Name:	
School:	

Total Mark	

BPhO British Physics Olympiad

Physics Challenge 2012-13

Time allowed: 1 hour

Attempt all questions

Write your answers on this question paper

You may use a calculator

Assume the gravitational field strength has a value of **10 N / kg**

Section A: Ten multiple choice questions worth 1 mark each (worth 10 marks in total)
Allow about 15 minutes for this section

Section B: Two short answer questions (worth 8 marks in total)
Questions require a clear explanation of the underlying physical principles
Allow about 10 minutes for this section

Section C: Longer answer questions requiring calculations (worth 32 marks in total)
Questions may be set on unfamiliar topics. Additional information necessary to answer the question will be given in the question
Allow 35 minutes for this section

Total 50 marks; mark allocations for each sub-section are shown in brackets

Section A: Multiple Choice Answers

Write the correct letter in the grid. The first column has been done as an example if the answer to question zero were C

Question	0	1	2	3	4	5	6	7	8	9	10
Answer	C										

Section A: Multiple Choice Questions

1. Which of the following is NOT a unit of energy?

A. Calorie
B. Joule per second
C. Kilowatt hour
D. Kilogram meter squared per second squared
E. Newton meter

2. The masses and dimensions of four samples of metal were measured. The results are shown below:

Sample	Dimensions (cm)	Mass (g)
i	2.0 x 2.0 x 2.0	40
ii	2.0 x 2.0 x 4.0	160
iii	2.0 x 4.0 x 4.0	160
iv	4.0 x 4.0 x 4.0	80

The two samples that could be the same material are:

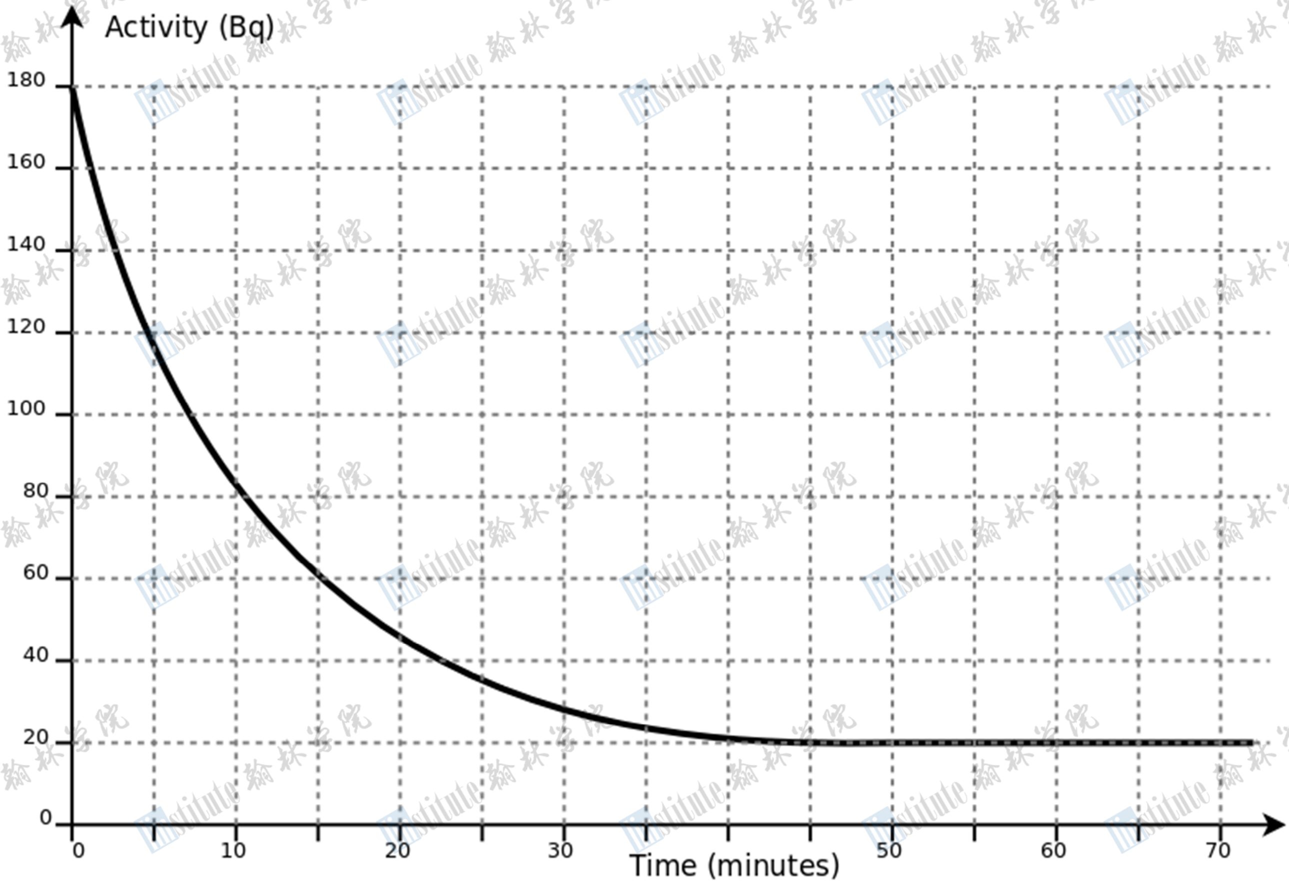
A. i and ii
B. i and iii
C. i and iv
D. ii and iii
E. ii and iv

3. In an experiment to investigate static electricity, two objects were found to attract each other.

One possible explanation for this is:

A. Both objects were positively charged
B. Both objects were negatively charged
C. Both objects were uncharged
D. One object was positively charged and the other was uncharged
E. One object was plastic and the other was metal

4. The graph shows how the activity of a radioactive sample changes over time.



The half-life of the sample is approximately:

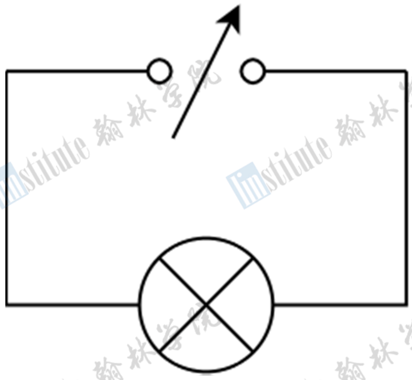
A. 5 minutes
B. 7.5 minutes
C. 9 minutes
D. 15 minutes
E. 40 minutes

5. In Rutherford's famous alpha particle scattering experiment, small positively charged sub-atomic particles called alpha particles were fired at a very thin sheet of gold foil. Most of the alpha particles passed straight through the gold foil as expected but, much to Rutherford's surprise, some of the alpha particles bounced off the gold foil at large angles.

The results of this experiment suggest that:

A. Atoms have a small dense nucleus
B. Atoms contain charged particles
C. Atoms have orbiting electrons
D. Atoms are small hard spherical objects
E. Gold can be used to make effective mirrors

6. The circuit shows a filament lamp connected to a variable power supply.
The lamp can work at any voltage up to 18 V without damage.



When the bulb is operated at a voltage of 6 V it dissipates a power of 12 W
When the voltage is increased to 12 V, the power dissipated will be:

A. 12 W
B. Between 12 W and 24 W
C. 24 W
D. Between 24 W and 48 W
E. 48 W

7. A 2.0 kW electric heater is used for 3 hours.
The total energy dissipated by the heater during this time period is:

A. 6 joules
B. 360 joules
C. 6,000 joules
D. 360,000 joules
E. 22,000,000 joules

8. A swimmer dives into a completely calm 25 m long swimming pool.
The ripple from the dive travels across the surface of the pool at 2.5 m/s, reflects off the far end and travels back down the pool to meet the swimmer.
After diving in at the end, the swimmer swims at a steady speed that would take him 20 seconds to swim the length of the pool.
The swimmer and the returning ripple meet when the swimmer has travelled approximately:

A. 10 m
B. 12.5 m
C. 17 m
D. 20 m
E. 25 m

9. An archery bow is pulled back 80 cm with an **average** force of 300N. An arrow of mass 50g is released from the bow. Assuming 60% the work done in pulling back the bow is transferred to the arrow as kinetic energy, the speed of the arrow will be approximately:

A. 2.4 m/s
B. 76 m/s
C. 98 m/s
D. 170 m/s
E. 5800 m/s

10. The time period for **one** oscillation of a long swinging pendulum is to be determined. The time is to be measured using a hand held stopwatch with a precision of $1/100^{th}$ of a second. The time period is known to be about 2 seconds.
Which of the following measurement techniques best reduces the uncertainty on the measured value of the time period?

A. Measuring the time for 10 swings and dividing the result by 10.
B. Measuring the time for 1 swing 10 times and taking an average.
C. Using a stopwatch that measures with a precision of $1/1000^{th}$ of a second.
D. Having 10 different people measure the time period and taking an average.
E. Ensure room temperature remains the same throughout the experiment.

Section B: Short Answer Questions

11. Explain what effect doubling the speed of a vehicle will have on the total stopping distance if all other factors such as driver alertness, braking performance and road surface stay the same.

[4 marks]

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12. Explain, in terms of pressure, how it is possible to use a drinking straw to drink from a glass of water.

[4 marks]

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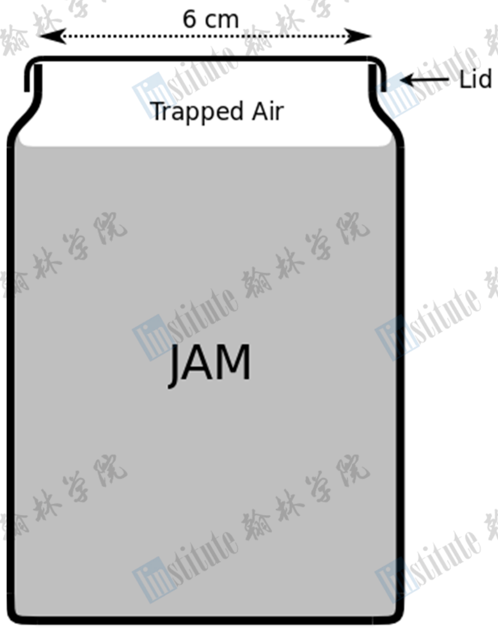
Section C: Longer Answer Questions

13. A question about opening a jam jar

When jam is made, it is put into the jam jar and the top screwed down whilst the jam is still hot. The top makes an airtight seal with the jar and the air trapped above the jam cools and so the pressure of the trapped air reduces.



Useful information:

For the air

$$p / T = \text{constant}$$

assuming no air escapes/enters and the volume of the trapped air remains constant

p = pressure of the trapped air
T = Temperature in Kelvin

Atmospheric pressure = 100 kPa
(at room temperature)
Absolute zero = -273 ºC

a) Calculate the force, due to atmospheric pressure, acting downwards on the top of the circular lid of the jam jar

[3 marks]

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b) The jam and the trapped air were initially at a temperature of 85 °C when the jam was put into the jar and lid secured.
Show that the pressure of the trapped air, once it has cooled to a room temperature of 15 °C inside the jar is approximately 80 kPa

[3 marks]

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c) Calculate the resultant force acting on the lid of the jam jar

[2 mark]

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d) Explain why running the jam jar under the hot tap can make it easier to remove the top

[2 mark]

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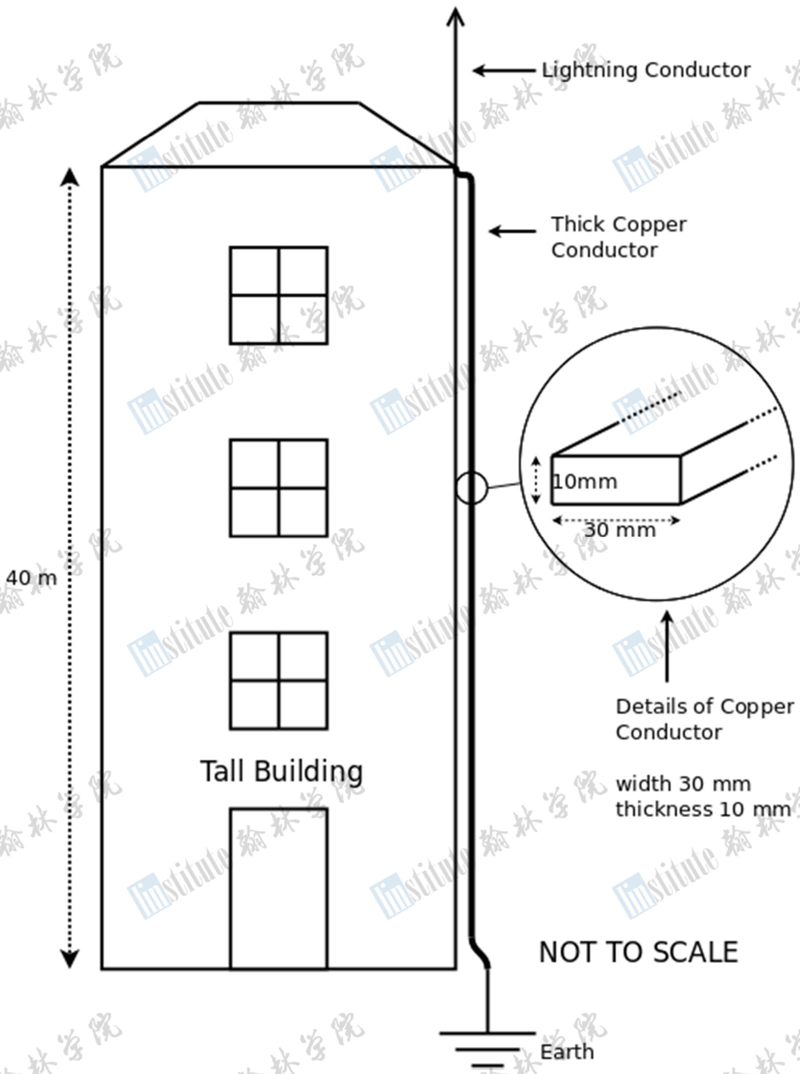
14. Analysis of a lightning strike (data analysis question)

This question asks you to use unfamiliar equations and concepts to solve a problem.
You will not have met some of the concepts in your normal physics course.
All of the information you need to solve the problem is given in the question.



A student was interested to work out if the copper cable connecting a lightning conductor to the ground would melt if it was struck by lightning.

They considered a simple model where a fixed current flowed through the conductor for a certain time

They found the following information about lightning strikes:

Average current flowing through conductor in a lightning strike = 300 kA

Average time for a lightning strike to fully discharge from cloud = 2×10^{-3} s

The students found the following useful data about the copper conductor:

Equation to calculate the resistance of a cable is $R = \rho L / A$
(R = resistance, L = length, A = cross-sectional area and ρ = constant called resistivity)

Resistivity of copper, $\rho = 1.7 \times 10^{-8}\ \Omega\text{m}$
Specific heat capacity of copper = 385 J $\text{kg}^{-1}\ {}^{\circ}\text{C}^{-1}$ (Energy needed to raise 1kg by 1°C)
Density of copper = 8900 kg/m^3
Melting point of copper = 1085 °C

a) Show that the resistance of the conductor is approximately 2 mΩ

[3 marks]

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For current flowing through a resistor we can use the equation, $P = I^2R$ where P = Power, I = Current and R = Resistance

b) Calculate the power dissipated in the conductor and hence show that the energy transferred to the conductor is approximately 400 kJ

[3 marks]

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c) Calculate the mass of the thick copper conductor

[3 marks]

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d) Hence calculate the temperature rise experienced by the conductor and show that the conductor is unlikely to melt

[3 marks]

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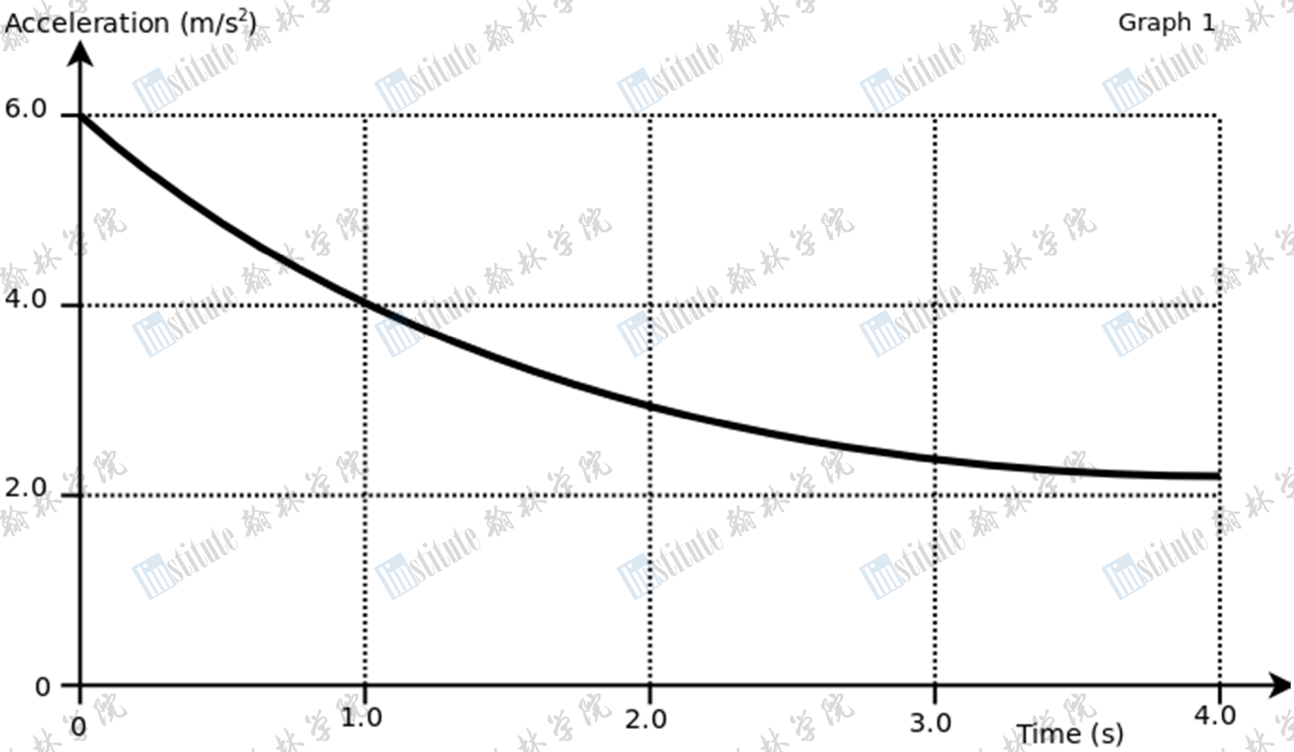
15. Modelling the acceleration of a car

A car accelerates from rest in a straight line.
The driving force from the engine remains constant but the acceleration of the car reduces over the next four seconds due to several factors including increased drag.
A graph of acceleration against time for the first four seconds is shown below:



To analyse the motion of the car, the graph is divided into 1 second time intervals.
Although the acceleration is constantly changing, the problem is simplified by assuming the acceleration in each 1 second time interval **remains constant** for the duration of that interval and is equal to the average acceleration for that time interval.
This is a simplified model of the complex motion of the car.

a) Use the graph to estimate the **average acceleration** for each time interval:

[2 mark]

$t = 0.0s$ to $t = 1.0s$ Average acceleration = ………………………………… m/s^2

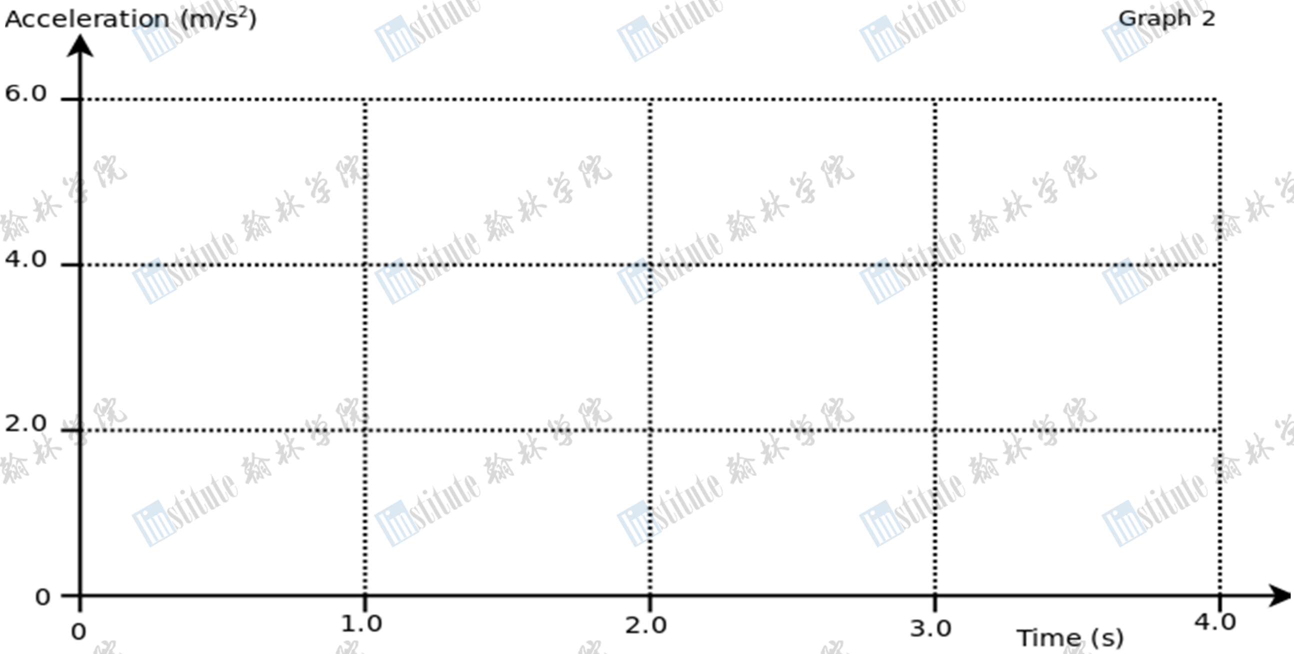
$t = 1.0s$ to $t = 2.0s$ Average acceleration = ………………………………… m/s^2

$t = 2.0s$ to $t = 3.0s$ Average acceleration = ………………………………… m/s^2

$t = 3.0s$ to $t = 4.0s$ Average acceleration = ………………………………… m/s^2

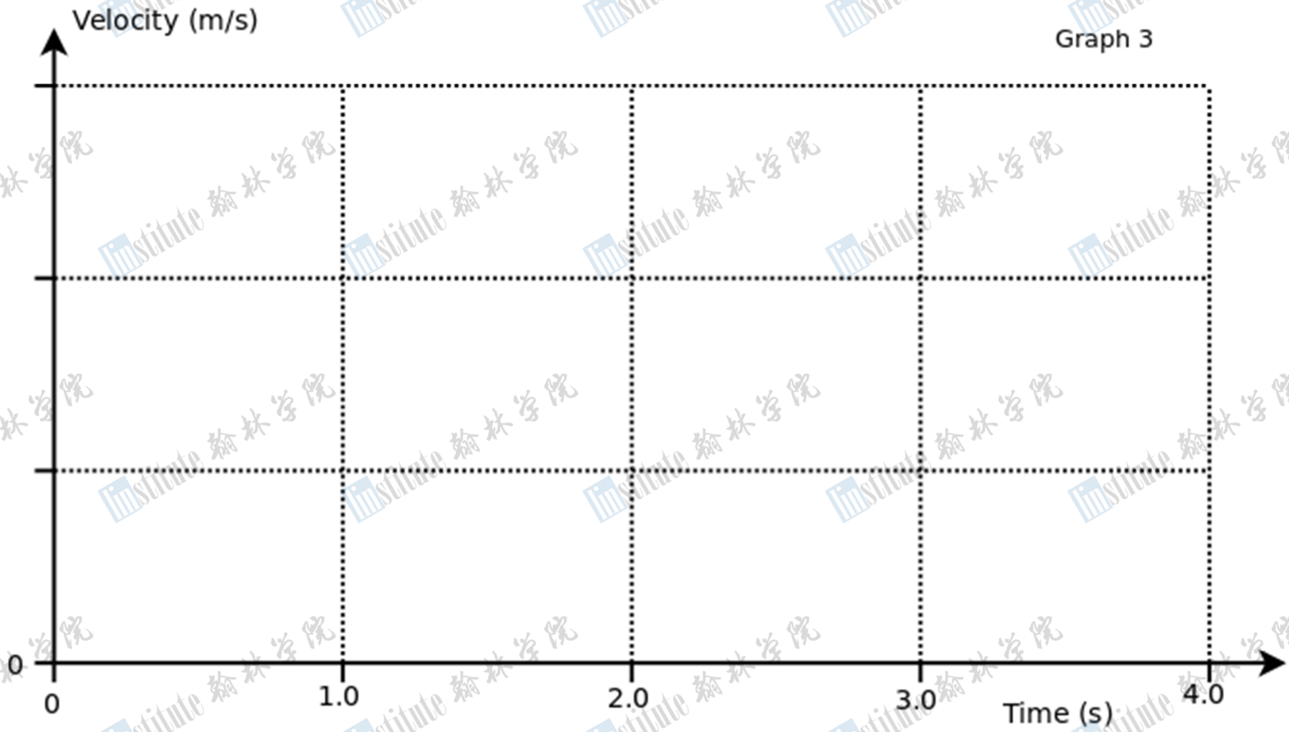
b) Complete graph 2 (below) to show **average acceleration** against time assuming that the acceleration remains **constant** for the given time interval

[2 marks]



c) Complete graph 3 (below) to show the velocity against time for the car assuming the acceleration remains constant for the given time interval.
Indicate significant numerical values on the y-axis

[2 marks]



d) Using the graph 3 or otherwise, calculate the distance travelled by the car in the first 4 seconds

[2 marks]

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An engineer suggests that the Drag force is directly proportional to the velocity of the car.

e) Use numerical data from the problem to demonstrate that, in this example, the drag force is NOT proportional to the velocity

[2 marks]

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