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Mark

SQ29/AH/01 Physics

Date — Not applicable

Duration — 2 hours 30 minutes

SQ29AH01

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 140

Attempt ALL questions.

Reference may be made to the Physics Relationships Sheet and the Data Sheet on *Page two*.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration on Earth	g	$9{\cdot}8\ m\,s^{-2}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}$ m	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}$ C
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}$ kg	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}$ kg	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Radius of Moon	R_M	$1{\cdot}7 \times 10^{6}$ m	Mass of alpha particle	m_a	$6{\cdot}645 \times 10^{-27}$ kg
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}$ m	Charge on alpha particle		$3{\cdot}20 \times 10^{-19}$ C
Solar radius		$6{\cdot}955 \times 10^{8}$ m	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Mass of Sun		$2{\cdot}0 \times 10^{30}$ kg	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\ F\,m^{-1}$
1 AU		$1{\cdot}5 \times 10^{11}$ m	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ H\,m^{-1}$
Stefan-Boltzmann constant	σ	$5{\cdot}67 \times 10^{-8}\ W\ m^{-2} K^{-4}$	Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\ m\,s^{-1}$
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\ m^{3}\ kg^{-1}\ s^{-2}$	Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\ m\,s^{-1}$

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49	Magnesium Fluoride	1·38

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 } 10590 }	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/ $kg\ m^{-3}$	*Melting Point*/ K	*Boiling Point*/K	*Specific Heat Capacity*/ $J\,kg^{-1}\,K^{-1}$	*Specific Latent Heat of Fusion*/ $J\,kg^{-1}$	*Specific Latent Heat of Vaporisation*/ $J\,kg^{-1}$
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	....
Glass	$2{\cdot}60 \times 10^{3}$	1400	....	$6{\cdot}70 \times 10^{2}$	....	....
Ice	$9{\cdot}20 \times 10^{2}$	273	....	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	....
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	....	....
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	....	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	....	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{4}$

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

Total marks — 140 marks

Attempt ALL questions

MARKS | DO NOT WRITE IN THIS MARGIN

1. Water is removed from clothes during the spin cycle of a washing machine. The drum holding the clothes has a maximum spin rate of 1250 revolutions per minute.

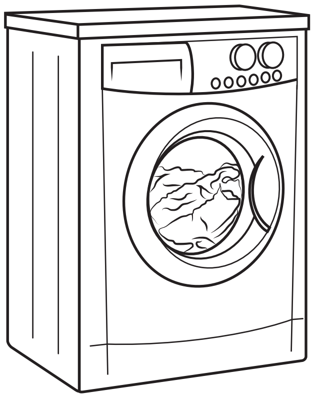


Figure 1A

(a) Show that the maximum angular velocity of the drum is $131\ \text{rad s}^{-1}$. **2**

Space for working and answer

(b) At the start of a spin cycle the drum has an angular velocity of $7{\cdot}50\ \text{rad s}^{-1}$. It then takes 12·0 seconds to accelerate to the maximum angular velocity.

(i) Calculate the angular acceleration of the drum during the 12·0 seconds, assuming the acceleration is uniform. **3**

Space for working and answer

1. (b) (continued)

(ii) Determine how many revolutions the drum will make during the 12·0 seconds. 5

Space for working and answer

(c) When the drum is rotating at maximum angular velocity, an item of wet clothing of mass $1{\cdot}5 \times 10^{-2}$ kg rotates at a distance of 0·28 m from the axis of rotation as shown in Figure 1B.

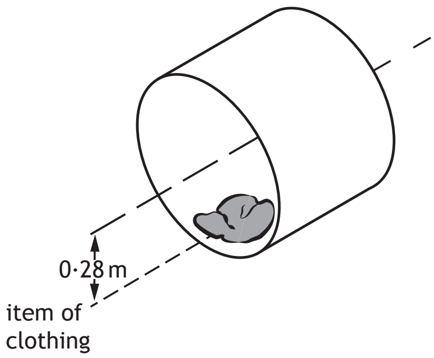


Figure 1B

Calculate the centripetal force acting on the item of clothing. 3

Space for working and answer

1. (continued) **MARKS** DO NOT WRITE IN THIS MARGIN

(d) The outer surface of the drum has small holes as shown in Figure 1C. These holes allow most of the water to be removed.

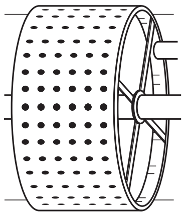


Figure 1C

(i) Explain why the water separates from the item of clothing during the spin cycle. **2**

(ii) The drum rotates in an anticlockwise direction. Indicate on Figure 1D the direction taken by a water droplet as it leaves the drum. **1**

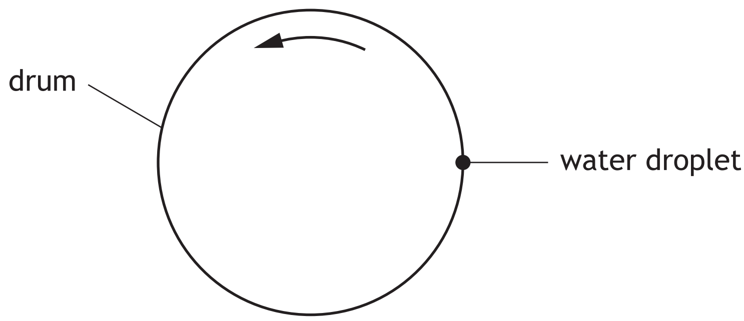


Figure 1D

(iii) Explain what happens to the value of the force on an item of clothing inside the drum as it rotates at its maximum angular velocity. **2**

2. A disc of mass 6·0 kg and radius 0·50 m is allowed to rotate freely about its central axis as shown in Figure 2A.

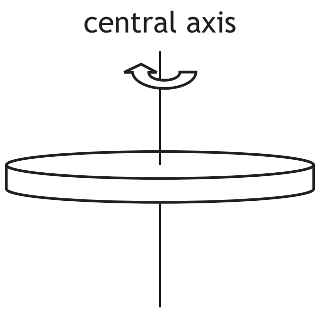


Figure 2A

(a) Show that the moment of inertia of the disc is 0·75 kg m^2. **2**

Space for working and answer

(b) The disc is rotating with an angular velocity of 12 rad s^{-1}. A cube of mass 2·0 kg is then dropped onto the disc. The cube remains at a distance of 0·40 m from the axis of rotation as shown in Figure 2B.

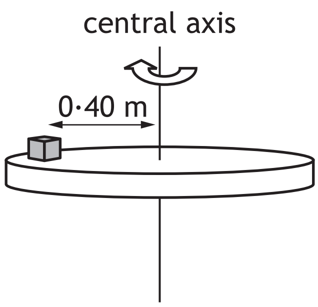


Figure 2B

2. (b) (continued)

(i) Determine the total moment of inertia of the disc and cube. **3**

Space for working and answer

(ii) Calculate the angular velocity of the disc after the cube lands. **3**

Space for working and answer

(iii) State **one** assumption you have made in your response to b(ii). **1**

(c) The cube is removed and the disc is again made to rotate with a constant angular velocity of 12 rad s^{-1}. A sphere of mass 2·0 kg is then dropped onto the disc at a distance of 0·40 m from the axis as shown in Figure 2C.

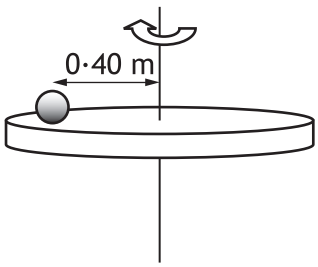


Figure 2C

State whether the resulting angular velocity of the disc is greater than, the same as, or less than, the value calculated in b(ii).

You must justify your answer. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

3. The International Space Station (ISS) is in orbit around the Earth.

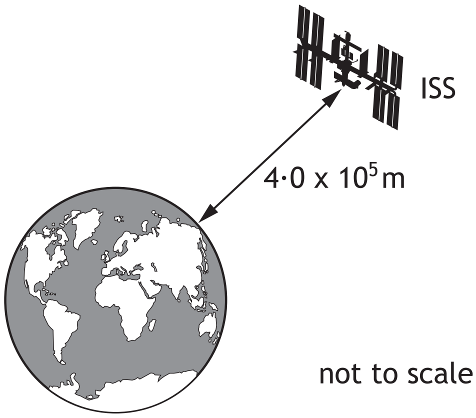


Figure 3A

(a) (i) The gravitational pull of the Earth keeps the ISS in orbit.

Show that for an orbit of radius r the period T is given by the expression

$$T = 2\pi\sqrt{\frac{r^3}{GM_E}}$$

where the symbols have their usual meaning. **2**

(ii) Calculate the period of orbit of the ISS when it is at an altitude of $4{\cdot}0 \times 10^5$ m above the surface of the Earth. **2**

Space for working and answer

3. (continued)

(b) The graph in Figure 3B shows how the altitude of the ISS has varied over time. Reductions in altitude are due to the drag of the Earth's atmosphere acting on the ISS.

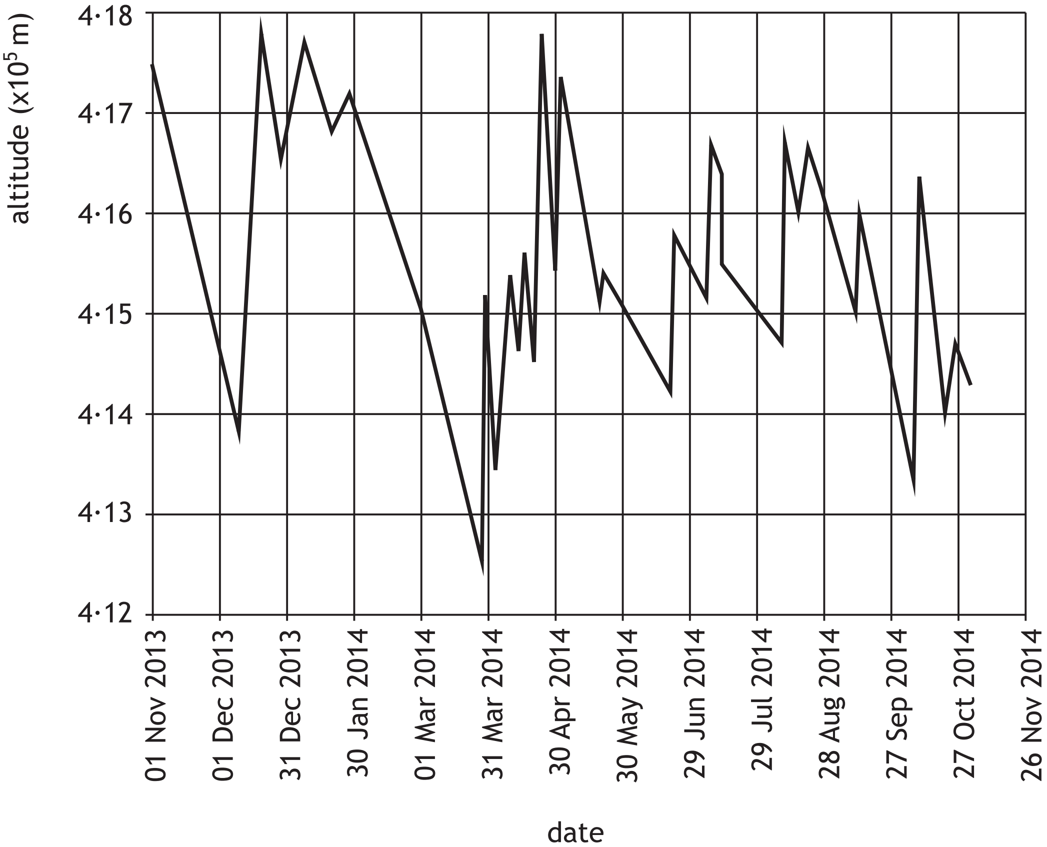


Figure 3B

(i) Determine the value of Earth's gravitational field strength at the ISS on 1 March 2014. **4**

Space for working and answer

3. (b) (continued)

(ii) In 2011 the average altitude of the ISS was increased from 350 km to 400 km.

Give an advantage of operating the ISS at this higher altitude. **1**

(c) Clocks designed to operate on the ISS are synchronised with clocks on Earth before they go into space. On the ISS a correction factor is necessary for the clocks to remain synchronised with clocks on the Earth.

Explain why this correction factor is necessary. **2**

MARKS DO NOT WRITE IN THIS MARGIN

4. The constellation Orion, shown in Figure 4A, is a common sight in the winter sky above Scotland.

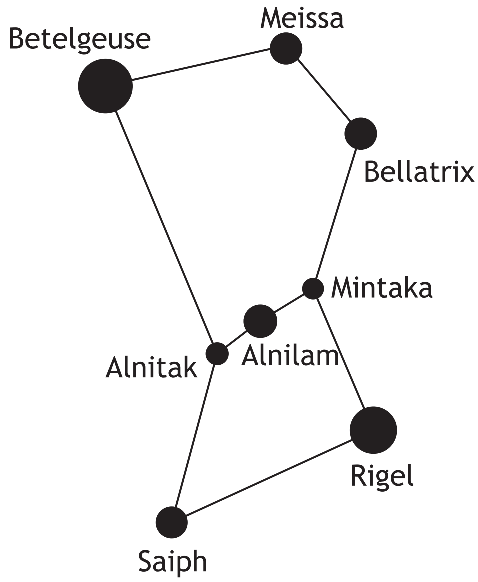


Figure 4A

Two of the stars in this constellation are known as Betelgeuse and Rigel. Their positions are shown on the Hertzsprung–Russell (H-R) diagram in Figure 4B.

MARKS DO NOT WRITE IN THIS MARGIN

4. (continued)

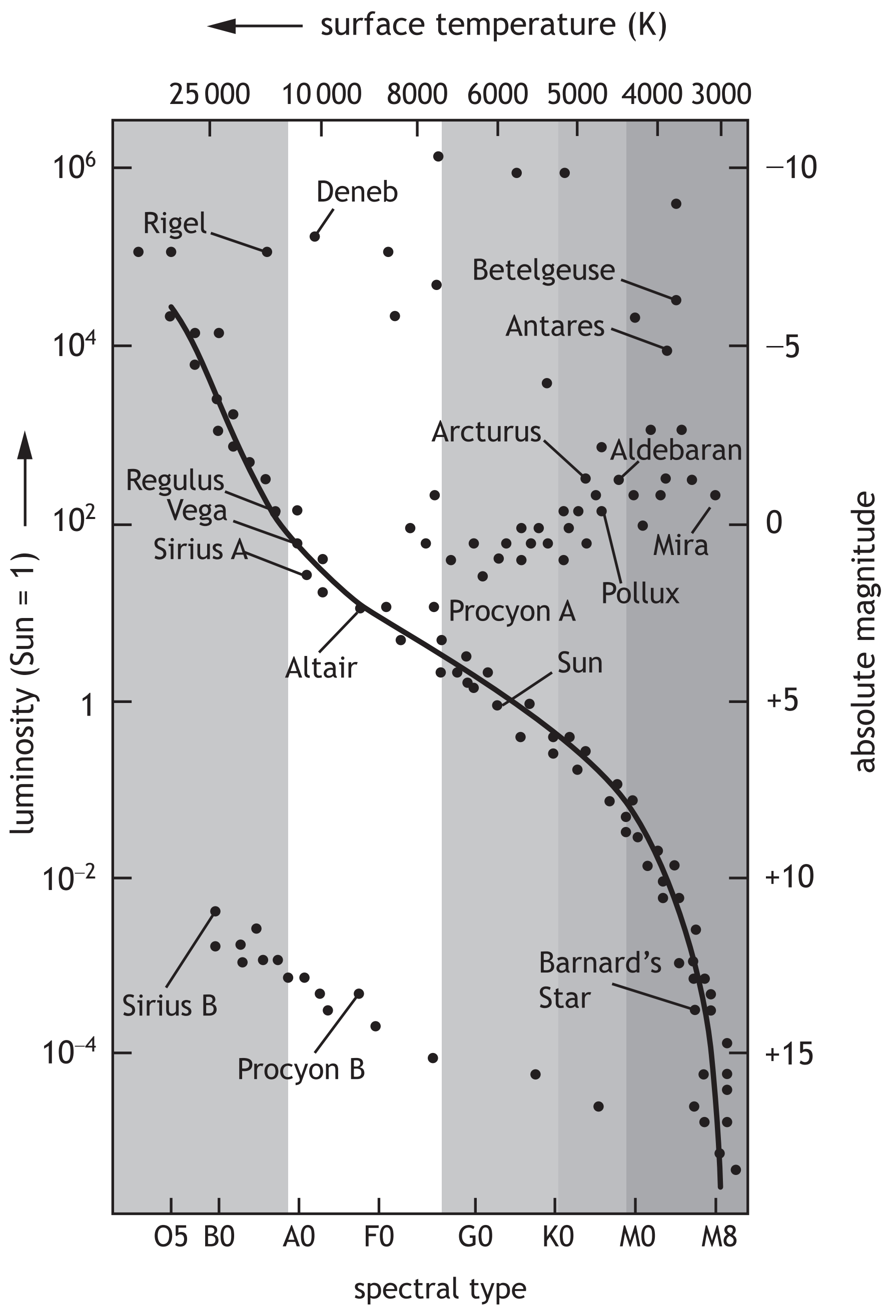


Figure 4B

(a) Using the H-R diagram, predict the colour of Betelgeuse. **1**

4. (continued)

(b) The table shows some of the physical properties of Rigel.

Property of Rigel	
Surface temperature	$(1{\cdot}20 \pm 0{\cdot}05) \times 10^4$ K
Radius	$(5{\cdot}49 \pm 0{\cdot}50) \times 10^{10}$ m
Mass	18 ± 1 solar masses
Distance to Earth	773 ± 150 light years

(i) (A) Calculate the luminosity of Rigel. **3**

Space for working and answer

(B) State the assumption made in your calculation. **1**

(ii) Calculate the absolute uncertainty in the value of the luminosity of Rigel. **4**

Space for working and answer

4. (continued)

(c) Calculate the apparent brightness of Rigel as observed from the Earth. **4**

Space for working and answer

(d) Betelgeuse is not on the Main Sequence region of the H-R diagram. Describe the changes that have taken place in Betelgeuse since leaving the Main Sequence. **2**

5. Figure 5A shows a snowboarder in a half pipe. The snowboarder is moving between positions P and Q. The total mass of snowboarder and board is 85 kg.

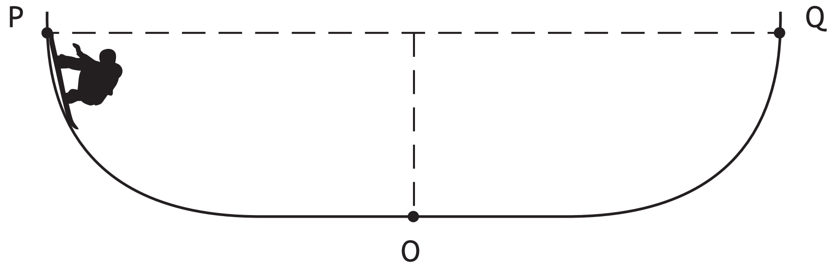


Figure 5A

A student attempts to model the motion of the snowboarder as simple harmonic motion (SHM).

The student uses measurements of amplitude and period to produce the displacement-time graph shown in Figure 5B.

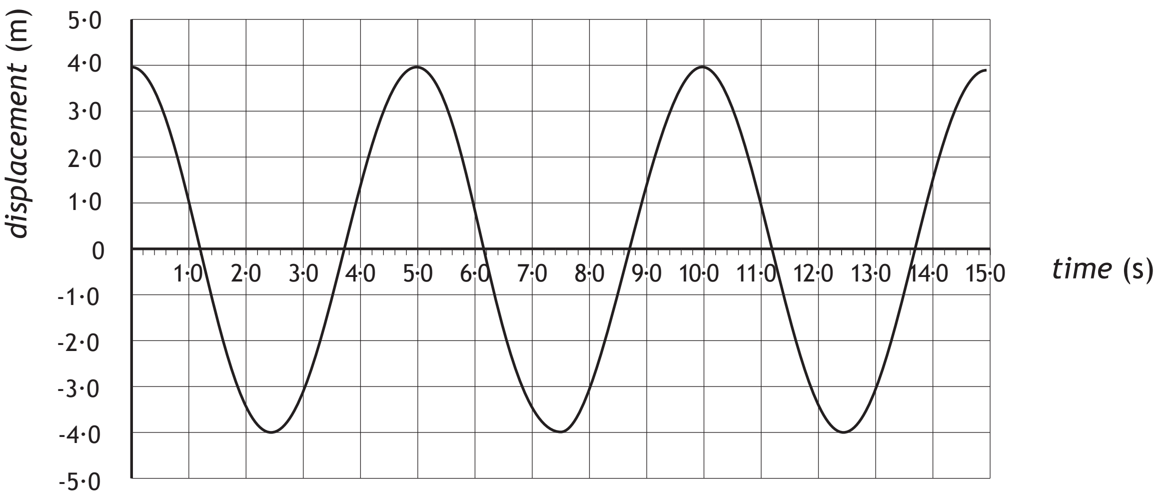


Figure 5B

(a) (i) State what is meant by the term *simple harmonic motion*. **1**

5. (a) (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(ii) Determine the angular frequency of the motion. **4**

Space for working and answer

(iii) Calculate the maximum acceleration experienced by the snowboarder on the halfpipe. **3**

Space for working and answer

(iv) Sketch a velocity-time graph for one period of this motion.

Numerical values are required on both axes. **3**

You may wish to use the square-ruled paper on *Page thirty*.

(v) Calculate the maximum potential energy of the snowboarder. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(b) Detailed video analysis shows that the snowboarder's motion is not fully described by the SHM model.

Using your knowledge of physics, comment on possible reasons for this discrepancy. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

6. The Bohr model of the hydrogen atom consists of a single electron orbiting a single proton. Due to the quantisation of angular momentum, in this model, the electron can only orbit at particular radii.

Figure 6A shows an electron with principal quantum number n = 1.

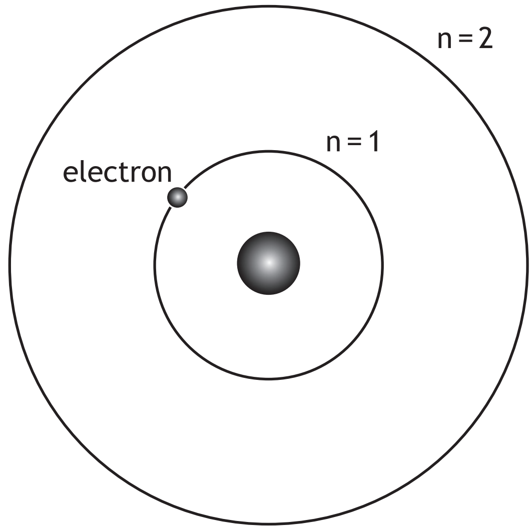


Figure 6A

(a) Explain what gives rise to the centripetal force acting on the electron. **1**

6. (continued) **MARKS** DO NOT WRITE IN THIS MARGIN

(b) (i) Show that the kinetic energy of the electron is given by

$$E_k = \frac{e^2}{8\pi\varepsilon_0 r}$$

where the symbols have their usual meaning. **2**

(ii) Calculate the kinetic energy for an electron with orbital radius 0·21 nm. **2**

Space for working and answer

(c) Calculate the principal quantum number for an electron with angular momentum $4{\cdot}22 \times 10^{-34}$ kg m^{2}s^{-1}. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

(d) Heisenberg's uncertainty principle addresses some of the limitations of classical physics in describing quantum phenomena.

(i) The uncertainty in an experimental measurement of the momentum of an electron in a hydrogen atom was determined to be $\pm 1{\cdot}5 \times 10^{-26}\,\mathrm{kg\,m\,s^{-1}}$.

Calculate the minimum uncertainty in the position of the electron. **3**

Space for working and answer

(ii) In a scanning tunnelling microscope (STM) a sharp metallic tip is brought very close to the surface of a conductor. As the tip is moved back and forth, an electric current can be detected due to the movement ("tunnelling") of electrons across the air gap between the tip and the conductor, as shown in Figure 6B.

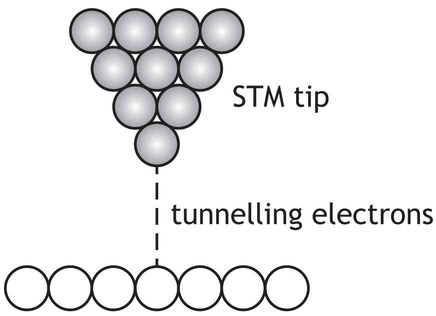


Figure 6B

According to classical physics, electrons should not be able to cross the gap as the kinetic energy of each electron is insufficient to overcome the repulsion between electrons in the STM tip and the surface.

Explain why an electron is able to cross the gap. **3**

MARKS DO NOT WRITE IN THIS MARGIN

7. When a microwave oven is switched on a stationary wave is formed inside the oven.

(a) Explain how a stationary wave is formed. **1**

(b) A student carries out an experiment to determine the speed of light using a microwave oven. The turntable is removed from the oven and bread covered in butter is placed inside. The oven is switched on for a short time, after which the student observes that the butter has melted only in certain spots, as shown in Figure 7A.

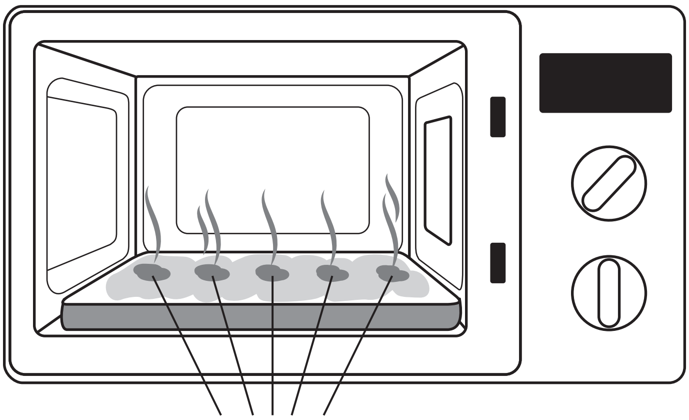


Figure 7A

Explain why the butter has melted in certain spots and not in others. **2**

7. **(continued)** **MARKS** DO NOT WRITE IN THIS MARGIN

(c) The student measures the distance between the first hot spot and fifth hot spot as 264 mm.

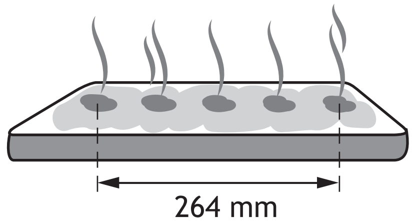


Figure 7B

From the data obtained by the student determine the wavelength of the microwaves. **2**

Space for working and answer

(d) The quoted value for the frequency of the microwaves is 2·45 GHz. The student calculates the speed of light using data from the experiment.

Show that the value obtained by the student for the speed of light is $3{\cdot}23 \times 10^{8}\,\mathrm{m\,s^{-1}}$. **2**

Space for working and answer

(e) The student repeats the experiment and obtains the following values for the speed of light,

$3{\cdot}26 \times 10^{8}\,\mathrm{m\,s^{-1}}$, $3{\cdot}19 \times 10^{8}\,\mathrm{m\,s^{-1}}$, $3{\cdot}23 \times 10^{8}\,\mathrm{m\,s^{-1}}$, $3{\cdot}21 \times 10^{8}\,\mathrm{m\,s^{-1}}$.

Comment on both the accuracy and precision of the student's results. **2**

8. A beam of electrons is incident on a grating as shown in Figure 8A.

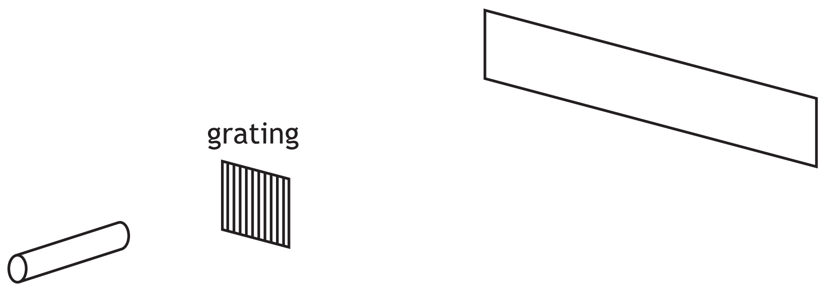


Figure 8A

(a) After passing through the grating the electrons are incident on a zinc sulfide coated screen. The coating emits light when struck by electrons.

Describe the pattern observed on the screen. **1**

(b) Scientists perform similar experiments with large molecules. One such molecule is buckminsterfullerene (C60) with a mass of $1{\cdot}20 \times 10^{-24}$ kg.

For C60 molecules with a velocity of $220\,\mathrm{m\,s^{-1}}$ estimate the slit spacing required to produce a pattern comparable to that observed for the electrons. You must justify your answer by calculation. **4**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

9. As part of a physics project a student carried out experiments to obtain values for the permeability of free space and the permittivity of free space.

The results obtained by the student were

permeability of free space, $\mu_0 = (1{\cdot}32 \pm 0{\cdot}05) \times 10^{-6}\,\text{H m}^{-1}$

permittivity of free space, $\varepsilon_0 = (8{\cdot}93 \pm 0{\cdot}07) \times 10^{-12}\,\text{F m}^{-1}$

(a) State the number of significant figures in the value of each result. **1**

(b) Use these results to determine a value for the speed of light.

Your answer must be consistent with (a). **3**

Space for working and answer

(c) (i) Determine which of the uncertainties obtained by the student is more significant for the calculation of the speed of light.

You must justify your answer by calculation. **3**

Space for working and answer

(ii) Calculate the absolute uncertainty in the value obtained for the speed of light. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

10. (a) Two point charges Q_1 and Q_2 are separated by a distance of 0·60 m as shown in Figure 10A. The charge on Q_1 is −8·0 nC. The electric field strength at point X is zero.

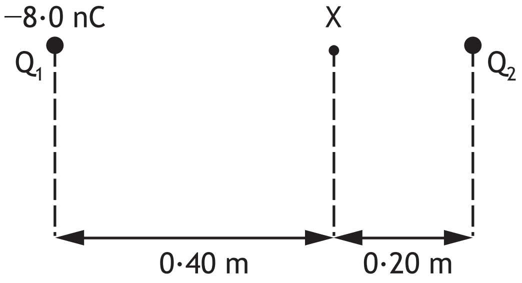


Figure 10A

(i) State what is meant by *electric field strength*. **1**

(ii) Show that the charge on Q_2 is −2·0 nC. **2**

Space for working and answer

(iii) Calculate the electrical potential at point X. **5**

Space for working and answer

*S Q 2 9 A H 0 1 2 5 *

10. (continued)

(b)

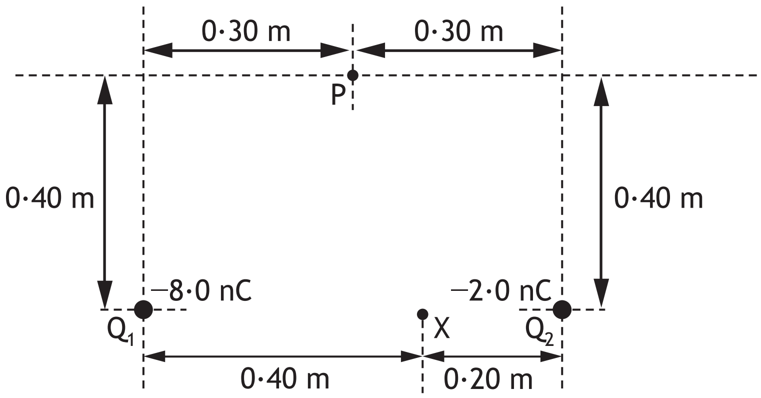


Figure 10B

(i) Calculate the electrical potential at point P. **3**

Space for working and answer

(ii) Determine the energy required to move a charge of +1·0 nC from point X to point P. **4**

Space for working and answer

11. The Nobel prize winning physicist Richard Feynman once stated "things on a small scale behave nothing like things on a large scale".

Using your knowledge of physics, comment on his statement. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

12. A student carries out a series of experiments to investigate properties of capacitors in a.c. circuits.

(a) The student connects a 5·0 μF capacitor to an a.c. supply of e.m.f. 15 V_{rms} and negligible internal resistance as shown in Figure 12A.

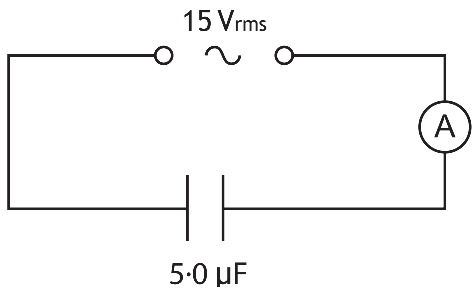


Figure 12A

The frequency of the a.c. supply is 65 Hz.

(i) Calculate the reactance of the capacitor. **3**

Space for working and answer

(ii) Determine the value of the current in the circuit. **3**

Space for working and answer

12. (continued)

(b) The student uses the following circuit to determine the capacitance of a second capacitor.

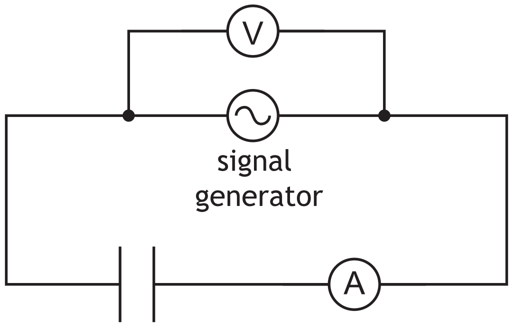


Figure 12B

The student obtains the following data.

Reactance (Ω)	*Frequency* (Hz)
$1{\cdot}60 \times 10^{6}$	10
$6{\cdot}47 \times 10^{5}$	40
$2{\cdot}99 \times 10^{5}$	100
$1{\cdot}52 \times 10^{5}$	200
$6{\cdot}35 \times 10^{4}$	500
$3{\cdot}18 \times 10^{4}$	1000

(i) On the square-ruled paper on *Page thirty*, plot a graph that would be suitable to determine the capacitance.

(ii) Use your graph to determine the capacitance of this capacitor. **3**

Space for working and answer

[END OF SPECIMEN QUESTION PAPER]

MARKS DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

National
Qualifications
SPECIMEN ONLY

SQ29/AH/01 **Physics**

Marking Instructions

These Marking Instructions have been provided to show how SQA would mark this Specimen Question Paper.

General Marking Principles for Advanced Higher Physics

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this paper. These principles must be read in conjunction with the Detailed Marking Instructions, which identify the key features required in candidate responses.

(a) Marks for each candidate response must always be assigned in line with these General Marking Principles and the Detailed Marking Instructions for this assessment.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

(c) There are **no half marks** awarded.

(d) Where a wrong answer to part of a question is carried forward and the wrong answer is then used correctly in the following part, the candidate should be given credit for the subsequent part or "follow on".

(e) Unless a numerical question specifically requires evidence of working to be shown, full marks should be awarded for a correct final answer (including units if required) on its own.

(f) Credit should be given where a diagram or sketch conveys correctly the response required by the question. It will usually require clear and correct labels (or the use of standard symbols).

(g) Marks are provided for knowledge of relevant relationships alone, but when a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values, no mark can be awarded.

(h) Marks should be awarded for non-standard symbols where the symbols are defined and the relationship is correct, or where the substitution shows that the relationship used is correct. This must be clear and unambiguous.

(i) Where a triangle type "relationship" is written down and then not used or used incorrectly, then any mark for a relationship should not be awarded.

(j) Significant figures.
Data in question is given to 3 significant figures.
Correct final answer is 8·16 J.
Final answer 8·2 J or 8·158 J or 8·1576 J — Award the final mark.
Final answer 8 J or 8·15761 J — Do not award the final mark.
Candidates should not be credited for a final answer that includes:

- three or more figures too many
  or
- two or more figures too few, **ie accept two more and one fewer.**

(k) The incorrect spelling of technical terms should usually be ignored and candidates should be awarded the relevant mark, provided that answers can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, the mark should not be awarded. Two specific examples of this would be when the candidate uses a term that might be interpreted as "reflection", "refraction" or "diffraction" (eg "defraction") or one that might be interpreted as either "fission" or "fusion" (eg "fussion").

(l) Marks are awarded only for a valid response to the question asked. For example, in response to questions that ask candidates to:

- **describe**, they must provide a statement or structure of characteristics and/or features;
- **determine** or **calculate**, they must determine a number from given facts, figures or information;
- **estimate**, they must determine an approximate value for something;

- **explain**, they must relate cause and effect and/or make relationships between things clear;
- **identify**, **name**, **give**, or **state**, they need only name or present in brief form;
- **justify**, they must give reasons to support their suggestions or conclusions, eg this might be by identifying an appropriate relationship and the effect of changing variables;
- **predict**, they must suggest what may happen based on available information;
- **show that**, they must use physics [and mathematics] to prove something, eg a given value — *all steps, including the stated answer, must be shown*;
- **suggest**, they must apply their knowledge and understanding of physics to a new situation. A number of responses are acceptable: marks will be awarded for any suggestions that are supported by knowledge and understanding of physics;
- **use your knowledge of physics or aspect of physics to comment on**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/situation presented (for example, by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). They will be rewarded for the breadth and/or depth of their conceptual understanding.

(m) Marking in calculations

Question:

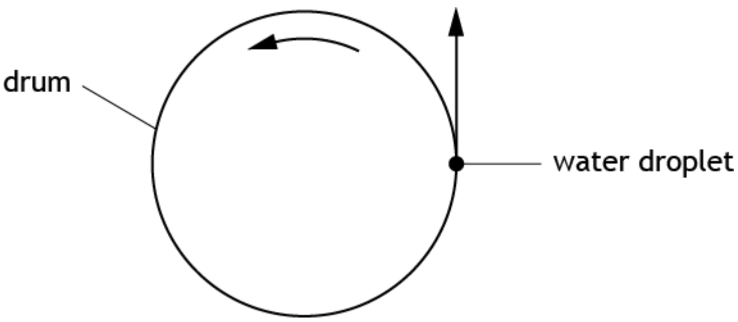
The current in a resistor is 1·5 amperes when the potential difference across it is 7·5 volts. Calculate the resistance of the resistor (3 marks).

	Candidate answer	Mark & comment
1	$V = IR$	1 mark: relationship
	$7\cdot5 = 1\cdot5R$	1 mark: substitution
	$R = 5\cdot0\ \Omega$	1 mark: correct answer
2	$5\cdot0\ \Omega$	3 marks: correct answer
3	$5\cdot0$	2 marks: unit missing
4	$4\cdot0\ \Omega$	0 marks: no evidence, wrong answer
5	$\_\_\ \Omega$	0 marks: no working or final answer
6	$R = \frac{V}{I} = \frac{7\cdot5}{1\cdot5} = 4\cdot0\ \Omega$	2 marks: arithmetic error
7	$R = \frac{V}{I} = 4\cdot0\ \Omega$	1 mark: relationship only
8	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: relationship only
9	$R = \frac{V}{I} = \frac{7\cdot5}{1\cdot5} = \_\_\ \Omega$	2 marks: relationship & subs, no final answer
10	$R = \frac{V}{I} = \frac{7\cdot5}{1\cdot5} = 4\cdot0$	2 marks: relationship & subs, wrong answer
11	$R = \frac{V}{I} = \frac{1\cdot5}{7\cdot5} = 5\cdot0\ \Omega$	1 mark: relationship but wrong substitution

12	$R = \frac{V}{I} = \frac{75}{1 \cdot 5} = 5 \cdot 0\ \Omega$	1 mark: relationship but wrong substitution
13	$R = \frac{I}{V} = \frac{1 \cdot 5}{7 \cdot 5} = 5 \cdot 0\ \Omega$	0 marks: wrong relationship
14	$V = IR$ $7 \cdot 5 = 1 \cdot 5 \times R$ $R = 0 \cdot 2\ \Omega$	2 marks: relationship & subs, arithmetic error
15	$V = IR$ $R = \frac{I}{V} = \frac{1 \cdot 5}{7 \cdot 5} = 0 \cdot 2\ \Omega$	1 mark: relationship correct but wrong rearrangement of symbols

Detailed Marking Instructions for each question

Question			Expected response	Max mark	Additional guidance
1	a		$\omega = \frac{\theta}{t}$ **(1)** $= \frac{1250 \times 2 \times \pi}{60}$ **(1)** $= 131\ \text{rad}\,\text{s}^{-1}$	2	If final answer is not shown then maximum of 1 mark can be awarded.
1	b	i	$\alpha = \frac{\omega_1 - \omega_0}{t}$ **(1)** $= \frac{131 - 7\cdot50}{12}$ **(1)** $= 10\cdot3\ \text{rad}\,\text{s}^{-2}$ **(1)**	3	Accept: 10 10·3 10·29 10·292
1	b	ii	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ **(1)** $= 7\cdot50 \times 12\cdot0 + 0\cdot5 \times 10\cdot3 \times 12\cdot0^2$ **(1)** $= 831\cdot6\ \text{(rad)}$ **(1)** $\text{revolutions} = \frac{831\cdot6}{2\pi}$ **(1)** $= 132$ **(1)**	5	If candidate stops here unit must be present for mark 3. Accept: 130 132 132·4 132·35
1	c		$\text{centripetal force} = m\omega^2 r$ **(1)** $= 1\cdot5 \times 10^{-2} \times 131^2 \times 0\cdot28$ **(1)** $= 72\ \text{N}$ **(1)**	3	Accept: 70 72 72·1 72·08
1	d	i	The drum exerts a centripetal/central force on the clothing. **(1)** No centripetal/central force acting on water. **(1)**	2	

Question			Expected response	Max mark	Additional guidance
1	d	ii	 **(1)**	1	
1	d	iii	Centripetal force decreases … **(1)** as mass of wet clothing decreases **(1)**	2	
2	a		$I = \frac{1}{2}mr^2$ **(1)** $= 0\cdot5 \times 6\cdot0 \times 0\cdot50^2$ **(1)** $= 0\cdot75 \text{ kg m}^2$	2	If final answer is not shown then maximum of 1 mark can be awarded.
2	b	i	2 kg mass: $I = mr^2$ **(1)** $= 2\cdot0 \times 0\cdot40^2$ **(1)** $= 0\cdot32 \text{ (kg m}^2\text{)}$ $\text{Total} = 0\cdot32 + 0\cdot75 = 1\cdot1 \text{ kg m}^2$ **(1)**	3	Accept: 1 1·1 1·07 1·070
2	b	ii	$I_1\omega_1 = I_2\omega_2$ **(1)** $0\cdot75 \times 12 = 1\cdot1 \times \omega_2$ **(1)** $\omega_2 = 8\cdot2 \text{ rad s}^{-1}$ **(1)**	3	Accept: 8 8·2 8·18 8·182 Also accept 8·4 if 1·07 is clearly used.
2	b	iii	No external torque acts on system. **Or**, 2 kg can be considered as a point mass	1	
2	c		• the (final) angular velocity will be greater **(1)** • the final moment of inertia is less than in b(ii) **(1)**	2	Reference must be made to moment of inertia for the second mark. Insufficient to say “sphere rolls off”

Question			Expected response	Max mark	Additional guidance
					without effect on moment of inertia.
3	a	i	$\frac{GM_E m}{r^2} = m\omega^2 r$ $\omega = \frac{2\pi}{T}$ **(1)** $\frac{GM_E m}{r^2} = m\frac{4\pi^2}{T^2}r$ **(1)** $T = 2\pi\sqrt{\frac{r^3}{GM_g}}$	2	To access any marks candidates must start with equating the forces/ acceleration. A maximum of 1 mark if final equation is not shown.
3	a	ii	$T = 2\pi\sqrt{\frac{\left(6\cdot4\times10^6 + 4\cdot0\times10^5\right)^3}{6\cdot67\times10^{-11}\times6\cdot0\times10^{24}}}$ **(1)** $= 5\cdot6\times10^3$ s **(1)**	2	Accept: 6 5·6 5·57 5·569
3	b	i	Value from graph $4\cdot15 \times 10^5$ (m) **(1)** $mg = \frac{GM_E m}{r^2}$ **(1)** $g = \frac{GM_E}{r^2}$ **(1)** $= \frac{6\cdot67\times10^{-11}\times6\cdot0\times10^{24}}{\left(4\cdot15\times10^5 + 6\cdot4\times10^6\right)^2}$ $= 8\cdot6 \text{ N kg}^{-1}$ **(1)**	4	Accept: 9 8·6 8·62 8·617
3	b	ii	Less atmospheric drag/friction **or** will reduce running costs. **(1)**	1	
3	c		The gravitational field is smaller at the ISS (compared to Earth). **(1)** The clocks on ISS will run faster (than those on Earth). **(1)**	2	
4	a		Betelgeuse will look red-orange.	1	
4	b	iA	$L = 4\pi r^2\sigma T^4$ **(1)** $L = 4\times\pi\times(5\cdot49\times10^{10})^2\times5\cdot67\times10^{-8}\times(1\cdot20\times10^4)^4$ **(1)** $L = 4\cdot45\times10^{31}$ W **(1)**	3	Accept: $4\cdot5 \times 10^{31}$ $4\cdot45 \times 10^{31}$ $4\cdot453 \times 10^{31}$ $4\cdot4531 \times 10^{31}$

Question			Expected response	Max mark	Additional guidance
4	b	iB	Rigel/stars behave as black body(ies).	1	
4	b	ii	$\%\Delta r = \frac{0\cdot50}{5\cdot49}\times100\% = 9\cdot1\%$ **(1)** $\%\Delta T = \frac{0\cdot05}{1\cdot20}\times100\% = 4\cdot2\%$ **(1)** $\text{Total }\%\Delta = \sqrt{(9\cdot1 \times 2)^2 + (4\cdot2 \times 4)^2}$ **(1)** = 25% $\Delta L = 4\cdot45 \times 10^{31} \times 0\cdot25 = 1 \times 10^{31}$ W **(1)**	4	Accept: 1·1 1·11
4	c		$b = \frac{L}{4\pi r^2}$ **(1)** $= \frac{4\cdot45\times10^{31}}{4\times\pi\times(773\times365\times24\times60\times60\times3\cdot00\times10^8)^2}$ **(1)** For ly to m conversion **(1)** $= 6\cdot62 \times 10^{-8}$ Wm^{-2} **(1)**	4	Accept: $6\cdot6 \times 10^{-8}$ $6\cdot62 \times 10^{-8}$ $6\cdot621 \times 10^{-8}$ $6\cdot6212 \times 10^{-8}$ The use of 3·14 or 365·25 may give 6·61.
4	d		Any two from: • (Most) hydrogen fusion has stopped. • Radius has (significantly) increased. • Surface temperature has decreased. • Core gets hotter.	2	
5	a	i	Acceleration is proportional to displacement (from a fixed point) and is always directed to (that) fixed point. **Or** The unbalanced force is proportional to the displacement (from a fixed point) and is always directed to (that) fixed point.	1	Accept: $F = -kx$ or $a = -kx$
5	a	ii	From graph T = 5·0 (s) **(1)** $\rightarrow f = \frac{1}{T} = \frac{1}{5\cdot0} = 0\cdot20$ s $\omega = 2\pi f$ **(1)** $= 2\times\pi\times0\cdot20$ **(1)** $= 1\cdot3$ rad s^{-1} **(1)**	4	Accept: 1 1·3 1·26 1·257 Use of $\omega = \frac{2\pi}{T}$ is possible.

Question			Expected response	Max mark	Additional guidance
5	a	iii	$a = (-)\omega^2 y$ **(1)** $a = (-)1\cdot3^2 \times (-)4\cdot0$ **(1)** $a = (-)6\cdot8\ \text{m s}^{-2}$ **(1)**	3	Accept: 7 6·8 6·76 6·760
5	a	iv	Sine shape graph for one period of oscillation from t = 0 s to t = 5 s **(1)** $v_{max} = \pm\omega\sqrt{(A^2 - y^2)}$ **(1)** $v_{max} = \pm1\cdot3\times\sqrt{(4\cdot0^2 - 0^2)}$ $v_{max} = \pm5\cdot2\ \text{m s}^{-1}$ **(1)**	3	Award a maximum of 2 marks if the labels, units or origin is/are missing.
5	a	v	$E_p = \frac{1}{2}m\omega^2 y^2$ **(1)** $E_p = 0\cdot5\times85\times1\cdot3^2\times4\cdot0^2$ **(1)** $E_p = 1\cdot1\times10^3\ \text{J}$ **(1)**	3	Accept: 1×10^3 $1\cdot1 \times 10^3$ $1\cdot15 \times 10^3$ $1\cdot149 \times 10^3$

Question			Expected response	Additional guidance
5	b		The whole candidate response should first be read to establish its overall quality in terms of accuracy and relevance to the problem/situation presented. There may be strengths and weaknesses in the candidate response: assessors should focus as far as possible on the strengths, taking account of weaknesses (errors or omissions) only where they detract from the overall answer in a significant way, which should then be taken into account when determining whether the response demonstrates reasonable, limited or no understanding. Assessors should use their professional judgement to apply the guidance below to the wide range of possible candidate responses.	This open-ended question requires comment on possible reasons for discrepancies in assuming SHM model. Candidate responses may include one or more of: snowboarder going too far; not a semicircle; movement down the half pipe; additional force caused by snowboarder or other relevant ideas/concepts.
			3 marks: The candidate has demonstrated a **good** conceptual understanding of the physics involved, providing a logically correct response to the problem/situation presented.	In response to this question, a **good** understanding might be demonstrated by a candidate response that:

Question			Expected response	Additional guidance
			This type of response might include a statement of principle(s) involved, a relationship or equation, and the application of these to respond to the problem/situation. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.	• makes a judgement on suitability based on one relevant physics idea/concept, in a **detailed/developed** response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response) **OR** • makes judgement(s) on suitability based on a range of relevant physics ideas/concepts, in a response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • otherwise demonstrates a good understanding of the physics involved.
			2 marks: The candidate has demonstrated a **reasonable** understanding of the physics involved, showing that the problem/situation is understood. This type of response might make some statement(s) that is/are relevant to the problem/situation, for example, a statement of relevant principle(s) or identification of a relevant relationship or equation.	In response to this question, a **reasonable** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that is **largely correct** but has **weaknesses** which detract to a small extent from the overall response, **OR** • otherwise demonstrates a reasonable understanding of the physics involved.
			1 mark: The candidate has demonstrated a **limited** understanding of the physics involved, showing that a little of the physics that is relevant to the problem/situation is understood. The candidate has made some statement(s) that is/are relevant to the problem/situation.	In response to this question, a **limited** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that has **weaknesses** which detract to a large extent from the overall response, **OR** • otherwise demonstrates a limited understanding of the physics involved.

Question			Expected response	Additional guidance
			0 marks: The candidate has demonstrated **no** understanding of the physics that is relevant to the problem/situation. The candidate has made no statement(s) that is/are relevant to the problem/situation.	Where the candidate has *only* demonstrated knowledge and understanding of physics **that is not relevant to the problem/situation presented,** 0 marks should be awarded.

Question			Expected response	Max mark	Additional guidance
6	a		Electrostatic force between the nucleus/proton and the electron. **(1)**	1	Any other forces shown 0 marks.
6	b	i	(Electrostatic force = centripetal force) $\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$ **(1)** $\frac{e^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$ $mv^2 = \frac{e^2}{4\pi\varepsilon_0 r}$ $\frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon_0 r}$ **(1)** $E_k = \frac{e^2}{8\pi\varepsilon_0 r}$	2	Equations must be shown from Relationships Sheet to gain any marks. If final line is not shown then maximum of 1 mark only can be awarded.
6	b	ii	$E_k = \frac{e^2}{8\pi\varepsilon_0 r}$ $E_k = \frac{(1\cdot60\times10^{-19})^2}{8\pi\times8\cdot85\times10^{-12}\times0\cdot21\times10^{-9}}$ **(1)** $E_k = 5\cdot5\times10^{-19}$ J **(1)**	2	Accept: 5×10^{-19} $5\cdot5 \times 10^{-19}$ $5\cdot48 \times 10^{-19}$ $5\cdot483 \times 10^{-19}$ If 9×10^9 used, then accept 5, 5·5, 5·49, 5·486

Question			Expected response	Max mark	Additional guidance
6	c		$mvr = \frac{nh}{2\pi}$ **(1)** $4\cdot22\times10^{-34} = \frac{n\times6\cdot63\times10^{-34}}{2\pi}$ **(1)** $n = 4$ **(1) (must be integer)**	3	
6	d	i	$\Delta x\Delta p_x \geq \frac{h}{4\pi}$ **(1)** $\Delta x\times1\cdot5\times10^{-26} \geq \frac{6\cdot63\times10^{-34}}{4\pi}$ **(1)** minimum $\Delta x = 3\cdot5\times10^{-9}\,\text{m}$ **(1)**	3	Accept: 4 x 10^{-9}, 3·52 x 10^{-9}, 3·517 x 10^{-9}
6	d	ii	$\Delta t\Delta E \geq \frac{h}{4\pi}$ **(1)** If Δt is small then ΔE is large **(1)** Therefore the largest possible energy of the electron may be big enough to overcome the repulsion and cross the gap. **(1)** **or** $\Delta x\Delta p \geq \frac{h}{4\pi}$ **(1)** If the momentum is measured with a small uncertainty, the uncertainty in the position of the electron is large enough **(1)** for the electron to exist on the other side of the gap **(1).**	3	
7	a		Reflected wave interferes with transmitted wave (to produce points of destructive and constructive interference). **(1)**	1	
7	b		Antinode (constructive), high energy, so melted spots.**(1)** Node (destructive), low energy, so no melting. **(1)**	2	
7	c		$4\times\frac{1}{2}\lambda = 0\cdot264\text{ m}$ **(1)** $\lambda = 0\cdot132\text{ m}$ **(1)**	2	
7	d		$v = f\lambda$ **(1)** $= 2\cdot45\times10^9\times0\cdot132$ **(1)** $= 3\cdot234\times10^8\text{ m s}^{-1}$ $= 3\cdot23\times10^8\text{ m s}^{-1}$	2	If final answer is not shown then maximum of 1 mark only can be awarded.

Question			Expected response	Max mark	Additional guidance
7	e		The range of the results is small, so the results are precise. **(1)** The difference between the mean value of the results and the accepted value of c is larger than the range, so the results are not accurate. **(1)**	2	
8	a		A series of bright and dark spots.	1	Accept fringes.
8	b		$p = mv$ $p = 1\cdot 20 \times 10^{-24} \times 220$ $= 2\cdot 64 \times 10^{-22}$ (kg m s^{-1}) $\lambda = \frac{h}{p}$ **(1) (for both formulae)** $= \frac{6\cdot 63 \times 10^{-34}}{2\cdot 64 \times 10^{-22}}$ **(1) (for both substitutions)** $= 2\cdot 5 \times 10^{-12}$ m **(1)** Estimate in the range of 10^{-12} to 10^{-9} **(1)**	4	Statement of value of slit separation must be distinct from value of λ.
9	a		3	1	
9	b		$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ **(1)** $= \frac{1}{\sqrt{8\cdot 93 \times 10^{-12} \times 1\cdot 32 \times 10^{-6}}}$ **(1)** $= 2\cdot 91 \times 10^{8}$ m s^{-1} **(1)**	3	The answer must be consistent with (a) in terms of significant figures. If not consistent then maximum of 2 marks only can be awarded.
9	c	i	%uncert in $\mu_0 = \pm \frac{5 \times 10^{-8}}{1\cdot 32 \times 10^{-6}} \times 100$ $= \pm 3\cdot 8\%$ **(1)** %uncert in $\varepsilon_0 = \pm \frac{7 \times 10^{-14}}{8\cdot 93 \times 10^{-12}} \times 100$ $= \pm 0\cdot 8\%$ **(1)** Uncertainty in μ_0 more significant **(1)**	3	

Question			Expected response	Max mark	Additional guidance
9	c	ii	uncert in $\frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \pm \frac{1}{2} \times \frac{3 \cdot 8}{100} \times 2 \cdot 91 \times 10^8$ **(1)** $= \pm 6 \times 10^6 \text{ m s}^{-1}$ **(1)**	2	If a candidate combines both uncertainties correctly full marks may be awarded.
10	a	i	Force acting per unit positive charge.	1	
10	a	ii	$\frac{Q_1}{4\pi\varepsilon_o r_1^2} = \frac{Q_2}{4\pi\varepsilon_o r_2^2}$ **(1)** $\frac{-8 \cdot 0 \times 10^{-9}}{4\pi\varepsilon_o (0 \cdot 4)^2} = \frac{Q_S}{4\pi\varepsilon_o (0 \cdot 2)^2}$ **(1)** $Q_2 = \frac{-8 \cdot 0 \times 10^{-9} \times (0 \cdot 2)^2}{(0 \cdot 4)^2}$ $Q_2 = -2 \cdot 0 \times 10^{-9} \text{ C}$	2	If final answer is not shown then maximum of 1 mark can be awarded.
10	a	iii	$V_1 = \frac{Q}{4\pi\varepsilon_0 r}$ **(1)** $V_1 = \frac{-8 \cdot 0 \times 10^{-9}}{4 \times \pi \times 8 \cdot 85 \times 10^{-12} \times 0 \cdot 40}$ **(1)** $V_1 = -180 \text{ V}$ **(1)** $V_2 = \frac{-2 \cdot 0 \times 10^{-9}}{4 \times \pi \times 8 \cdot 85 \times 10^{-12} \times 0 \cdot 20}$ $V_2 = -90 \text{ V}$ **(1)** Potential at X = −180 − 90 = −270 V **(1)**	5	V_1 = −179·84 V_2 = −89·92
10	b	i	$V_1 = \frac{-8 \cdot 0 \times 10^{-9}}{4 \times \pi \times 8 \cdot 85 \times 10^{-12} \times 0 \cdot 50}$ $V_1 = -140 \text{ V}$ **(1)** $V_2 = \frac{-2 \cdot 0 \times 10^{-9}}{4 \times \pi \times 8 \cdot 85 \times 10^{-12} \times 0 \cdot 50}$ $V_2 = -36 \text{ V}$ **(1)** Potential at P = −140 − 36 = −176 V = −180 V **(1)**	3	Accept V_1 = −144 V Accept −176 V

Question			Expected response	Max mark	Additional guidance
	b	ii	Potential difference = -180 − (−270) = 90 (V) **(1)** $E = QV$ **(1)** $= 1 \cdot 0 \times 10^{-9} \times 90$ **(1)** $= 9 \cdot 0 \times 10^{-8}$ J **(1)**	4	Accept potential difference = −176 − (−270) = 94 V leading to E = $9{\cdot}4 \times 10^{-8}$ J

Question			Expected response	Additional guidance
11			The whole candidate response should first be read to establish its overall quality in terms of accuracy and relevance to the problem/situation presented. There may be strengths and weaknesses in the candidate response: assessors should focus as far as possible on the strengths, taking account of weaknesses (errors or omissions) only where they detract from the overall answer in a significant way, which should then be taken into account when determining whether the response demonstrates reasonable, limited or no understanding. Assessors should use their professional judgement to apply the guidance below to the wide range of possible candidate responses.	This open-ended question requires comment on the statement "things on a small scale behave nothing like things on a large scale". Candidate responses may include one or more of: macroscopic/microscopic, duality; uncertainty; double slit; failure of Newtonian rules in the atomic world; intuition applies to large objects or other relevant ideas/concepts.
			3 marks: The candidate has demonstrated a **good** conceptual understanding of the physics involved, providing a logically correct response to the problem/situation presented. This type of response might include a statement of principle(s) involved, a relationship or equation, and the application of these to respond to the problem/situation. This does not mean the answer has to be what might be termed an "excellent' answer" or a "complete" one.	In response to this question, a **good** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one relevant physics idea/concept, in a **detailed/developed** response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • makes judgement(s) on suitability based on a range of relevant physics ideas/concepts, in a response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • otherwise demonstrates a good understanding of the physics involved.

Question			Expected response	Additional guidance
			2 marks: The candidate has demonstrated a **reasonable** understanding of the physics involved, showing that the problem/situation is understood. This type of response might make some statement(s) that is/are relevant to the problem/situation, for example, a statement of relevant principle(s) or identification of a relevant relationship or equation.	In response to this question, a **reasonable** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that is **largely correct** but has **weaknesses** which detract to a small extent from the overall response, **OR** • otherwise demonstrates a reasonable understanding of the physics involved.
			1 mark: The candidate has demonstrated a **limited** understanding of the physics involved, showing that a little of the physics that is relevant to the problem/situation is understood. The candidate has made some statement(s) that is/are relevant to the problem/situation.	In response to this question, a **limited** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that has **weaknesses** which detract to a large extent from the overall response, **OR** • otherwise demonstrates a limited understanding of the physics involved.
			0 marks: The candidate has demonstrated **no** understanding of the physics that is relevant to the problem/situation. The candidate has made no statement(s) that is/are relevant to the problem/situation.	Where the candidate has *only* demonstrated knowledge and understanding of physics **that is not relevant to the problem/situation presented,** 0 marks should be awarded.

Question			Expected response	Max mark	Additional guidance
12	a	i	$X_C = \frac{1}{2\pi fC}$ **(1)** $= \frac{1}{2\times\pi\times 65\times 5\cdot 0\times 10^{-6}}$ **(1)** $= 490\ \Omega$ **(1)**	3	Accept: 500 490 489·7
12	a	ii	$I_{rms} = \frac{V_{rms}}{X_C}$ **(1)** $= \frac{15}{490}$ **(1)** $= 3\cdot 1\times 10^{-2}$ A **(1)**	3	Accept: 3 3·1 3·06 3·061
12	b	i	Plot X_C against 1/f **(1)** Labels (quantities and units) and scale **(1)** Points plotted correctly **(1)** Correct best fit line **(1)**	4	Non-linear scale a maximum of 1 mark is available. Allow ± half box tolerance when plotting points.
12	b	ii	Gradient of best fit line **(1)** Gradient = $\frac{1}{2\pi C}$ or $C = \frac{1}{(2\pi\times \text{ gradient})}$ **(1)** Final value of C **(1)**	3	If candidates use data points not on their line of best fit, then maximum of 1 mark available. A representative gradient value of $3\cdot 13 \times 10^7$ gives a capacitance of $5\cdot 08 \times 10^{-9}$ F. Final value of C must be consistent with candidate's value for gradient.

[END OF SPECIMEN MARKING INSTRUCTIONS]

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SQ29/AH/11

Physics
Relationships Sheet

Date — Not applicable

SQ29AH11

Relationships required for Physics Advanced Higher

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

$$v = u + at$$

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

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

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\omega = \omega_o + \alpha t$$

$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_o^{\,2} + 2\alpha\theta$$

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

$$a_r = \frac{v^2}{r} = r\omega^2$$

$$F = \frac{mv^2}{r} = mr\omega^2$$

$$T = Fr$$

$$T = I\alpha$$

$$L = mvr = mr^2\omega$$

$$L = I\omega$$

$$E_K = \frac{1}{2}I\omega^2$$

$$F = G\frac{Mm}{r^2}$$

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

$$v = \sqrt{\frac{2GM}{r}}$$

$$\text{apparent brightness, } b = \frac{L}{4\pi r^2}$$

$$\text{Power per unit area} = \sigma T^4$$

$$L = 4\pi r^2 \sigma T^4$$

$$r_{Schwarzschild} = \frac{2GM}{c^2}$$

$$E = hf$$

$$\lambda = \frac{h}{p}$$

$$mvr = \frac{nh}{2\pi}$$

$$\Delta x\, \Delta p_x \geq \frac{h}{4\pi}$$

$$\Delta E\, \Delta t \geq \frac{h}{4\pi}$$

$$F = qvB$$

$$\omega = 2\pi f$$

$$a = \frac{d^2y}{dt^2} = -\omega^2 y$$

$$y = A\cos\omega t \quad \text{or} \quad y = A\sin\omega t$$

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

$$E_K = \frac{1}{2}m\omega^2(A^2 - y^2)$$

$$E_P = \frac{1}{2}m\omega^2 y^2$$

$$y = A\sin 2\pi(ft - \frac{x}{\lambda})$$

$$\phi = \frac{2\pi x}{\lambda}$$

$$\text{optical path difference} = m\lambda \quad \text{or} \quad \left(m + \frac{1}{2}\right)\lambda$$

where $m = 0, 1, 2....$

$$\Delta x = \frac{\lambda l}{2d}$$

$$d = \frac{\lambda}{4n}$$

$$\Delta x = \frac{\lambda D}{d}$$

$$n = \tan i_P$$

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$$

$$E = \frac{Q}{4\pi\varepsilon_o r^2}$$

$$V = \frac{Q}{4\pi\varepsilon_o r}$$

$$F = QE$$

$$V = Ed$$

$$F = IlB\sin\theta$$

$$B = \frac{\mu_o I}{2\pi r}$$

$$c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$$

$$t = RC$$

$$X_C = \frac{V}{I}$$

$$X_C = \frac{1}{2\pi fC}$$

$$\mathcal{E} = -L\frac{dI}{dt}$$

$$E = \frac{1}{2}LI^2$$

$$X_L = \frac{V}{I}$$

$$X_L = 2\pi fL$$

$$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$$

$$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

$$d = \bar{v}t$$

$$s = \bar{v}t$$

$$v = u + at$$

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

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

$$s = \frac{1}{2}(u + v)t$$

$$W = mg$$

$$F = ma$$

$$E_W = Fd$$

$$E_P = mgh$$

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

$$P = \frac{E}{t}$$

$$p = mv$$

$$Ft = mv - mu$$

$$F = G\frac{Mm}{r^2}$$

$$t' = \frac{t}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

$$l' = l\sqrt{1 - \left(\frac{v}{c}\right)^2}$$

$$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$$

$$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$$

$$z = \frac{v}{c}$$

$$v = H_0 d$$

$$E_W = QV$$

$$E = mc^2$$

$$E = hf$$

$$E_K = hf - hf_0$$

$$E_2 - E_1 = hf$$

$$T = \frac{1}{f}$$

$$v = f\lambda$$

$$d\sin\theta = m\lambda$$

$$n = \frac{\sin\theta_1}{\sin\theta_2}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

$$\sin\theta_c = \frac{1}{n}$$

$$I = \frac{k}{d^2}$$

$$I = \frac{P}{A}$$

$$\text{path difference} = m\lambda \quad \text{or} \quad \left(m + \frac{1}{2}\right)\lambda \quad \text{where } m = 0,\ 1,\ 2...$$

$$\text{random uncertainty} = \frac{\text{max. value - min. value}}{\text{number of values}}$$

$$V_{peak} = \sqrt{2}V_{rms}$$

$$I_{peak} = \sqrt{2}I_{rms}$$

$$Q = It$$

$$V = IR$$

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

$$R_T = R_1 + R_2 + ...$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ...$$

$$E = V + Ir$$

$$V_1 = \left(\frac{R_1}{R_1 + R_2}\right)V_S$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

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

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

Additional Relationships

Circle

$circumference = 2\pi r$

$area = \pi r^2$

Sphere

$area = 4\pi r^2$

$volume = \frac{4}{3}\pi r^3$

Trigonometry

$\sin\theta = \dfrac{opposite}{hypotenuse}$

$\cos\theta = \dfrac{adjacent}{hypotenuse}$

$\tan\theta = \dfrac{opposite}{adjacent}$

$\sin^2\theta + \cos^2\theta = 1$

Moment of inertia

point mass
$I = mr^2$

rod about centre
$I = \frac{1}{12}ml^2$

rod about end
$I = \frac{1}{3}ml^2$

disc about centre
$I = \frac{1}{2}mr^2$

sphere about centre
$I = \frac{2}{5}mr^2$

Table of standard derivatives

$f(x)$	$f'(x)$
$\sin ax$	$a\cos ax$
$\cos ax$	$-a\sin ax$

Table of standard integrals

$f(x)$	$\int f(x)dx$
$\sin ax$	$-\frac{1}{a}\cos ax + C$
$\cos ax$	$\frac{1}{a}\sin ax + C$

Electron Arrangements of Elements

Key

Atomic number Symbol Electron arrangement Name

Transition Elements

Group 1 (1)	Group 2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Group 3 (13)	Group 4 (14)	Group 5 (15)	Group 6 (16)	Group 7 (17)	Group 0 (18)
1 H 1 Hydrogen																	2 He 2 Helium
3 Li 2, 1 Lithium	4 Be 2, 2 Beryllium											5 B 2, 3 Boron	6 C 2, 4 Carbon	7 N 2, 5 Nitrogen	8 O 2, 6 Oxygen	9 F 2, 7 Fluorine	10 Ne 2, 8 Neon
11 Na 2, 8, 1 Sodium	12 Mg 2, 8, 2 Magnesium											13 Al 2, 8, 3 Aluminium	14 Si 2, 8, 4 Silicon	15 P 2, 8, 5 Phosphorus	16 S 2, 8, 6 Sulphur	17 Cl 2, 8, 7 Chlorine	18 Ar 2, 8, 8 Argon
19 K 2, 8, 8, 1 Potassium	20 Ca 2, 8, 8, 2 Calcium	21 Sc 2, 8, 9, 2 Scandium	22 Ti 2, 8, 10, 2 Titanium	23 V 2, 8, 11, 2 Vanadium	24 Cr 2, 8, 13, 1 Chromium	25 Mn 2, 8, 13, 2 Manganese	26 Fe 2, 8, 14, 2 Iron	27 Co 2, 8, 15, 2 Cobalt	28 Ni 2, 8, 16, 2 Nickel	29 Cu 2, 8, 18, 1 Copper	30 Zn 2, 8, 18, 2 Zinc	31 Ga 2, 8, 18, 3 Gallium	32 Ge 2, 8, 18, 4 Germanium	33 As 2, 8, 18, 5 Arsenic	34 Se 2, 8, 18, 6 Selenium	35 Br 2, 8, 18, 7 Bromine	36 Kr 2, 8, 18, 8 Krypton
37 Rb 2, 8, 18, 8, 1 Rubidium	38 Sr 2, 8, 18, 8, 2 Strontium	39 Y 2, 8, 18, 9, 2 Yttrium	40 Zr 2, 8, 18, 10, 2 Zirconium	41 Nb 2, 8, 18, 12, 1 Niobium	42 Mo 2, 8, 18, 13, 1 Molybdenum	43 Tc 2, 8, 18, 13, 2 Technetium	44 Ru 2, 8, 18, 15, 1 Ruthenium	45 Rh 2, 8, 18, 16, 1 Rhodium	46 Pd 2, 8, 18, 18, 0 Palladium	47 Ag 2, 8, 18, 18, 1 Silver	48 Cd 2, 8, 18, 18, 2 Cadmium	49 In 2, 8, 18, 18, 3 Indium	50 Sn 2, 8, 18, 18, 4 Tin	51 Sb 2, 8, 18, 18, 5 Antimony	52 Te 2, 8, 18, 18, 6 Tellurium	53 I 2, 8, 18, 18, 7 Iodine	54 Xe 2, 8, 18, 18, 8 Xenon
55 Cs 2, 8, 18, 18, 8, 1 Caesium	56 Ba 2, 8, 18, 18, 8, 2 Barium	57 La 2, 8, 18, 18, 9, 2 Lanthanum	72 Hf 2, 8, 18, 32, 10, 2 Hafnium	73 Ta 2, 8, 18, 32, 11, 2 Tantalum	74 W 2, 8, 18, 32, 12, 2 Tungsten	75 Re 2, 8, 18, 32, 13, 2 Rhenium	76 Os 2, 8, 18, 32, 14, 2 Osmium	77 Ir 2, 8, 18, 32, 15, 2 Iridium	78 Pt 2, 8, 18, 32, 17, 1 Platinum	79 Au 2, 8, 18, 32, 18, 1 Gold	80 Hg 2, 8, 18, 32, 18, 2 Mercury	81 Tl 2, 8, 18, 32, 18, 3 Thallium	82 Pb 2, 8, 18, 32, 18, 4 Lead	83 Bi 2, 8, 18, 32, 18, 5 Bismuth	84 Po 2, 8, 18, 32, 18, 6 Polonium	85 At 2, 8, 18, 32, 18, 7 Astatine	86 Rn 2, 8, 18, 32, 18, 8 Radon
87 Fr 2, 8, 18, 32, 18, 8, 1 Francium	88 Ra 2, 8, 18, 32, 18, 8, 2 Radium	89 Ac 2, 8, 18, 32, 18, 9, 2 Actinium	104 Rf 2, 8, 18, 32, 32, 10, 2 Rutherfordium	105 Db 2, 8, 18, 32, 32, 11, 2 Dubnium	106 Sg 2, 8, 18, 32, 32, 12, 2 Seaborgium	107 Bh 2, 8, 18, 32, 32, 13, 2 Bohrium	108 Hs 2, 8, 18, 32, 32, 14, 2 Hassium	109 Mt 2, 8, 18, 32, 32, 15, 2 Meitnerium									

Lanthanides	57 La 2, 8, 18, 18, 9, 2 Lanthanum	58 Ce 2, 8, 18, 20, 8, 2 Cerium	59 Pr 2, 8, 18, 21, 8, 2 Praseodymium	60 Nd 2, 8, 18, 22, 8, 2 Neodymium	61 Pm 2, 8, 18, 23, 8, 2 Promethium	62 Sm 2, 8, 18, 24, 8, 2 Samarium	63 Eu 2, 8, 18, 25, 8, 2 Europium	64 Gd 2, 8, 18, 25, 9, 2 Gadolinium	65 Tb 2, 8, 18, 27, 8, 2 Terbium	66 Dy 2, 8, 18, 28, 8, 2 Dysprosium	67 Ho 2, 8, 18, 29, 8, 2 Holmium	68 Er 2, 8, 18, 30, 8, 2 Erbium	69 Tm 2, 8, 18, 31, 8, 2 Thulium	70 Yb 2, 8, 18, 32, 8, 2 Ytterbium	71 Lu 2, 8, 18, 32, 9, 2 Lutetium
Actinides	89 Ac 2, 8, 18, 32, 18, 9, 2 Actinium	90 Th 2, 8, 18, 32, 18, 10, 2 Thorium	91 Pa 2, 8, 18, 32, 20, 9, 2 Protactinium	92 U 2, 8, 18, 32, 21, 9, 2 Uranium	93 Np 2, 8, 18, 32, 22, 9, 2 Neptunium	94 Pu 2, 8, 18, 32, 24, 8, 2 Plutonium	95 Am 2, 8, 18, 32, 25, 8, 2 Americium	96 Cm 2, 8, 18, 32, 25, 9, 2 Curium	97 Bk 2, 8, 18, 32, 27, 8, 2 Berkelium	98 Cf 2, 8, 18, 32, 28, 8, 2 Californium	99 Es 2, 8, 18, 32, 29, 8, 2 Einsteinium	100 Fm 2, 8, 18, 32, 30, 8, 2 Fermium	101 Md 2, 8, 18, 32, 31, 8, 2 Mendelevium	102 No 2, 8, 18, 32, 32, 8, 2 Nobelium	103 Lr 2, 8, 18, 32, 32, 9, 2 Lawrencium