 . 2 A piano repairer replaces the wire that produces the highest note on a piano. The wire has a vibrating length of 0.050 m. He uses a wire with the following properties:

$$\begin{aligned} \text{diameter} &= 3.5 \times 10^{-4} \text{ m} \\ \text{density} &= 7.8 \times 10^3 \text{ kg m}^{-3} \\ \text{breaking stress} &= 3.0 \times 10^9 \text{ N m}^{-2} \end{aligned}$$

Calculate the tension required for the vibrating wire to produce its correct frequency of 4.1 kHz.

[2 marks]

tension = _____ N



0 2 . **3** Evaluate, using the data provided in **Question 2.2**, whether it is safe to use this wire.

[2 marks]

0 2 . **4** The repairer uses faulty wire so that the diameter of the wire increases linearly with distance along its length. The profile of the vibration produced when the wire sounds its second harmonic is shown in **Figure 3**.

Figure 3



The speed c of a transverse progressive wave travelling along a string of mass per unit length μ and under tension T is given by

$$c = \sqrt{\frac{T}{\mu}}$$

Explain which end of the wire, **A** or **B**, has the greater diameter and why the profile of the stationary wave has the shape shown in **Figure 3**.

[4 marks]



0 3

More than 200 subatomic particles have been discovered so far. However, most are not fundamental and are composed of other particles including quarks.

It has been shown that a proton can be made to change into a neutron and that protons and neutrons are made of quarks.

0 3

. 1

Name **one** process in which a proton changes to a neutron.

[1 mark]

0 3

. 2

Name the particle interaction involved in this process.

[1 mark]

0 3

. 3

Write down an equation for the process you stated in **Question 3.1** and show that the baryon number and lepton number are conserved in this process.

[2 marks]

baryon number _____

lepton number _____



0 3 . 4

The strange quark was used to explain the existence of particles whose tracks had been seen in experiments in the early 1950s. These were unexplained at that time and were referred to as 'strange particles'. One of these particles was later named the K^+ kaon.

State the quark composition of a K^+ kaon.

[1 mark]

0 3 . 5

A K^+ kaon decays into a π^+ particle and a π^0 particle.

Explain **one** property which is conserved and **one** property which is not conserved in this decay.

[2 marks]

conserved _____

not conserved _____

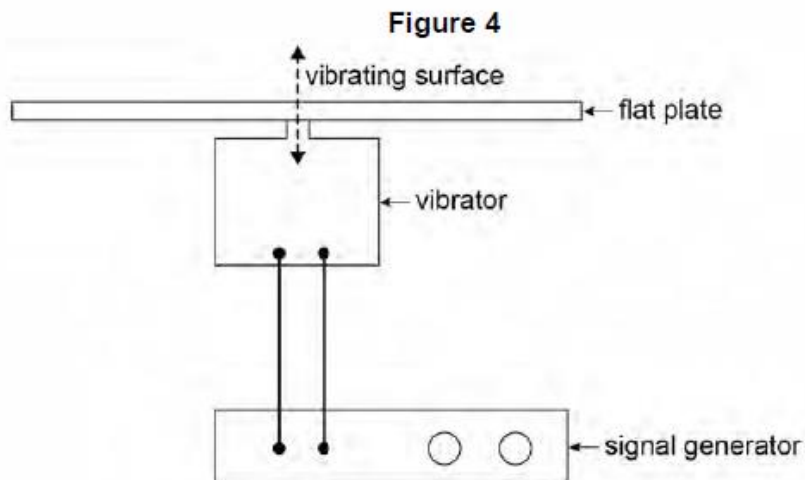


0 4 . 1 State the conditions for simple harmonic motion.

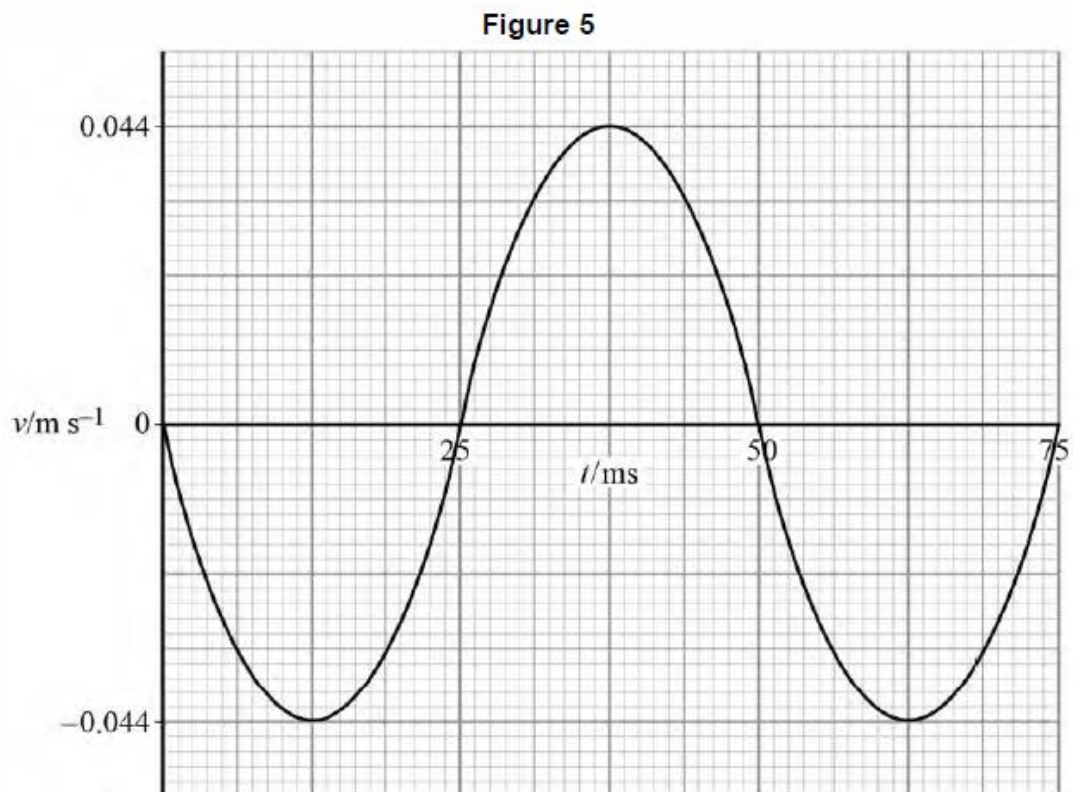
[2 marks]



- 0 4 . 2 A rigid flat plate is made to vibrate vertically with simple harmonic motion. The frequency of the vibration is controlled by a signal generator as shown in **Figure 4**.



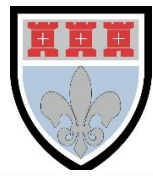
The velocity–time ($v-t$) graph for the vibrating plate at one frequency is shown in **Figure 5**.



Show that the maximum displacement of the plate is 3.5×10^{-4} m.

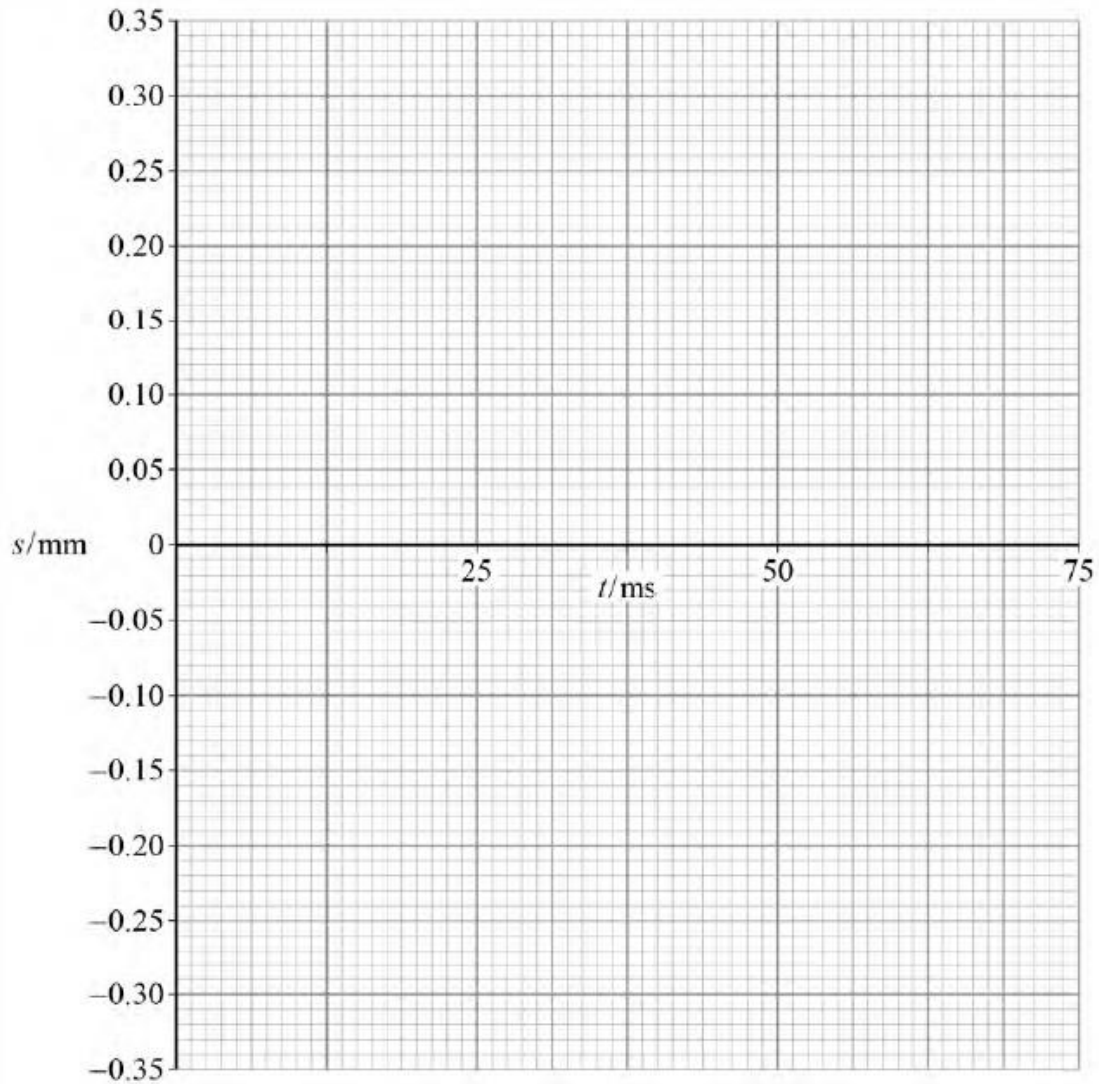
[2 marks]

Question 4 continues on the next page



0 4 . **3** Draw on **Figure 6** the displacement–time ($s-t$) graph between 0 and 75 ms. **[1 mark]**

Figure 6



0 4 . **4** State **one** time at which the plate has maximum potential energy. **[1 mark]**

time = _____ s



0 4 . 5

A small quantity of fine sand is placed onto the surface of the plate. Initially the sand grains stay in contact with the plate as it vibrates. The amplitude of the vibrating surface remains constant at $3.5 \times 10^{-4} \text{ m}$ over the full frequency range of the signal generator. Above a particular frequency the sand grains lose contact with the surface.

Explain how and why this happens.

[3 marks]

0 4 . 6

Calculate the lowest frequency at which the sand grains lose contact with the surface of the plate.

[2 marks]

frequency = _____ Hz

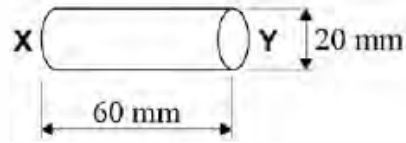
Turn over for the next question



0 5

Figure 7 shows a cylinder of conducting putty which is 60 mm long and 20 mm in diameter.

Figure 7



0 5

. 1

The conducting putty obeys Ohm's law.

State Ohm's law.

[1 mark]

0 5

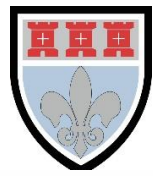
. 2

A 1.50 V dc supply of negligible internal resistance is connected across the ends **X** and **Y** of the cylinder of putty. The resistance of the cylinder of putty is 20.0Ω .

Calculate, in mA, the current in the putty.

[1 mark]

current = _____ mA



- 0 5 . 4 Show that the resistivity ρ of the putty can be calculated using the formula

$$\rho = \frac{R}{l^2} \times \text{volume of the cylinder}$$

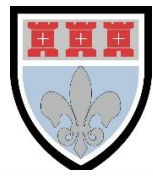
where R is the resistance of the cylinder and l is the length of the cylinder.

[1 mark]

- 0 5 . 5 Calculate, using the formula in **Question 5.4**, the resistivity of the putty.
Give an appropriate unit for your answer.

[3 marks]

resistivity = _____ unit = _____

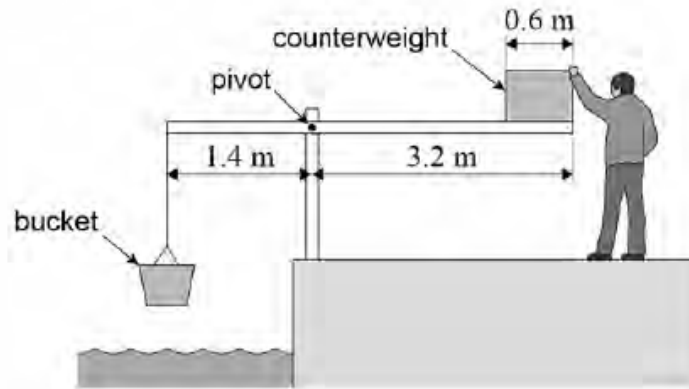


0 6

A shaduf is a device used to lift water from a well. It consists of an upright support to which a uniform beam is pivoted. It can be assumed that the weight of the beam is negligible. On one end of the beam is a counterweight, and on the other a bucket which can hold the water.

Figure 9 shows a diagram of a typical shaduf.

Figure 9



The counterweight is of uniform material and has a weight of 50 N. It is 0.60 m long.

0 6

1

Calculate the moment of the counterweight about the pivot when the beam is horizontal.

[2 marks]

moment = _____ N m



0 6 . 2

The bucket has a weight of 120 N and has a capacity of 0.16 m^3 . When the bucket is half full, a force is required at the end of the beam to lift the bucket and water.

Calculate the value of this force when the beam is horizontal.

density of water = 1000 kg m^{-3}

[5 marks]

additional force = _____ N

0 6 . 3

Explain how the force in **Question 6.2** would be different if the weight of the beam is **not** considered to be negligible.

[3 marks]

END OF SECTION A









Section B


Each of Questions 7 to 31 is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response.

Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD  WRONG METHODS    

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked.

0 7

Which nucleus has a smaller value of specific charge than the nucleus $^{18}_8\text{O}$?

[1 mark]

- A** ^7_3Li
- B** $^{11}_5\text{B}$
- C** $^{13}_6\text{C}$
- D** $^{37}_{17}\text{Cl}$

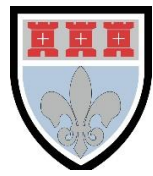
0 8

When bombarded with an α particle the nuclide $^{25}_{12}\text{Mg}$ changes into another nuclide with the emission of a neutron and γ radiation.

What are the correct values for the nucleon number and proton number of the nuclide which is formed?

[1 mark]

	Nucleon number	Proton number	
A	29	14	<input type="radio"/>
B	29	12	<input type="radio"/>
C	28	14	<input type="radio"/>
D	27	12	<input type="radio"/>



0 9

Which sequence of radioactive emissions results in the formation of an isotope of the original element?

[1 mark]

- A one α particle and one β^- particle
- B one α particle and two β^- particles
- C two α particles and one β^- particle
- D two α particles and two β^- particles

1 0

Which statement concerning the forces between particles is **incorrect**?

[1 mark]

- A Leptons experience the weak interaction.
- B Leptons experience the strong interaction.
- C Hadrons experience the weak interaction.
- D Hadrons experience the strong interaction.

1 1

What of the following is a hadron of zero charge?

[1 mark]

- A neutrino
- B photon
- C proton
- D neutron

Turn over for the next question



1 2

What is the correct order of increasing photon energy in the electromagnetic spectrum?

1 is least energy, 4 is greatest energy.

[1 mark]

	Radio waves	γ rays	Visible light	Infrared	
A	1	4	3	2	<input type="checkbox"/>
B	4	1	2	3	<input type="checkbox"/>
C	1	4	2	3	<input type="checkbox"/>
D	4	1	3	2	<input type="checkbox"/>

1 3

Electromagnetic radiation incident on a metal surface can cause electrons to be emitted.

Which of the following statements is correct?

[1 mark]

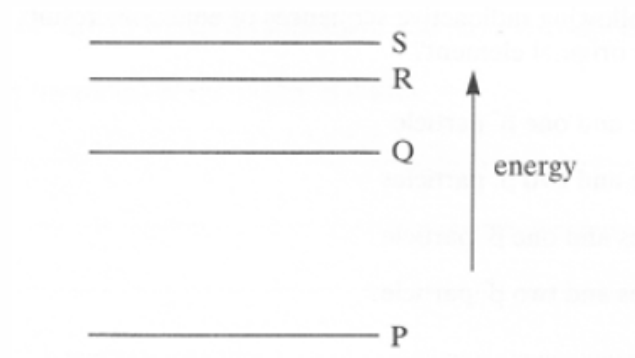
- A** Every photon incident on the surface causes an electron to be emitted.
- B** All the emitted electrons have the same energy.
- C** The range of energy of the emitted electrons depends on the intensity of the radiation.
- D** If the incident radiation is of a single frequency, the number of electrons emitted per second increases if the intensity of the radiation increases.



1 4

The diagram shows the four lowest energy levels for an electron in an atom. P, Q, R and S represent, to scale, the relative energy values of these energy levels.

[1 mark]



An electron transition from level R to level Q is accompanied by the emission of a photon of visible light.

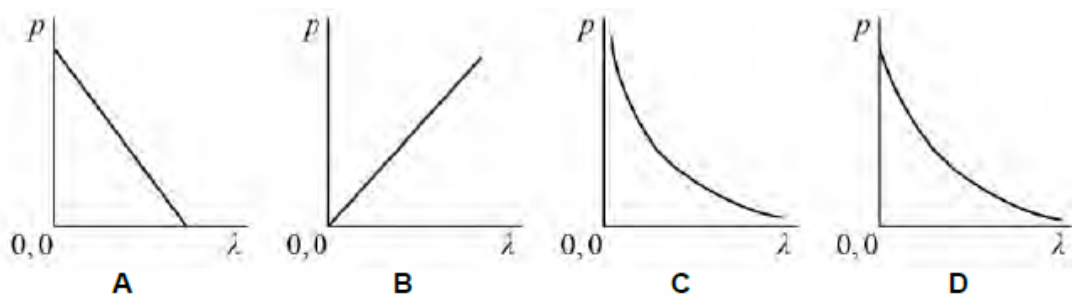
Which electron transition would be accompanied by the emission of a photon of infrared radiation?

- A S to R
- B S to Q
- C Q to P
- D R to P

1 5

Which graph best shows the relationship between the momentum p and the wavelength λ for photons?

[1 mark]

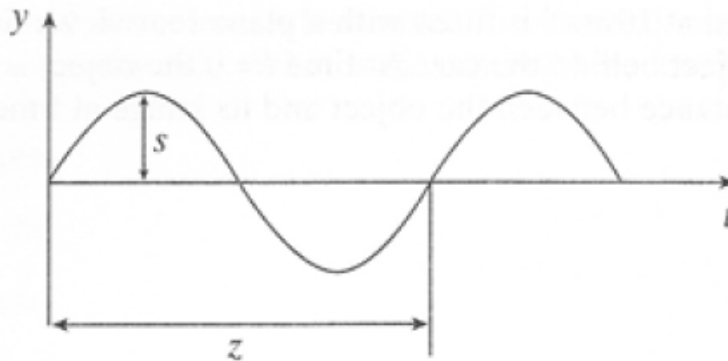


- A
- B
- C
- D



1 6

For waves on a water surface, the following graph shows how the displacement y of a water particle in the surface varies with the time t .



What are the quantities z and s ?

[1 mark]

	z	s	
A	frequency	amplitude	<input type="checkbox"/>
B	period	half-amplitude	<input type="checkbox"/>
C	wavelength	half-amplitude	<input type="checkbox"/>
D	period	amplitude	<input type="checkbox"/>

1 7

Two coherent sources generate sound waves of wavelength 0.40 m. The waves leave the sources in phase. A detector some distance from the sources receives the sound waves. The path difference between the detector and the sources is 0.90 m.

What is the phase difference between the waves arriving at the detector?

[1 mark]

- A** zero
- B** 45°
- C** 90°
- D** 180°



1 8

Monochromatic light of wavelength 600 nm is used to illuminate a pair of slits 0.50 mm apart. The fringes are observed at a distance of 1.50 m from the slits.

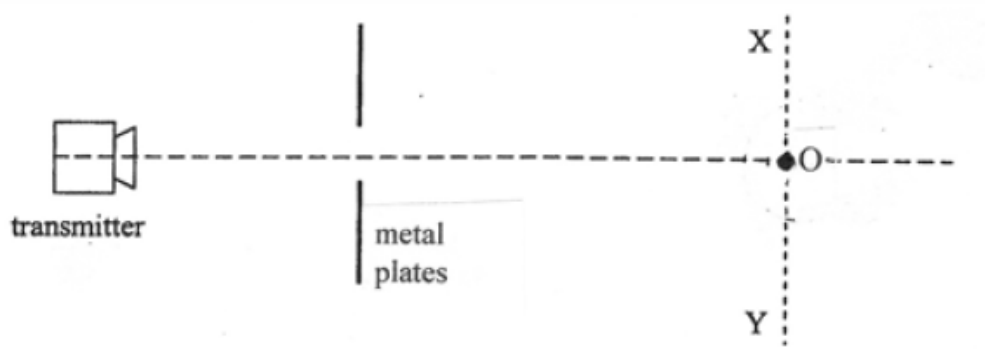
What is the separation of the fringes?

[1 mark]

- A $2.0 \times 10^{-7} \text{ mm}$
- B $1.8 \times 10^{-3} \text{ mm}$
- C $5.6 \times 10^{-1} \text{ mm}$
- D 1.8 mm

1 9

Microwaves from a transmitter are incident on a gap between two metal plates. The microwaves that pass through the gap are detected by a receiver.



The receiver is placed at O.

What change causes the received signal to decrease and then increase?

[1 mark]

- A make the gap narrower
- B move the receiver towards X
- C rotate the receiver through 90°
- D move the transmitter away from the receiver

2 0

What is correct for the quantities impulse and force?

[1 mark]

	Impulse	Force	
A	scalar	scalar	<input type="radio"/>
B	scalar	vector	<input type="radio"/>
C	vector	scalar	<input type="radio"/>
D	vector	vector	<input type="radio"/>



2 1

A firework is fired vertically up into the air and subsequently falls to the ground.

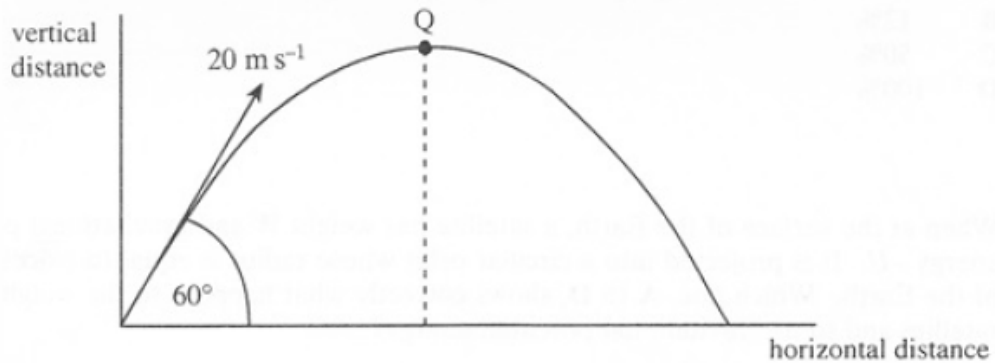
Which quantity relating to the motion of the rocket is never zero before it hits the ground? Assume that air resistance is negligible.

[1 mark]

- | | | |
|----------|----------------|--------------------------|
| A | acceleration | <input type="checkbox"/> |
| B | velocity | <input type="checkbox"/> |
| C | momentum | <input type="checkbox"/> |
| D | kinetic energy | <input type="checkbox"/> |

2 2

A ball of mass 0.20 kg is thrown and moves in a curved path, as shown below. At Q it is travelling horizontally.



Assume air resistance is negligible.

What is the momentum of the ball at Q?

[1 mark]

- | | | |
|----------|-------------------|--------------------------|
| A | zero | <input type="checkbox"/> |
| B | 2.0 N s | <input type="checkbox"/> |
| C | 3.5 N s | <input type="checkbox"/> |
| D | 4.0 N s | <input type="checkbox"/> |

**2 3**

A steel wire has a cross-sectional area 0.5 mm^2 . The Young modulus of steel is $2.0 \times 10^{11} \text{ Pa}$. Assume the wire obeys Hooke's law.

What load must be suspended from the wire to produce an extension which is 0.1% of the original length?

[1 mark]

- A 40 N
- B 50 N
- C 100 N
- D 200 N

2 4

When a constant potential difference (pd) is applied across the ends of a uniform wire there is a current I in the wire.

The wire is replaced by one made from the same material, but of double the length and double the diameter. The same pd is applied across the ends.

What is the new current?

[1 mark]

- A $4I$
- B $2I$
- C $\frac{I}{2}$
- D $\frac{I}{4}$

2 5

A pd V is applied across a resistor. Another identical resistor is then connected in series with it and the same pd V is applied across the combination.

Which statement is **incorrect**?

[1 mark]

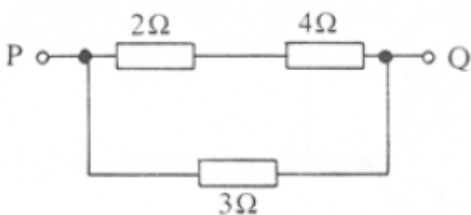
- A The total resistance is doubled.
- B The pd across one resistor is $\frac{V}{2}$.
- C The current in the resistors is halved.
- D The power dissipated in one resistor is halved.



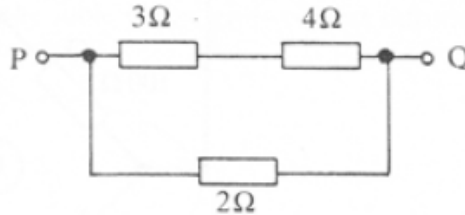
2 6

Which resistor arrangement has the greatest value of resistance?

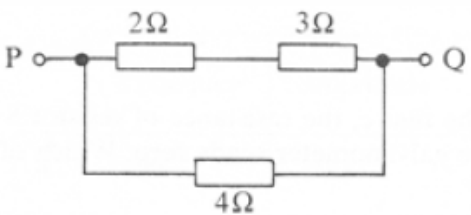
[1 mark]



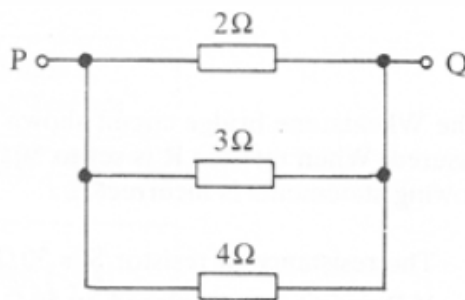
A



B



C

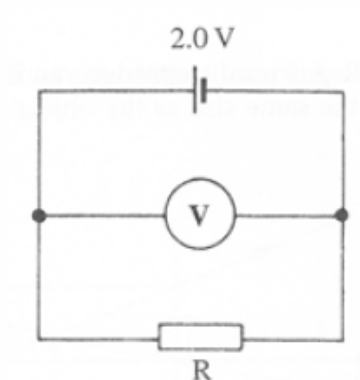


D

- A
- B
- C
- D

2 7

The cell in the following circuit has an emf of 2.0 V and an internal resistance of 1.0 Ω.



The digital voltmeter reads 1.6 V. What is the resistance of R?

[1 mark]

- A 0.4 Ω
- B 1.0 Ω
- C 2.0 Ω
- D 4.0 Ω



2 8

A helicopter circles continuously at a constant speed around a horizontal path of diameter 800 m, taking 5.0 minutes to complete each orbit of the path.

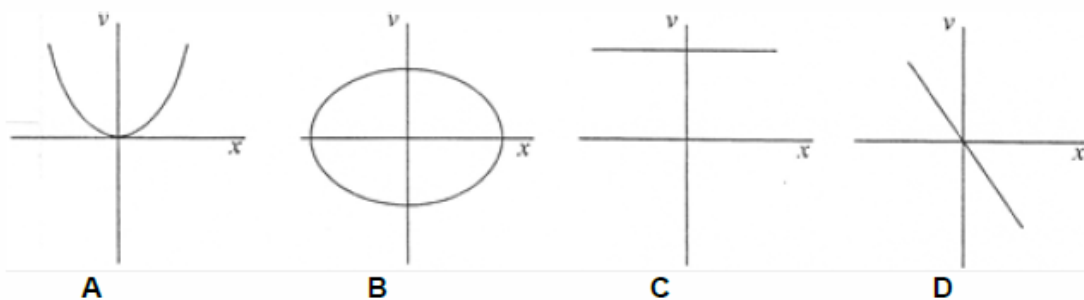
What are the speed v and the centripetal acceleration a of the helicopter?

[1 mark]

	$v / \text{m s}^{-1}$	$a / \text{m s}^{-2}$	
A	0.021	0.18	<input type="radio"/>
B	8.4	0.088	<input type="radio"/>
C	8.4	0.18	<input type="radio"/>
D	17	0.35	<input type="radio"/>

2 9

Which graph shows how the velocity v of a body moving with simple harmonic motion varies with its displacement x ?



[1 mark]

- A**
- B**
- C**
- D**

Turn over for the next question



3 0

A simple pendulum and a mass–spring system perform simple harmonic oscillations on Earth with the same period T . Both systems are moved to a region where the gravitational field strength is four times that at the surface of Earth.

What is the period of each system when oscillating at this new location?

[1 mark]

	Pendulum	Mass–spring	
A	$\frac{T}{2}$	T	<input type="radio"/>
B	$\frac{T}{4}$	T	<input type="radio"/>
C	$4T$	$2T$	<input type="radio"/>
D	$2T$	$2T$	<input type="radio"/>

3 1

A mechanical oscillator is set into motion by a periodic driving force whose frequency is steadily increased from a low value.

What is correct for this system?

[1 mark]

- A Forced vibrations occur only at particular frequencies.
- B The oscillator is subject to damping only at the resonant frequency.
- C When resonance occurs the damping force is a minimum.
- D The oscillator will not continue to resonate when the periodic driving force is removed.

END OF QUESTIONS



MARK SCHEME

Question	Answers	Additional Comments/Guidance	Mark
01.1	Vertical velocity = $40 \sin 30$ = $20 \text{ (m s}^{-1}\text{)}$ ✓		1
01.2	Line vertically downward from point X ✓	Ignore labelling unless two or more arrows drawn	1
01.3	Method leading to a numerical answer e.g. $v = u + at$ / $0 = 20 - (9.81 \times t)$ gives $t = 2.0(4)$ ✓ total time of flight = $4.08 / 4.1 \text{ (s)}$ ✓	Any alternative acceptable method allowed Need to see one or more dp for final credit	2
01.4	Straight line (of positive or negative gradient) ✓ Starting at 20 ms^{-1} (or -20 ms^{-1}) ✓ Crossing the x axis at 2.0s approximately ✓	Any single straight line over the 6.0s will score this mark Or ecf from Q1.1 Any line which crosses at 2.0s (and only here) will score this mark	3
01.5	Area under graph (between 4s and 6s) ✓ = $(20 \times 2) + \frac{1}{2}(20 \times 2)$ ✓ = 60 m ✓	Alternative to use equation of motion selecting $s = ut + \frac{1}{2}at^2$ ✓ $s = (20 \times 2) + \frac{1}{2}(9.81 \times 2^2)$ ✓ $s = 59.6 \text{ m}$ ✓ (values with 58 – 62 acceptable from graph)	3
01.6	MAX 2 reaches lower height than X ✓ at an earlier time ✓ hits ground closer to cliff base ✓		MAX 2

Question	Answers	Additional Comments/Guidance	Mark
02.1	Refers to relative direction of oscillations to that of the direction of propagation/transfer of energy ✓ For transverse waves oscillations are at right angles to direction of propagation while in longitudinal waves they are in the same direction ✓	allow direction the wave is travelling in	2
02.2	Correct value for $\mu = (1 \times) \frac{\pi d^2}{4} \rho = 7.5 \times 10^{-4} \text{ (kg m}^{-1}\text{)}$ ✓ (uses $f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$) ✓ Tension = 126 N (allow 9.7×10^5 x their value for μ) ✓		2
02.3	Max tension permissible before breaking = $3.0 \times 10^9 \times \frac{\pi \times (3.5 \times 10^{-4})^2}{4} = 288 \text{ (289)(290) N}$ ✓ This is greater than required tension so wire is suitable. ✓ OR stress in operation = $\frac{126 \times 4}{\pi \times (3.5 \times 10^{-4})^2} = 1.3 \times 10^9 \text{ (N m}^{-2}\text{)}$ ✓ which is less than breaking stress \therefore safe to use ✓	Allow ecf for incorrect area in 2.2	2
02.4	Shows second harmonic $\lambda = \frac{1}{f} \sqrt{\frac{T}{\mu}}$ ✓ Identify f and T are constant so λ is proportional to $\frac{1}{\sqrt{\mu}}$ ✓ λ increases from A to B ✓ mass per unit length decreases from A to B so A has a greater diameter ✓		4



Question	Answers	Additional Comments/Guidance	Mark
03.1	Any suitable process such as electron capture or beta plus decay. ✓		1
03.2	The weak interaction ✓		1
03.3	Valid equation must be given or no marks for the question. For electron capture: baryon number conserved $1 + 0 = 1 + 0$ ✓ lepton number conserved $0 + 1 = 0 + 1$ ✓	Baryon and Lepton numbers to be conserved	2
03.4	up and antistrange ✓		1
03.5	conserved any correct answer such as charge ✓ not conserved is strangeness which is 1 before decay and 0 after decay ✓		2

Question	Answers	Additional Comments/Guidance	Mark
04.1	SHM is when The acceleration is proportional to the displacement ✓ the acceleration is in opposite direction to displacement ✓		2
04.2	$f = 1/T = 1/0.05 = 20$ Hz ✓ $(v_{\max} = 2\pi fA)$ $A = \frac{0.044}{2\pi \times 20}$ ✓ ($= 3.5 \times 10^{-4}$ m)		2
04.3	Cosine shape drawn, maximum at $t = 0$, amplitude 3.5×10^{-4} m ✓		1
04.4	(any of the following when the velocity is zero) 0.00s, 0.025s, 0.050s or 0.075s ✓		1
04.5	when the vibrating surface accelerates <u>down</u> with an acceleration less than the acceleration of free fall the sand stays in contact. ✓ above a particular frequency, the acceleration is greater than g ✓ there is no contact force on the sand OR sand no longer in contact when downwards acceleration of plate is greater than acceleration of sand due to gravity ✓		3
04.6	(when the surface acceleration is the same as free fall) $g = r \omega^2 = A (2\pi f)^2$ ✓ $f = \sqrt{(g / A 4\pi^2)} = (9.81 / (3.5 \times 10^{-4} \times 4\pi^2))^{1/2} = 26.6(7)$ Hz ✓		2



Question	Answers	Additional Comments/Guidance	Mark
05.1	The current through a conductor between two points is directly proportional to the potential difference across the two points (provided the temperature remains constant) ✓	Or ratio of voltage / current is constant	1
05.2	75 (mA) ✓		1
05.3	MAX 4 voltmeter position is incorrect because it is across the cell ✓ voltmeter should be connected across the putty ✓ the 10 Ω resistor is not suitable to control the current ✓ because its resistance is only half that of the putty ✓ pd range is 1.0 to 1.5 V, this is insufficient for experiment ✓		MAX 4
05.4	Substitution of $V = A \times l$ into $\rho = \frac{R \times A}{l}$ ✓ (leading to $\rho = \frac{RV}{I^2}$)	Complete argument needed	1
05.5	$V = 60 \times 10^{-3} \times \pi \times (10 \times 10^{-3})^2$ (= $1.88 \times 10^{-5} \text{ m}^3$) ✓ $\rho = 20 \times 1.88 \times 10^{-5} / (60 \times 10^{-3})^2$ = 0.10 ✓Ωm ✓	Will not gain this mark only if POT error correctly followed through. Stand alone unit mark	3

Question	Answers	Additional Comments/Guidance	Mark
06.1	Distance to centre of mass of counterweight from pivot = 2.9 m ✓ Moment = ($f \times d = 50 \times 2.9 =$) 145 (N m) ✓	No credit for use of 3.2 m (or 2.6 m) here, but maybe ecf later	2
06.2	mass of water = 0.08×1000 (= 80 kg) ✓ total weight of bucket + water = $80g + 120$ (= 905 N) ✓ moment of bucket + water = $905 \times 1.4 = 1270$ (N m) ✓ $905 \times 1.4 = 145 + F \times 3.2$ ✓ 350 (N) ✓	No credit for 1000×1.6 here Allow ecf from any mass Ecf from Q6.1	5
06.3	Weight of beam acts to right of the pivot/centre of mass is to the right of the pivot ✓ provides an additional clockwise moment ✓ Therefore the value calculated in Q6.2 would be less to have equilibrium ✓	Need "moment" and some sense of direction No credit for unsubstantiated statement of change of force.	3

Keys to Multiple Choice Questions (each correct answer is worth 1 mark)									
7	8	9	10	11	12	13	14	15	16
A	C	B	B	D	A	D	A	C	D
17	18	19	20	21	22	23	24	25	26
C	D	B	D	A	B	C	B	D	C
27	28	29	30	31					
D	C	B	A	D					



DATASHEET

DATA - FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^8	m s^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^7	C kg^{-1}
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m s^{-2}
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^8
Earth	5.97×10^{24}	6.37×10^6

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
curved surface area of cylinder	$= 2\pi r h$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3} \pi r^3$



Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	e^\pm	0.510999
	muon	μ^\pm	105.659
	π meson	π^\pm	139.576
mesons		π^0	134.972
	K meson	K^\pm	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

	Lepton number
Particles: $e^-, \nu_e; \mu^-, \nu_\mu$	+1
Antiparticles: $e^+, \bar{\nu}_e, \mu^+, \bar{\nu}_\mu$	-1

Photons and energy levels

photon energy	$E = hf = hc / \lambda$
photoelectricity	$hf = \phi + E_{k(\max)}$
energy levels	$hf = E_1 - E_2$
de Broglie wavelength	$\lambda = \frac{h}{p} = \frac{h}{mv}$

Waves

wave speed	$c = f\lambda$	period	$f = \frac{1}{T}$
first harmonic	$f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$		
fringe spacing	$w = \frac{\lambda D}{s}$	diffraction grating	$d \sin \theta = n\lambda$
refractive index of a substance s,	$n = \frac{c}{c_s}$		
for two different substances of refractive indices n_1 and n_2 ,			
law of refraction	$n_1 \sin \theta_1 = n_2 \sin \theta_2$		
critical angle	$\sin \theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$		

Mechanics

moments	moment = Fd
velocity and acceleration	$v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$
equations of motion	$v = u + at$ $s = \left(\frac{u+v}{2}\right)t$
	$v^2 = u^2 + 2as$ $s = ut + \frac{at^2}{2}$
force	$F = ma$
force	$F = \frac{\Delta(mv)}{\Delta t}$
impulse	$F \Delta t = \Delta(mv)$
work, energy and power	$W = F s \cos \theta$
	$E_k = \frac{1}{2} m v^2$ $\Delta E_p = mg \Delta h$
	$P = \frac{\Delta W}{\Delta t}, P = Fv$
	efficiency = $\frac{\text{useful output power}}{\text{input power}}$

Materials

density	$\rho = \frac{m}{v}$	Hooke's law	$F = k \Delta L$
Young modulus =	$\frac{\text{tensile stress}}{\text{tensile strain}}$	tensile stress =	$\frac{F}{A}$
		tensile strain =	$\frac{\Delta L}{L}$
energy stored	$E = \frac{1}{2} F \Delta L$		



Electricity

current and pd $I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$ $R = \frac{V}{I}$

resistivity $\rho = \frac{RA}{L}$

resistors in series $R_T = R_1 + R_2 + R_3 + \dots$

resistors in parallel $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$

power $P = VI = I^2R = \frac{V^2}{R}$

emf $\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$

Circular motion

magnitude of angular speed $\omega = \frac{v}{r}$

$$\omega = 2\pi f$$

centripetal acceleration $a = \frac{v^2}{r} = \omega^2 r$

centripetal force $F = \frac{mv^2}{r} = m\omega^2 r$

Simple harmonic motion

acceleration $a = -\omega^2 x$

displacement $x = A \cos(\omega t)$

speed $v = \pm \omega \sqrt{(A^2 - x^2)}$

maximum speed $v_{\max} = \omega A$

maximum acceleration $a_{\max} = \omega^2 A$

for a mass-spring system $T = 2\pi \sqrt{\frac{m}{k}}$

for a simple pendulum $T = 2\pi \sqrt{\frac{l}{g}}$

Thermal physics

energy to change temperature $Q = mc\Delta\theta$

energy to change state $Q = ml$

gas law $pV = nRT$
 $pV = NkT$

kinetic theory model $pV = \frac{1}{3}N m (c_{\text{rms}})^2$

kinetic energy of gas molecule $\frac{1}{2}m (c_{\text{rms}})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$

Gravitational fields

force between two masses $F = \frac{Gm_1m_2}{r^2}$

gravitational field strength $g = \frac{F}{m}$

magnitude of gravitational field strength in a radial field $g = \frac{GM}{r^2}$

work done $\Delta W = m\Delta V$

gravitational potential $V = -\frac{GM}{r}$

$$g = -\frac{\Delta V}{\Delta r}$$

Electric fields and capacitors

force between two point charges $F = \frac{1}{4\pi\epsilon_0} \frac{Q_1Q_2}{r^2}$

force on a charge $F = EQ$

field strength for a uniform field $E = \frac{V}{d}$

work done $\Delta W = Q\Delta V$

field strength for a radial field $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$

electric potential $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$

$$E = \frac{\Delta V}{\Delta r}$$

capacitance $C = \frac{Q}{V}$

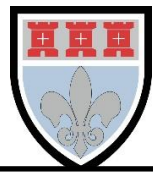
$$C = \frac{A\epsilon_0\epsilon_r}{d}$$

capacitor energy stored $E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2} \frac{Q^2}{C}$

capacitor charging $Q = Q_0(1 - e^{-t/RC})$

decay of charge $Q = Q_0e^{-t/RC}$

time constant RC



Magnetic fields

<i>force on a current</i>	$F = BIl$
<i>force on a moving charge</i>	$F = BQv$
<i>magnetic flux</i>	$\Phi = BA$
<i>magnetic flux linkage</i>	$N\Phi = BAN \cos \theta$
<i>magnitude of induced emf</i>	$\varepsilon = N \frac{\Delta \Phi}{\Delta t}$
	$N\Phi = BAN \cos \theta$
<i>emf induced in a rotating coil</i>	$\varepsilon = BAN\omega \sin \omega t$
<i>alternating current</i>	$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} \quad V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$
<i>transformer equations</i>	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$
	$\text{efficiency} = \frac{I_s V_s}{I_p V_p}$

Nuclear physics

<i>the inverse square law for γ radiation</i>	$I = \frac{k}{x^2}$
<i>radioactive decay</i>	$\frac{\Delta N}{\Delta t} = -\lambda N, N = N_0 e^{-\lambda t}$
<i>activity</i>	$A = \lambda N$
<i>half-life</i>	$T_{1/2} = \frac{\ln 2}{\lambda}$
<i>nuclear radius</i>	$R = R_0 A^{1/3}$
<i>energy-mass equation</i>	$E = mc^2$

OPTIONS

Astrophysics

1 astronomical unit	$= 1.50 \times 10^{11} \text{ m}$
1 light year	$= 9.46 \times 10^{15} \text{ m}$
1 parsec	$= 206265 \text{ AU} = 3.08 \times 10^{16} \text{ m}$
	$= 3.26 \text{ light year}$

$$\text{Hubble constant, } H = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

$$\text{in normal adjustment} \quad M = \frac{f_o}{f_e}$$

$$\text{Rayleigh criterion} \quad \theta \approx \frac{\lambda}{D}$$

$$\text{magnitude equation} \quad m - M = 5 \log \frac{d}{10}$$

$$\text{Wien's law} \quad \lambda_{\text{max}} T = 2.9 \times 10^{-3} \text{ m K}$$

$$\text{Stefan's law} \quad P = \sigma AT^4$$

$$\text{Schwarzschild radius} \quad R_s \approx \frac{2GM}{c^2}$$

$$\text{Doppler shift for } v \ll c \quad \frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$$

$$\text{red shift} \quad z = -\frac{v}{c}$$

$$\text{Hubble's law} \quad v = Hd$$

Medical physics

$$\text{lens equations} \quad P = \frac{1}{f}$$

$$m = \frac{v}{u}$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\text{threshold of hearing} \quad I_0 = 1.0 \times 10^{-12} \text{ W m}^{-2}$$

$$\text{intensity level} \quad \text{intensity level} = 10 \log \frac{I}{I_0}$$

$$\text{absorption} \quad I = I_0 e^{-\mu x}$$

$$\mu_m = \frac{\mu}{\rho}$$

$$\text{ultrasound imaging} \quad Z = p c$$

$$\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2$$

$$\text{half-lives} \quad \frac{1}{T_B} = \frac{1}{T_B} + \frac{1}{T_P}$$



Engineering physics

moment of inertia	$I = \Sigma mr^2$
angular kinetic energy	$E_k = \frac{1}{2} I \omega^2$
equations of angular motion	$\omega_2 = \omega_1 + \alpha t$ $\omega_2^2 = \omega_1^2 + 2\alpha\theta$ $\theta = \omega_1 t + \frac{\alpha t^2}{2}$ $\theta = \frac{(\omega_1 + \omega_2) t}{2}$
torque	$T = I \alpha$ $T = F r$
angular momentum	angular momentum = $I \omega$
angular impulse	$T \Delta t = \Delta(I \omega)$
work done	$W = T \theta$
power	$P = T \omega$
thermodynamics	$Q = \Delta U + W$ $W = p \Delta V$
adiabatic change	$pV^\gamma = \text{constant}$
isothermal change	$pV = \text{constant}$
heat engines	$\text{efficiency} = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$ $\text{maximum theoretical efficiency} = \frac{T_H - T_C}{T_H}$
work done per cycle	= area of loop
input power	= calorific value \times fuel flow rate
indicated power	= (area of $p - V$ loop) \times (number of cycles per second) \times (number of cylinders)
output or brake power	$P = T \omega$
friction power	= indicated power - brake power
heat pumps and refrigerators	$\text{refrigerator: } COP_{\text{ref}} = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C}$ $\text{heat pump: } COP_{\text{hp}} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C}$

Turning points in physics

electrons in fields	$F = \frac{eV}{d}$ $F = Bev$ $r = \frac{mv}{Be}$ $\frac{1}{2} mv^2 = eV$
Millikan's experiment	$\frac{QV}{d} = mg$ $F = 6\pi\eta r v$
Maxwell's formula	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$ $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$
special relativity	$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$ $l = l_0 \sqrt{1 - \frac{v^2}{c^2}}$ $E = mc^2 = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$

Electronics

resonant frequency	$f_0 = \frac{1}{2\pi \sqrt{LC}}$
Q-factor	$Q = \frac{f_0}{f_B}$
operational amplifiers: open loop	$V_{\text{out}} = A_{\text{OL}}(V_+ - V_-)$
inverting amplifier	$\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_f}{R_{\text{in}}}$
non-inverting amplifier	$\frac{V_{\text{out}}}{V_{\text{in}}} = 1 + \frac{R_f}{R_1}$
summing amplifier	$V_{\text{out}} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \dots \right)$
difference amplifier	$V_{\text{out}} = (V_+ - V_-) \frac{R_f}{R_1}$
Bandwidth requirement:	
for AM	bandwidth = $2f_M$
for FM	bandwidth = $2(\Delta f + f_M)$



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Only constructive and reasoned feedback will be considered.