Government of **Western Australia**
School Curriculum and Standards Authority

PHYSICS

Stage 2

WACE Examination 2014

Marking Key

Marking keys are an explicit statement about what the examiner expects of candidates when they respond to a question. They are essential to fair assessment because their proper construction underpins reliability and validity.

Section One: Short answers **40% (66 marks)**

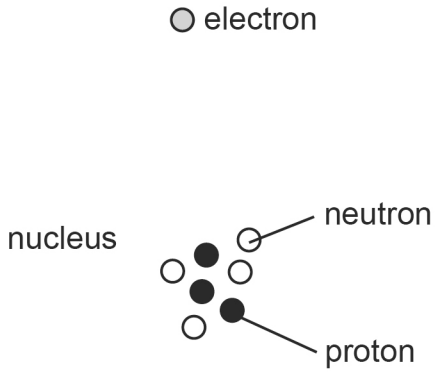
Question 1 **(4 marks)**

A farmer walked 745 m west from a gate to repair a fence post. When that job was finished he turned around and walked 984 m east to repair another part of the fence. Draw and label a vector diagram of his total journey then calculate his resultant displacement.

Description	Marks
745 m 984 m Labels 1 Direction 1	1–2
984 – 745 = 239 east	1–2
Total	**4**

Question 2 **(4 marks)**

Using the lithium-7 atom as the example, draw a labelled diagram to represent the model of the atom.

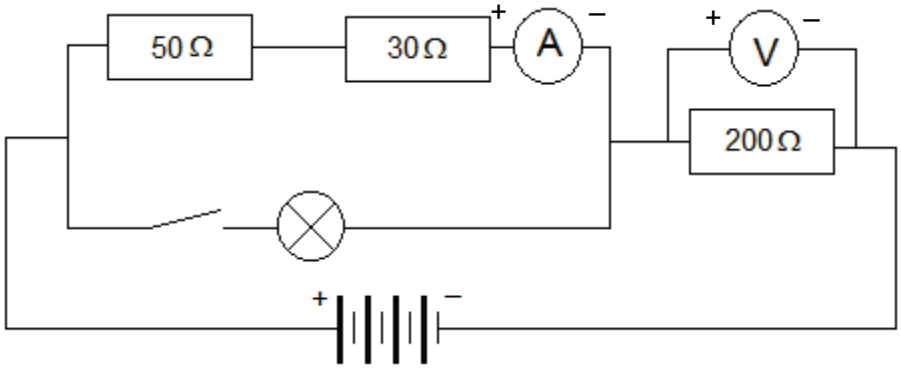


Description	Marks
Protons and neutrons in nucleus and electrons around nucleus	1
3 protons and 3 electrons	1
4 neutrons	1
Labels for proton, neutron, electron and nucleus	1
Doesn't need to be to scale If student draws x protons, y neutrons and x electrons, maximum 2 marks	
Total	**4**

Question 3 **(5 marks)**

To the circuit diagram below, add:

- an ammeter to measure the current through the 50 Ω resistor, indicating which connection is positive and which is negative
- a voltmeter to measure the potential difference across the 200 Ω resistor, indicating which connection is positive and which is negative
- a switch to allow the lamp to be turned on and off without switching the rest of the circuit on or off.



Description	Marks
Ammeter and voltmeter correctly placed, polarities correct	1–4
Switch correctly placed	1
Total	**5**

Question 4 **(3 marks)**

The fusion of deuterium and tritium to form helium can be represented by the equation:

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + ^{1}_{0}\mathrm{n}.$$

If the mass defect for this reaction is 0.0189 u, calculate the energy released, in joules, in one such fusion reaction.

Description		Marks
Mass defect in kg $0.0189 \times 1.66 \times 10^{-27}$ $= 3.137 \times 10^{-29}$ kg	**or** E = m × 931 = 17.59 MeV	1
$E = mc^2$ $= 3.137 \times 10^{-29} \times (3 \times 10^{8})^2$	$= 17.59 \times 10^{6} \times 1.6 \times 10^{-19}$	1
$= 2.82 \times 10^{-12}$	$= 2.82 \times 10^{-12}$	1
	Total	**3**

Question 5 **(3 marks)**

(a) Will the spheres attract or repel each other? Circle the correct response: (1 mark)

Attract Repel

Description	Marks
Attract	1
Total	**1**

(b) (i) The student touched the spheres together, and they then moved apart. Determine the overall charge, in coulombs, on the pair of spheres after they were touched together. (1 mark)

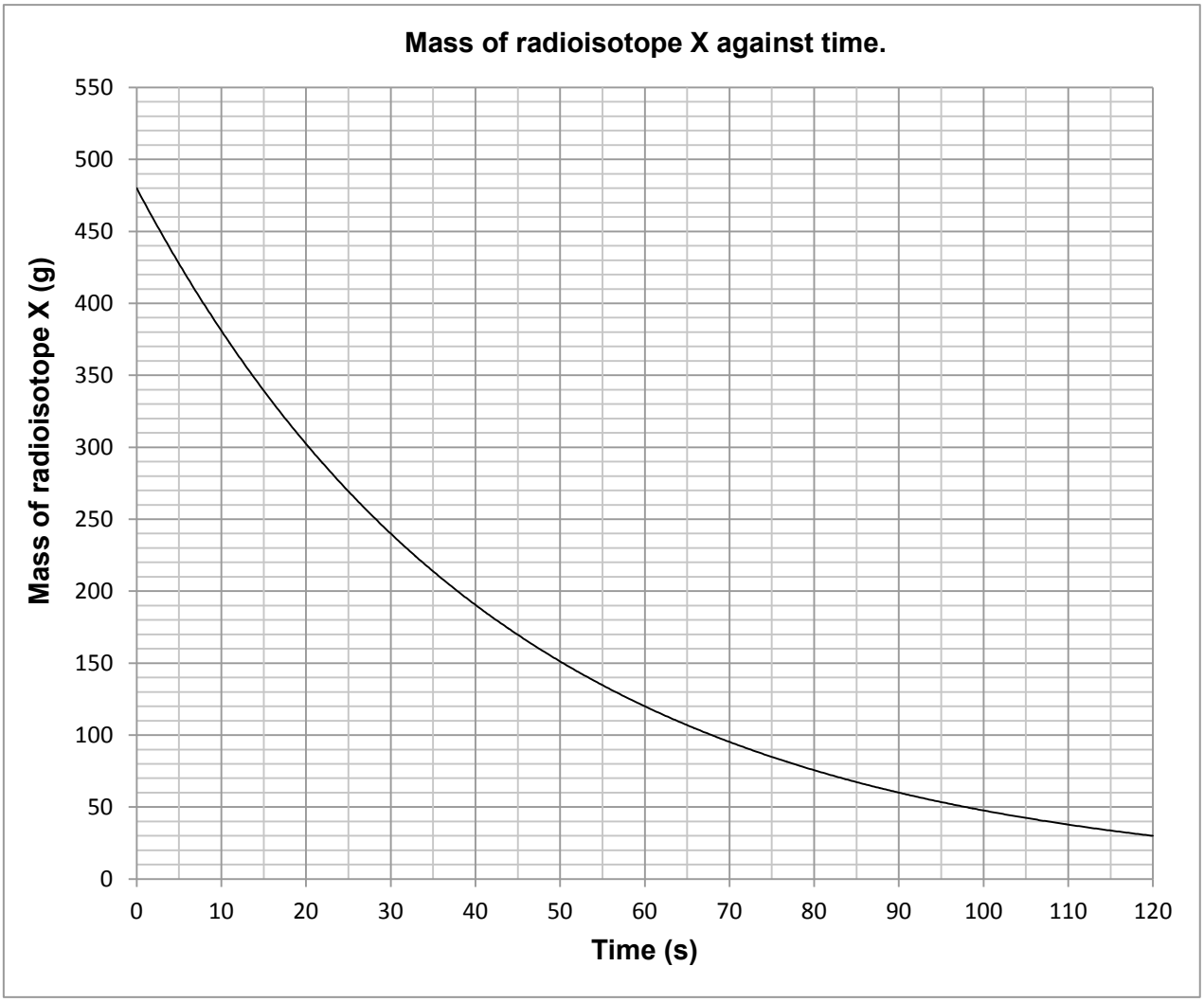
Description	Marks
-3.0 mC + 6.0 mC = +3.0 mC	1
Total	**1**

(ii) Determine the charge on each sphere after they had separated. (1 mark)

Description	Marks
Charge is shared between each sphere so A = B = +1.5 mC Positive sign not required for full marks.	1
Total	**1**

Question 6 **(3 marks)**

Radioisotope X has a half-life of 30 s. Given an initial mass of 480 g of pure X, draw a graph of the mass of X present between time = 0 and time = 120 s.



Description	Marks
Obvious curve clearly shown starting at 480	1
Mass at 30 s is about 240 g Mass at 120 s is about 30 g	1–2
Total	**3**

Question 7 **(4 marks)**

(a) Calculate the current, in amperes, between the cloud and the ground. (2 marks)

Description	Marks
$q = 1.50 \times 10^{20} \times 1.6 \times 10^{-19}$ $= 24$ C	1
$I = q/t$ $= 24 / 0.200$ $I = 120$	1
Total	**2**

(b) If the potential difference between the storm cloud and the Earth was 7.00×10^8 V, calculate the energy, in joules, that was released by the lightning during the strike. (2 marks)

Description	Marks
$E = P \times t$ $= VIt$ $= 7.00 \times 10^8 \times 120 \times 0.2$	1
$E = 1.68 \times 10^{10}$	1
Total	**2**

Question 8 **(4 marks)**

A runway at a small airport is 1220 m long. A light aircraft accelerates at 0.785 m s^{-2} along this runway, starting at one end and taking off 200 m before reaching the other end. If the aircraft was initially stationary, calculate its speed when it took off. Show **all** workings, and give the appropriate unit.

description	Marks
$s = 1220 - 200 = 1020$ m	1
$v^2 = u^2 + 2as$ $v^2 = 0 + (2 \times 0.785 \times 1020) = 1601.4$	1
$v = 40.0$	1
m s^{-1}	1
Total	**4**

Question 9 **(4 marks)**

(a) Circle the correct response. (1 mark)

When the lamps are turned on,

Lamp A is brighter than Lamp B.	the lamps are the same brightness.	Lamp B is brighter than Lamp A.

Description	Marks
Lamp A is brighter than Lamp B	1
Total	**1**

(b) Explain your answer to Part (a) with reference to Ohm's Law. (3 marks)

Description	Marks
The long extension cord will have a resistance and so Lamp B is effectively in series with a non-zero resistor so total resistance greater.	1
V = IR with the same V, if R is increased then I decreases	1
As current determines the brightness of the lamp, lower current means Lamp B is dimmer. Students may also discuss power	1
Total	**3**

Question 10 **(3 marks)**

In a uranium mine the workers are lowered into the mine shaft in an enclosed metal lift. If alpha, beta and gamma radiation are all emitted by the rocks around the lift shaft, state the main radiation type or types the workers are exposed to inside the lift. Justify your answer.

Description	Marks
Gamma radiation	1
The metal will block all of the alpha and most of the beta radiation therefore only the gamma radiation can pass through the metal	1–2
Total	**3**

Question 11 **(4 marks)**

State whether each of the following statements is true or false.

	Statement	True or False
A	When a nucleus is unstable it decays to emit alpha, beta and gamma radiation all at the same time.	
B	Ionising radiation causes an atom to lose a proton and thus become charged.	
C	Solar energy is produced by nuclear fusion reactions.	
D	Binding energy is the energy needed to bind atoms to each other.	

	Description	Marks
A	False	1
B	False	1
C	True	1
D	False	1
	Total	**4**

Question 12 **(4 marks)**

The temperature measured by the thermometer is _____ ºC.

The uncertainty is _____ ºC.

The length of the metal strip measured by the ruler is _____ cm

The uncertainty is _____ cm

Description	Marks
33.0 ºC or 33 ºC	1
$\pm$ 0.5	1
7.2	1
$\pm$ 0.05 or $\pm$ 0.1	1
Total	**4**

Question 13 **(3 marks)**

On a hot day, Sam stepped off a bridge into the water below. Using the idea of conservation of energy, calculate Sam's speed, in metres per second, when he reached the water 3.40 m below. Show **all** workings.

Description	Marks
E_p lost = E_k gained $mgh = ½ mv^2$ m cancels $gh = ½ v^2$ $v = \sqrt{2gh}$ $v = \sqrt{(2 \times 9.8 \times 3.40)}$	1–2
v = 8.16 or 8.2 or 8.1	1
Total	**3**

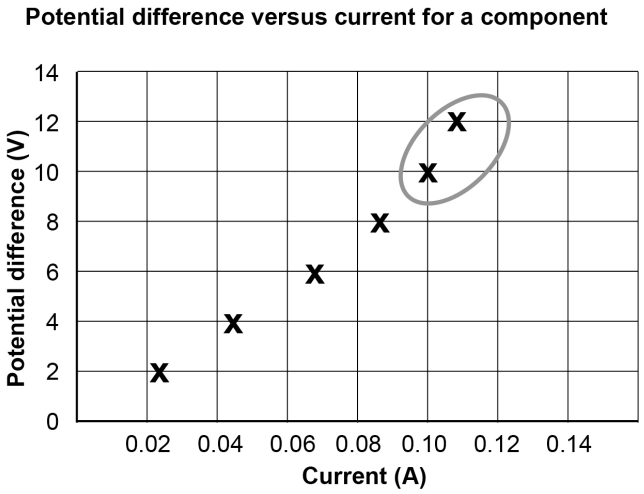
Question 14 **(3 marks)**

When you walk across a bridge you sometimes see expansion joints. These are gaps between the different parts of the bridge. On hot, sunny days these gaps are narrower than on cold winter days. Use your understanding of the kinetic theory to explain why this is so.

Description	Marks
The reason objects expand is as they heat up the atoms having more kinetic energy and therefore vibrate more and take up more space.	1–2
When a solid is heated (particularly a metal) it increases in size	1
Total	**3**

Question 15 **(3 marks)**

On the graph circle the section that shows the component acting as a non-ohmic resistor. Justify your answer.



Description	Marks
Identifies section by circling two or more crosses.	1
If an ohmic component with a constant resistance, V is proportional to I a straight line graph is produced. Crosses at the top curved so not proportional so must be a non-ohmic section	1–2
Total	**3**

Question 16 **(4 marks)**

A worker with a mass of 85.5 kg was involved in a nuclear accident and received 9.55 J of radioactive energy from an alpha source. Calculate the dose equivalent the worker received. Include the correct unit in your answer. Show **all** workings.

Description	Marks
Absorbed dose = energy / mass = 9.55 / 85.5 = 0.112 Gy	1–2
Dose equivalent = absorbed dose × quality factor = 0.112 × 20 = 2.23	1
Sv	1
Total	**4**

Question 17 **(3 marks)**

Explain, using your understanding of one of Newton's laws, how the padding reduces injury to the batsman's leg if it is hit by a cricket ball.

Description	Marks
Relates to Newton's Second Law, Ft = mv - mu	1
Change in momentum, mv – mu, is constant	1
Padding increases the time over which the change in momentum occurs thus decreasing force on shin	1
Total	**3**

Question 18 **(5 marks)**

(a) Do the arrows on the diagram indicate conventional current or electron current? Circle the correct response. (1 mark)

Conventional current Electron current

Description	Marks
electron current	1
Total	**1**

(b) Calculate the current, in amperes, in the ammeter shown in the circuit diagram above. Show **all** workings. (4 marks)

Description	Marks
150 + 100 = 250 $\frac{1}{R_p} = \frac{1}{250} + \frac{1}{150}$ $R_p = 93.75$	1–2
$R_T = 93.75 + 50$ $= 143.75$	1
I = V/R = 12/143.7 = 0.0835	1
Total	**4**

Section Two: Problem-solving **50% (87 Marks)**

Question 19 **(16 marks)**

(a) When the sliding contact is in contact with Point A only, is the circuit a series or parallel circuit? Circle the correct response: (1 mark)

Series Parallel

Description	Marks
Series	1
Total	**1**

(b) When the sliding contact is in contact with both Points A and B, is the circuit a series or parallel circuit? Circle the correct response: (1 mark)

Series Parallel

Description	Marks
Parallel	1
Total	**1**

(c) The siren has a resistance of 3.00 Ω. If the circuit is powered by a 9.00 V battery, calculate the current, in amperes, when only the siren is operating. (2 marks)

Description	Marks
$I = V \div R$ $= 9 / 3$	1
3.00	1
Total	**2**

(d) When both the lamp and the siren are on, the current supplied by the battery is 1.5 times higher than when the siren is on by itself.

(i) Determine the current, in amperes, in the operating lamp. (3 marks)

Description	Marks
Total current is 1.5 × 3 = 4.5 A	1
Current through lamp 4.5 – 3.0 = 1.50	2
Total	**3**

(ii) Calculate the resistance, in ohms, of the operating lamp. (2 marks)

Description	Marks
R = V ÷ I = 9.00 / 1.50	1
R = 6.00	1
Total	**2**

(e) The contact is first placed so that only the lamp comes on. The contact is then moved so that only the siren comes on. Which of these two components has the greater power consumption? Explain. (4 marks)

Description	Marks
siren	1
Potential difference (V) is the same for each of the components	1
P = VI so if 'V' is the same, P $\propto$ I The siren has the larger current therefore draws the greater power	1–2
Total	**4**

(f) Calculate the total power drawn from the battery when both components are switched on. Include the correct unit in your answer. (3 marks)

Description	Marks
P = VI = 9.00 × 4.5	1
40.5	1
W	1
Total	**3**

Question 20 **(18 marks)**

(a) Define the term 'internal energy'. (2 marks)

Description	Marks
In a closed system (the tea in the cup) internal energy is the sum of the potential and kinetic energies of the particles.	1–2
Total	**2**

(b) Calculate the heat energy lost to the environment as 0.250 kg of tea in the cup cooled down from 90.0 ºC to 65.0 ºC. Assume that the specific heat capacity of tea is the same as that for water. (2 marks)

Description	Marks
$\Delta T = 90 - 65 = 25$ $Q = mc\Delta T$ $= 0.25 \times 4.18 \times 10^3 \times 25$ $Q = 2.61 \times 10^4$ J	1–2
Total	**2**

(c) Use the kinetic theory to explain why blowing on the surface of the tea helps the tea to cool down quickly. (5 marks)

Description	Marks
Blowing removes the hot saturated air from above the tea	1
This allows more water to evaporate into the air	1
The process of evaporation removes energy from the tea	1
Causing the average kinetic energy to decrease	1
and hence the temperature decreases	1
Total	**5**

On hot days, Pat makes ice tea by adding ice cubes at 0.00 ºC to the pot of freshly brewed tea, cooling it from 90.0 º to 0.00 ºC.

(d) If the amount of liquid in the teapot was 0.250 kg, calculate the difference in internal energy between tea at 90.0 °C and iced tea at 0.00 °C. (2 marks)

Description	Marks
Difference in temperature is 90.0° $Q = mc\Delta T$ $= 0.250 \times 4.18 \times 10^3 \times 90.0$	1
$Q = 9.41 \times 10^4$ J	1
Total	**2**

(e) Calculate the mass of ice, in kilograms, that has to be added to the tea in the pot in Part (d) to bring the temperature of the liquid down to 0.00 ºC. Assume no loss of heat to the surroundings, and show **all** workings. (4 marks)

Description	Marks
Energy lost from the tea = $0.25 \times 4.18 \times 10^3 \times 90$ (from part (d)) = 94050 J	1
Energy absorbed by ice, Q = 94050 J	1
Q = mL m = Q ÷ L = $94050 \div 3.34 \times 10^5$	1
m = 0.282 kg	1
Total	**4**

(f) In the real world, Pat would not need to add as much ice to the tea as calculated in Part (e) above. Using your understanding of heat transfer, explain why this is so. (3 marks)

Description	Marks
Energy would be lost to the environment Conduction to the cup/radiation/convection to the air	1–2
So not as much energy needs to be absorbed by the ice	1
Total	**3**

Question 21 **(13 marks)**

(a) An isotope of thorium decays to form radium-228 and an alpha particle.

(i) Write the nuclear equation to represent this decay. (2 marks)

Description	Marks
$^{232}_{90}Th \rightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$	1–2
Total	**2**

(ii) State the atomic number and mass number of the thorium isotope. (2 marks)

Atomic number: 90

Mass number: 232

Description	Marks
Atomic number = 90	1
Mass number = 232	1
Total	**2**

(b) Radium-228 is an isotope of radium. Define the term 'isotope'. (2 marks)

Description	Marks
Same number of protons	1
Different mass number or number of neutrons	1
Total	**2**

(c) The radium-228 paint on a pilot's instruments had an initial activity of 140 kBq. If the half-life of radium-228 is 5.80 years determine the activity in kBq of the radium on the instruments, 52.2 years later. Show **all** workings. (3 marks)

Description	Marks
Number of half-lives = $52.2 \div 5.8 = 9$	1
$A = A_0 (0.5)^n$ $= 140 \times (0.5)^9$	1
$A = 0.273$ kBq	1
Total	**3**

(d) Alpha particles, $^4_2\alpha$, are often emitted during the decay of radium. An alpha particle is similar in structure to a helium nucleus. Determine the binding energy, in MeV, of a helium nucleus. Use the information in your **Formulae and Data Booklet**, and show **all** workings.

Description	Marks
Helium nucleus has 2 protons and 2 neutrons $(4 \times 1.67 \times 10^{-27}) - 6.64 \times 10^{-27}$ 4.00×10^{-29}	1–2
$4.00 \times 10^{-29} / 1.66 \times 10^{-27}$ $= 0.02410$ u	1
0.0241×931 $= 22.4$	1
Total	**4**

Question 22 **(12 marks)**

(a) The heater in the dishwasher draws half the total current to heat the water during the washing cycle. Determine the power rating of the heater, including the correct unit. Show **all** workings. (3 marks)

Description	Marks
P = VI 240 × 6.00	1
1.44×10^3	1
W	1
Total	**3**

(b) During the washing cycle, the dishwasher heats 6.50 kg of water from 15.0 ºC to 90.0 ºC. Using your answer from Part (a) above, calculate the time taken to heat the water. If you were unable to calculate a value for the power in Part (a), use a value of 1.50×10^3. Show **all** workings. (4 marks)

Description	Marks
E = Q = mcΔT = 6.50 × 4180 × (90 – 15)	1
E = Q = 2 037 750 J	1
P = E/t So t = E/P t = 2 037 750 / 1.44×10^3 = 1415	1
1.42×10^3 s (23.6 minutes)	1
Alternative answer: 1.36×10^3 (22.6 minutes)	
Total	**4**

(c) In reality, the time taken to heat the water is longer than the time calculated in part (b). Suggest **two** reasons why this is so. (2 marks)

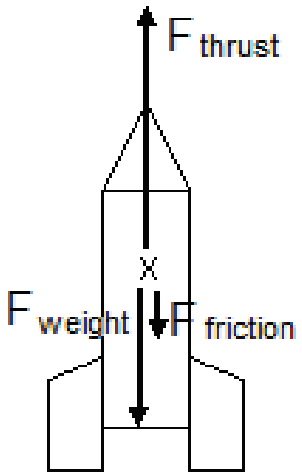
Description	Marks
Not all the electrical energy is converted into heat energy	1
Heat energy is lost to the dishes and metal of the dishwasher	1
Or any other reasonable reason	
Total	**2**

(d) Occasionally a piece of toast will get caught in the toaster. Explain why it is dangerous to use a metal knife to remove this toast without first turning off the toaster. (3 marks)

Description	Marks
If the toaster is still on, the knife may touch a 'live' part of the circuit	1
The metal knife would then act as a path for the current to pass from the toaster to the user	1
This could cause serious injuries such as burns, heart attack, etc	1
Total	**3**

Question 23 **(18 marks)**

(a) Draw labelled vector arrows from point X on the rocket to show all the forces acting on the rocket in the first 1.80 s of flight. Include any frictional forces. The length of each arrow should represent the approximate magnitude of the force acting. (5 marks)



Description	Marks
F thrust upwards	1
F friction downwards	1
F weight downwards	1
Length upwards arrow longer than combined length of downward arrows.	1
Appropriate labels	1
Total	**5**

(b) The net acceleration of the rocket is affected by the thrust of the engine and the force of gravity. Calculate the acceleration of the rocket just before its engine stops working. Ignore any other forces acting on the rocket, and show **all** workings. (4 marks)

Description	Marks
$a_{rocket} = F_{engine} \div m_{rocket}$ $= 8.50 \div 0.650$	1
$a_{rocket} = 13.08$	1
Acceleration up subtract gravity down 13.1 – 9.8	1
3.28	1
Total	**4**

(c) Calculate the height, in metres, reached by the rocket at the moment when the engine stops working. If you were unable to calculate an answer to Part (b), use an acceleration value of 3.00 m s^{-2}. (2 marks)

Description	Marks
$s = ut + ½ at^2$ but as u = 0 $s = ½ at^2$ $s = 0.5 \times 3.28 \times 1.80^2$	1
s = 5.31	1
Alternative answer 4.86	
Total	**2**

(d) Calculate the velocity in metres per second of the rocket, 1.80 s after the engine starts. If you could not calculate an answer to Part (b), use an acceleration of 3.00 m s^{-2} upward. Show **all** workings. (3 marks)

Description		Marks
Let up be positive. $v^2 = u^2 + 2as$ $v^2 = 0 + (2 \times 3.28 \times 5.31)$ $= 34.83$	Alternative answer Let up be positive. $v^2 = u^2 + 2as$ $v^2 = 0 + (2 \times 3.00 \times 4.86)$ $= 29.16$	1–3
v = 5.90	v = 5.40	
Total		**3**

(e) Calculate the maximum height, in metres, reached by the rocket. Show **all** workings. (4 marks)

(Hint: When calculating the displacement of the rocket after the engine stops working, use the velocity you calculated in Part (d) above as an initial velocity.)

Description	Marks
$v^2 = u^2 + 2as$ $0 = (5.91)^2 + (2 \times -9.8 \times s)$ $0 = 34.83 + (-19.6s)$ $34.83 = 19.6s$	1–2
s = 1.78 m	1
s total = 5.35 + 1.78 = 7.13	1
Total	**4**

Question 24 **(10 marks)**

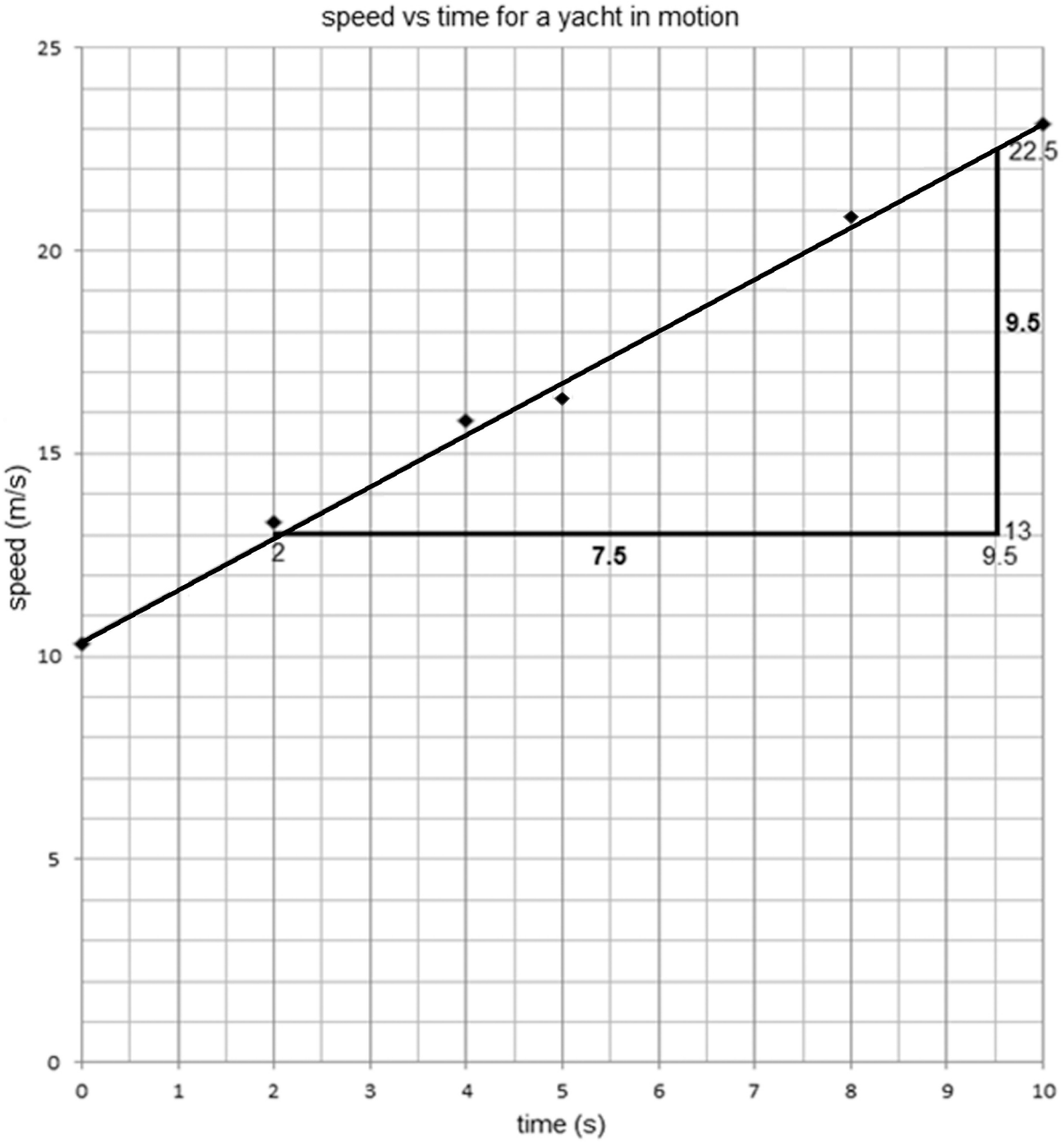
(a) Given that 1 knot equals 0.5144 m s^{-1}, complete the third column of the table below to three significant figures. (2 marks)

Time (s)	speed in knots	speed in m s^{-1}
0	20.0	10.3
2.00	25.9	13.3
4.00	30.7	**15.8**
5.00	31.9	**16.4**
8.00	40.4	20.8
10.0	45.0	23.1

Description	Marks
Values correct in third column	1
All answers to three significant figures	1
Total	**2**

(b) Using the grid on page 29, plot a graph of speed (in m s^{-1}) against time and draw a straight line of best fit. (4 marks)

Description	Marks
Time on the x-axis	1
Axis labelled with units	1
Points clearly shown and plotted correctly	1
Line of best fit drawn	1
Total	**4**



(c) Calculate the gradient of the line of best fit, including the correct units. Show **all** workings. (4 marks)

Description	Marks
gradient taken from line of best fit and not data points	1
Gradient = 9.5 / 7.5 = 1.3 range 1.2 to 1.4	1–2
m s^{-2}	1
Total	**4**

End of Section Two

Section Three: Comprehension **10% (18 marks)**

Question 25

(a) In steam locomotives, the energy from burning coal heats the water and converts it into steam. Using the kinetic theory of matter, explain the process involved in converting water into steam. (3 marks)

Description	Marks
Water (liquid phase) particles close together strong attractive forces	1
Adding heat increases vibration of particles	1
Particles move much further apart to become steam (gas phase)	1
Total	**3**

(b) Calculate the horsepower required to keep a train moving at 40 km h^{-1} if the engine provides a driving force of 1.45×10^5 N. Show **all** workings. (4 marks)

Description	Marks
$40 / 3.6 = 11.1$ m s^{-1}	1
$P = Fv$ $= 1.45 \times 10^5 \times 11.1 = 1611111$	1
P in horsepower = 522000 / 746	1
2.16×10^3	1
Total	**4**

(c) Calculate the momentum of an electric train travelling at 30.0 m s^{-1} (108 km h^{-1}). Include the correct units in your answer. Show **all** workings. (4 marks)

Description	Marks
$120 \times 1000 = 1.2 \times 10^5$ kg	1
$p = mv$ $= 1.2 \times 10^5 \times 30 = 3.60 \times 10^6$	1
Direction given, e.g. 'forward'	1
kg m s^{-1} or N s	1
Total	**4**

(d) The energy released when 240.0 kg of coal burns can power one 60 W lamp continuously for one year. Calculate the mass, in tonnes, of coal required to power five hundred (500), 60 W lamps for one year. Show **all** workings. (2 marks)

Description	Marks
$500 \times 240 = 120\,000$ (kg)	1
120 (tonnes)	1
Total	**2**

(e) When the two 120 tonne electric trains collided at the depot, Train A was travelling at 3.40 m s^{-1} north, while Train B was travelling at 2.20 m s^{-1} south. After the crash, Train B rebounded to be travelling at 3.00 m s^{-1} north. Assuming that momentum was conserved in this collision, calculate the speed, in metres per second, and the direction of Train A after the collision. Show **all** workings. (5 marks)

Description	Marks
Let north be positive south be negative $\Sigma p_i = \Sigma p_f$ $m_A u_A + m_B u_B = m_A v_A + m_B v_B$ $(120 \times 10^3 \times 3.40) + (120 \times 10^3 \times -2.20)$ $= (120 \times 10^3 \times v_A) + (120 \times 10^3 \times 3.00)$	1–2
$4.08 \times 10^5 - 2.64 \times 10^5 = 1.20 \times 10^5 v_A + 3.60 \times 10^5$	1
$V_A = -2.16 \times 10^5 \div 1.20 \times 10^5$ $= -1.80$ (full marks for 1.80)	1
south	1
Total	**5**

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