The King's School Canterbury

Sixth Form Entrance 2015

PHYSICS

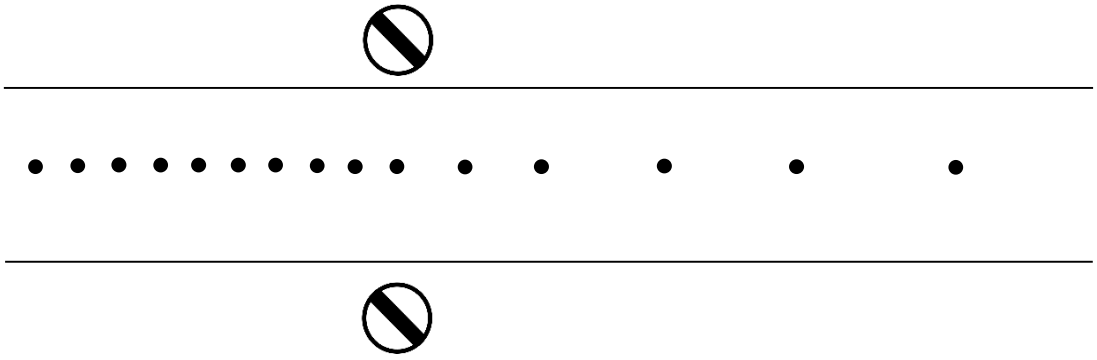
1 hour

ANSWER ALL THE QUESTIONS ON THE PAPER

Name (Capital Letters): .....

Present School: .....

Q1a) A car engine is leaking oil. The oil drops hit the ground at regular time intervals, 2 times every second. The diagram below shows the pattern of the drops that the car leaves on part of its journey.



i) What can you say about the speed of the car before it reaches the speed limit signs?

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(1 mark)

ii) Calculate the distance between the drops on the road before it reaches the signs if the car is travelling at 10 m/s.

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(2 marks)

iii) After the car passes the signs, what happens to the gaps between the drops of oil? What does this tell you about the motion of the car?

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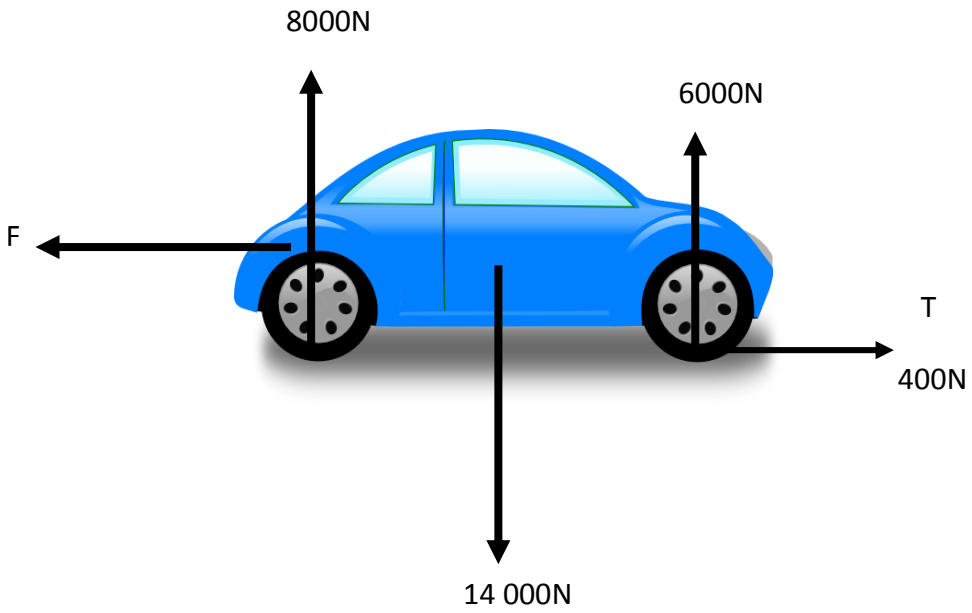
(2 marks)

b) A front-wheel drive car is travelling at **constant velocity.** The forces acting on the car are shown in the diagram below.



i) What is the cause of force T?

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(1 mark)

ii) What is the cause of force F?

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(1 mark)

iii) What is the **size** of force F? Explain your answer.

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(2 marks)

iv) Force T is now increased. **Describe** and **explain** what effect this has on the speed of the car.

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(2 marks)

c) The acceleration of a moving object is calculated using the following equation

$$a = \frac{v-u}{t}$$

a = acceleration in m/s^2

v = final velocity in m/s

u = initial velocity in m/s

t = time in s

i) A motorbike travelling at 20 m/s accelerates at a rate of 0.6 m/s^2 for 12s. Calculate its new velocity. Show all of your workings.

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(3 marks)

The total distance travelled by a vehicle that is accelerating can be calculated using the following equation

$$s = u\,t + \tfrac{1}{2}\,a\,t^2$$

Where s = distance travelled (in m) and all other symbols are as defined in the previous question.

ii) Calculate the distance travelled by the motorbike in the previous question over the 12s that it is accelerating.

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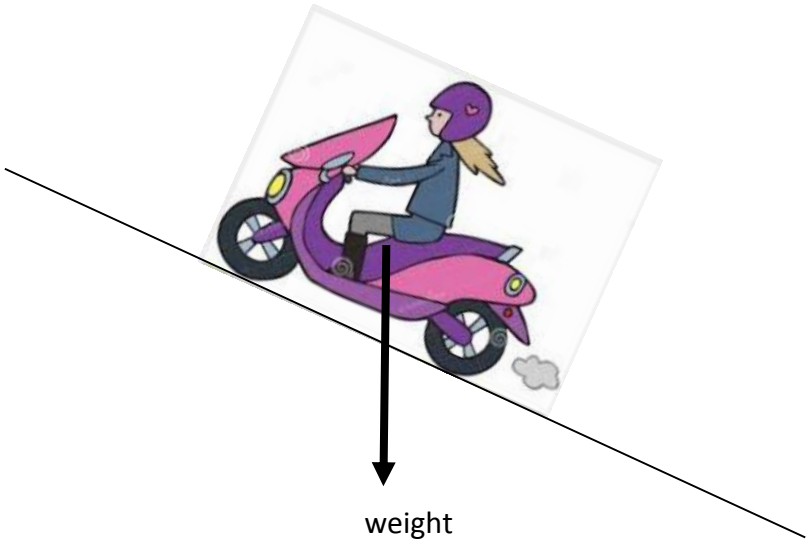
(3 marks)

The motorbike now starts to go up a hill.



iii) What effect will this have on the **acceleration** of the motorbike? Try to explain your answer in terms of the **forces** acting.

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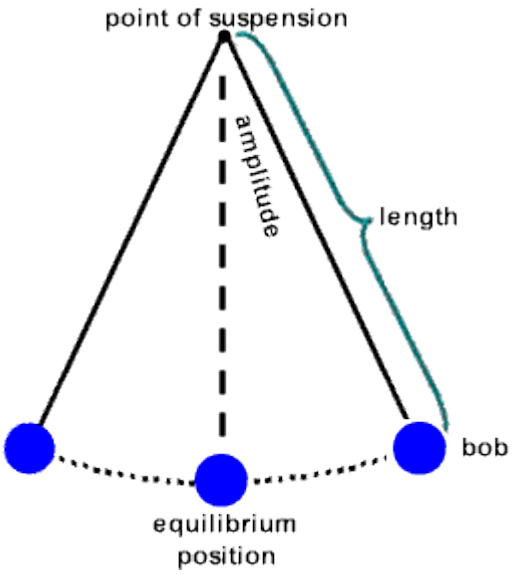
…… (2 marks)

Q2) A pupil is carrying out an experiment using a pendulum. She is looking at the relationship between the length of the string and time period (ie the time it takes for the pendulum bob to swing from one side to the other and back again).



a) Design an experiment that she could carry out to look at the relationship between length and time period. You should include the following:

- The variables that she would need to measure and the measuring devices she could use for this.
- A brief method explaining how she might carry out this experiment.
- A comment about how she could make this a fair test.
- A description of what she could do to make her experiment as accurate as possible.

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(4 marks)

b) The equation that relates the time period of a pendulum to the length of the string is given below

$$T = 2\pi\sqrt{\frac{L}{g}}$$

T = time period in s

L= length of string in m

g = gravitational field strength (= 10 N/kg on Earth)

π = 3.14

i) Calculate the time period of a 1.5m long pendulum.

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(2 marks)

Since this is a non-linear relationship, a graph of T against L would **not** be a straight line and so would be difficult to analyse. A straight line graph can be obtained if the equation is **squared** on both sides to eliminate the square root sign.

ii) Square the equation on both sides.

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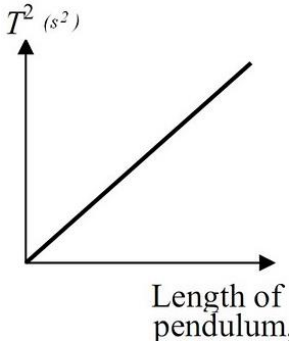
(1 mark)

Now if you plot T^2 on the y axis and L on the X axis of a graph, it should give you a straight line graph.

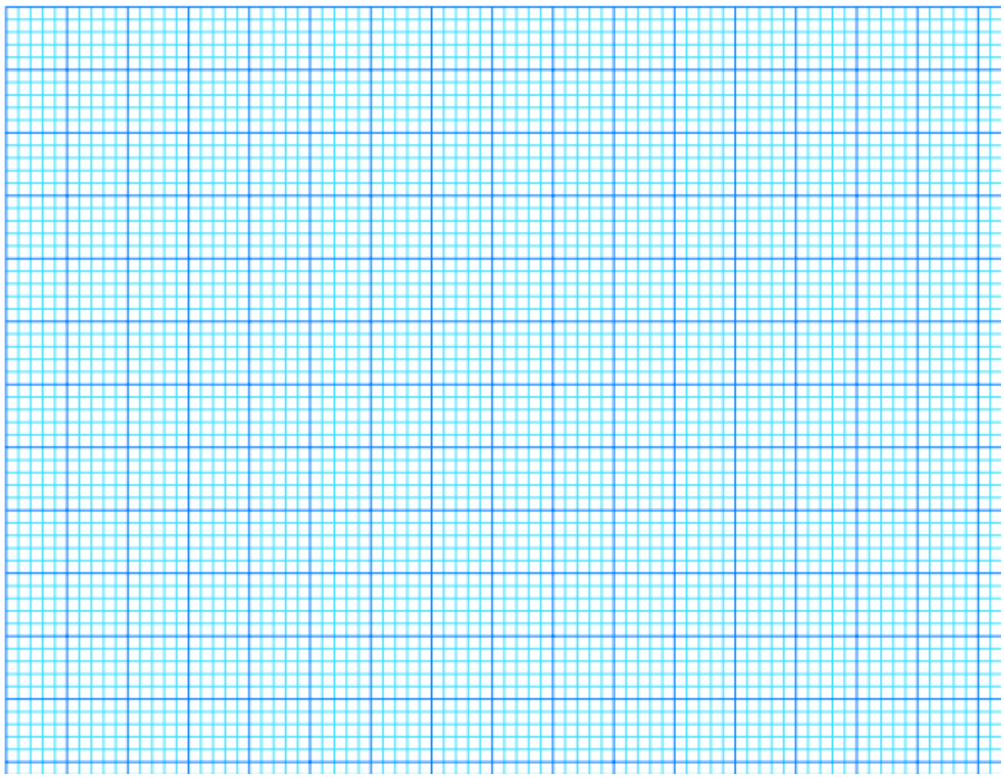


iii) In the table below are the results that the pupil collected from her experiment. Calculate the values for T^2 and quote them to **2 significant figures**.

L (in m)	T (in s)	T^2 (in s^2) to 2 sig figs
0.10	0.64	
0.20	0.91	
0.30	1.08	
0.40	1.25	
0.50	1.39	

(2 marks)

iv) Draw a graph of T^2 (on the y axis) against L (on the x axis). Choose suitable scales and include a line of best fit.



(5 marks)

v) Does your graph support the equation suggested? Give a reason why.

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(2 marks)

vi) The **gradient** (ie rise/run) of the graph is equal to $\frac{4\pi^2}{g}$

Find the gradient of your graph and use this to calculate a value for g, the gravitational field strength.

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(3 marks)

vii) Why do you think it is better to find g from the gradient of the graph, rather than just using a pair of values from the table?

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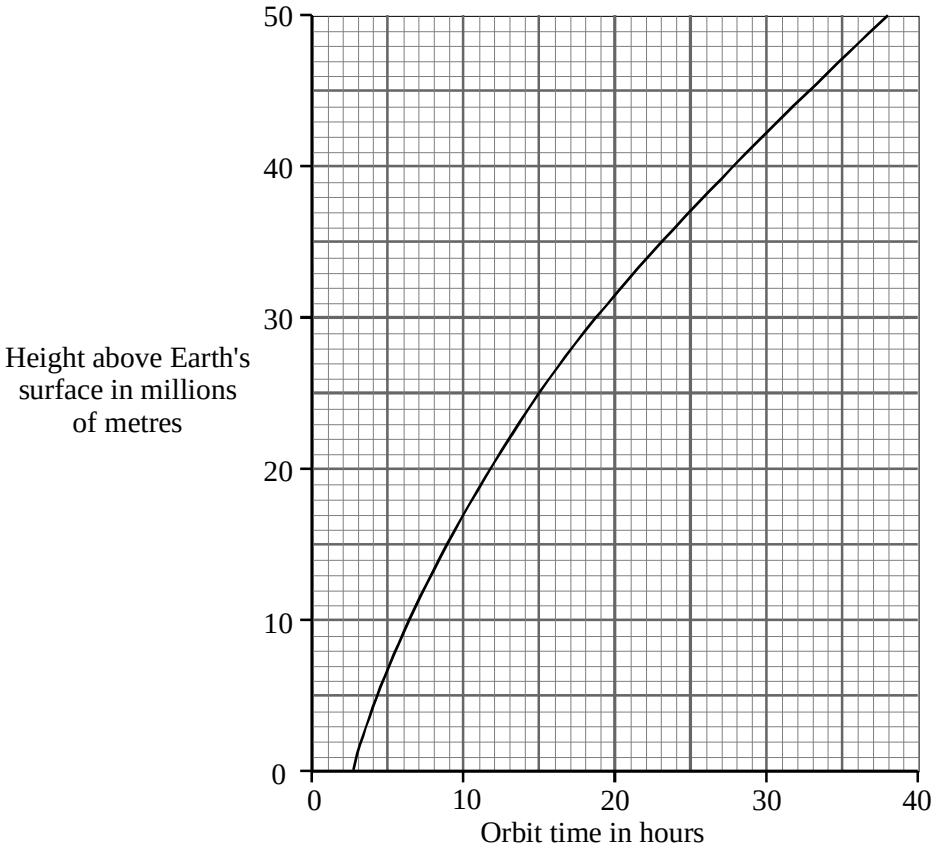
(1 mark)

Q3) The graph below shows how the orbit time of an artificial satellite depends on its height above the Earth's surface.



a) How does the orbit time change with increasing height above the Earth's surface?

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(1 mark)

b) Some satellites are in **geostationary orbit**. They have an orbital time of 24 hours which mean that they remain above the same point on the Earth's surface.

i) Use the graph to find the height above the Earth's surface of a geostationary satellite.

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(1 mark)

ii) Suggest **two** uses of satellites that are in geostationary orbit.

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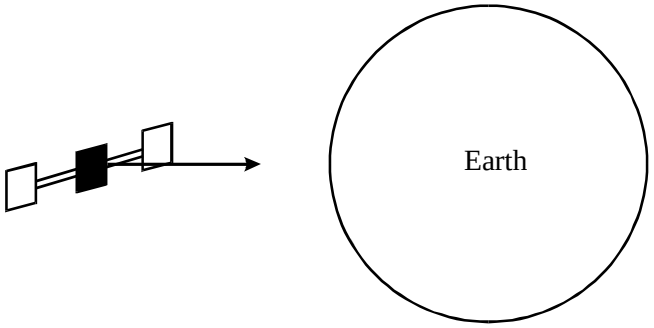
(2 marks)

c) The diagram shows the force that acts on a geostationary satellite.



i) What causes this force

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(1 mark)

ii) Eventually, a satellite in orbit around the Earth loses energy and slows down because of frictional forces acting on it.

Describe what is likely to happen to the satellite over a period of time.

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(2 marks)

The orbital velocity of a satellite can be calculated using the following equation

$$v = \frac{2\pi r}{T}$$

where v = orbital velocity in m/s

r = radius of orbit in m (measured from the **centre** of the objects)

T = time for one complete orbit **in s** (also called time period)

d) A satellite is in a geostationary orbit that has a radius of 42 400 km
Show that the orbital velocity of this satellite is nearly 3100 m/s.

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(3 marks)

e) The speed of radio waves is 3.0×10^8 m/s.

Speed (in m/s) = distance (in m) / time (in s)

The geostationary satellite in part d) is used for telephone communications.

Estimate the time delay between a voice message being sent **and** received via this satellite.

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(3 marks)

The table below gives some information about three satellites.

satellite name	purpose	orbit height above Earth's surface	approximate orbit time
Hubble space telescope	to observe the stars	612 km	1.5 h
NOAA-17	to monitor the Earth's atmosphere and oceans	833 km	1.7 h
Intelsat-906	geostationary communications satellite	36 000 km	24 h

f) NOAA-17 is in a polar orbit. This means that it travels around the earth from pole to pole as shown below

i) Approximately how many orbits does NOAA-17 make in **one** day?

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(1 mark)

ii) Explain how this type of orbit allows NOAA-17 to monitor **all** the Earth's oceans.

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(2 marks)

iii) The Hubble Space Telescope is used to study the faint light from distant stars.

Suggest why it is placed in orbit just **above** the Earth's atmosphere.

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(1 mark)

g) A polar orbiting satellite has a time period of 90 minutes.
Calculate its height **<u>above the Earth's surface</u>**. Take the gravitational field strength at the height of the orbit as 10 N/kg and the radius of the Earth as 6400 km.

You will need to use the following equations

$$v = \frac{2\pi r}{T} \qquad\qquad g = \frac{v^2}{r}$$

Note: r = total radius of the **orbit** of the satellite.

g = gravitational field strength in N/kg

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(4 marks)

END OF EXAMINATION

To the member of staff supervising the physics 6th form entrance exam for The King's School, Canterbury,

This paper includes a number of equations that have been formatted using Word equation writer. Very rarely, some older versions of Word can have problems displaying these equations correctly. In the unlikely event of this happening, the equations that should be apparent are as written below.

Q1 part c $a= (v-u) / t$ and $s=ut+1/2at^2$
Q2 part b $T = 2\pi \sqrt{(L/g)}$
Q2 part b vi $(4\pi^2)/g$
Q3 part c ii $v=(2\pi r)/T$
Q3 part g $v=(2\pi r)/T$ and $g=v^2/r$

Apologies for any inconvenience caused.

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THE KING'S SCHOOL, CANTERBURY

SIXTH FORM ENTRANCE EXAMINATION

2014-2015

Physics

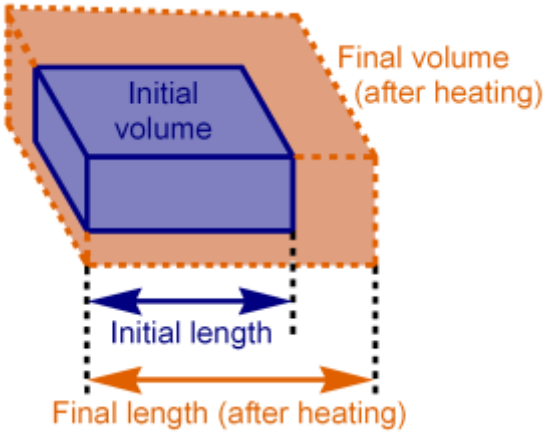
1 Hour

ANSWER ALL THE QUESTIONS ON THE PAPER

Name (Capital Letters): .....

Present School: .....

Q1. When certain materials are heated, they expand ie they increase in size.



a) Using ideas about particles and energy, explain why a material expands upon heating.

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(2 marks)

The linear expansivity of a substance is the amount by which one metre length will increase for every one degree Celcius rise in temperature. Engineers can use this to work out how much their material will expand over the range of temperature in which they are to be used.

b) Why is it important to know this when building a bridge?

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(2 marks)

ci) The linear expansivity of steel is 0.000 012m per ^{o}C.

What will be the length of a 500m steel bridge if the temperature rises by 50^{o}C?

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(2 marks)

ii) The linear expansivity of copper is 0.000 023m per ^{o}C and that of aluminium is 0.00003m per ^{o}C. Which will expand most, 50m of copper heated by 40^{o}C or 50m of aluminium heated by 30^{o}C.

Justify your answers by calculations.

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(3 marks)

iii) How was the idea of expansivity used in fitting metal tyres to wooden cart wheels as shown in the diagram below?

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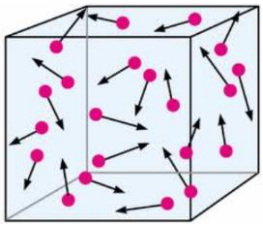
(2 marks)

Gases exert a pressure on the container that they are in due to collisions between the particles and the walls of the container.



When gases are heated they expand.

d) The pressure of a gas is related to its temperature. How would you expect the pressure of a gas to change if the temperature was increased? Explain your answer.

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(3 marks)

The pressure is also related to the volume of the gas. The relationship between these 2 variables is called Boyle's Law which is summarised by the following equation:

$$p_1 \times V_1 = p_2 \times V_2$$

where:

- p_1 = initial pressure in Pa
- V_1 = initial volume in m^3
- p_2 = final pressure in Pa
- V_2 = final volume in m^3

e) A gas at a pressure of 100 kPa is compressed from a volume of $0.3m^3$ down to a volume of $0.15m^3$. The temperature of the gas does not change.

Calculate the new pressure of the gas. Show all of your workings.

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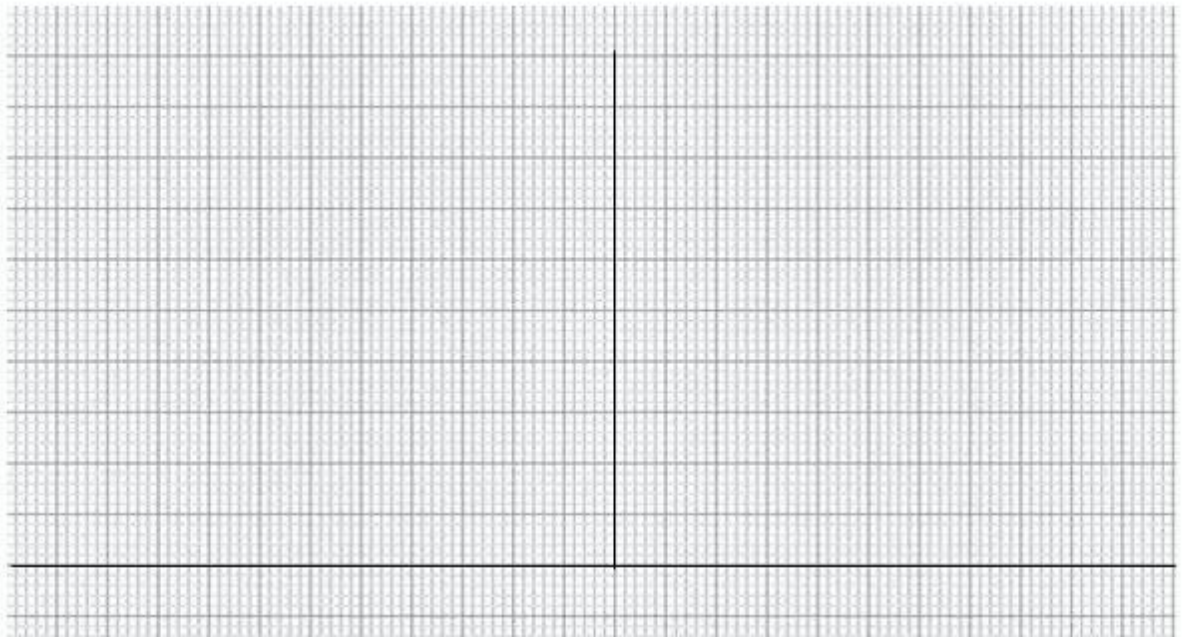
……(2 marks)

f) A sealed container contains air. The pressure of the air is measured at different temperatures. The table shows the results.

An *atmosphere* is a unit of pressure that gives the pressure in multiples of normal atmospheric pressure.

Temperature (^{0}C)	Pressure (atmospheres)
-150	0.45
0	1.00
100	1.40
250	1.95

i) Using the grid below, add a suitable scale to the axes and plot a line graph of pressure on the y axis and temperature on the x axis. Draw a line of best fit. (4 marks)



ii) Use your graph to find the temperature of the air at which its pressure is zero.

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(1 mark)

This temperature is known as *absolute zero.*

iii) Describe the motion of the particles at absolute zero if they are not exerting any pressure on the container.

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(1 mark)

Q2. You may find the following information useful for this question:

Resistance (in Ω) = Voltage (in V) / Current (in A)

The higher the resistance, the lower the current in a circuit.

A student is asked to investigate how the resistance of a wire varies with its length.

a) Briefly describe how she might do this experiment, giving details of any variables that she needs to measure, the equipment that she could use, any calculations she would need to do and an explanation as to how she could make this a fair test.

You may include a diagram if you wish.

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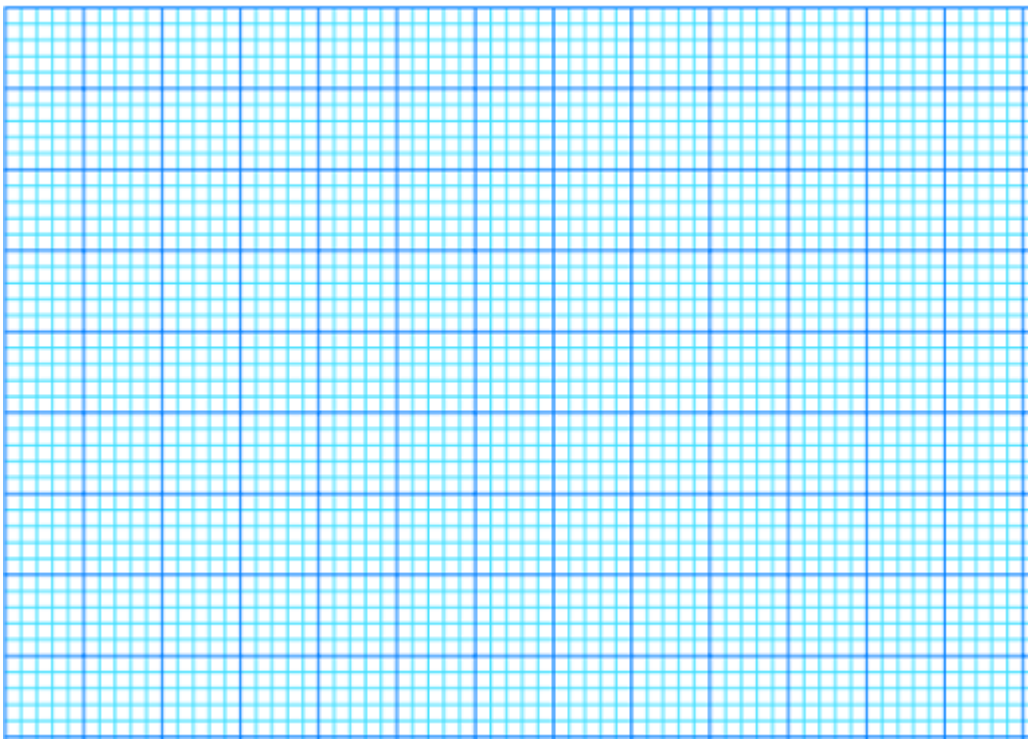
(5 marks)

Here are the results of the experiment that she carried out.

Length of wire/cm	0.0	10	20	30	40	50
Resistance/ Ω	0.0	4.5	9.1	13.6	18.1	22.3

bi) Plot a graph of length of wire against resistance. Include a line of best fit.



(4 marks)

ii) What can you conclude about the *mathematical* relationship between the resistance of the wire and its length?

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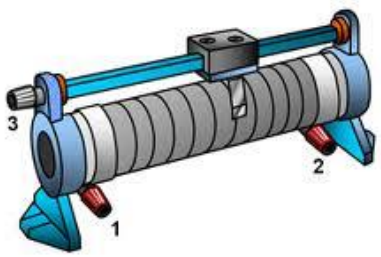
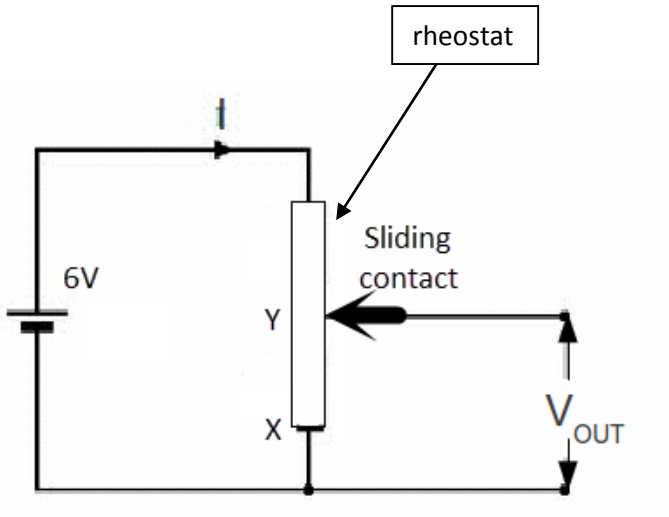
(1 mark)

A rheostat is a device that can be used to produce varying output voltages from a fixed voltage supply. It is essentially just a long coil of wire. A sliding contact can be moved along the coil of wire to vary the resistance in the circuit. This in turn varies the output voltage.



Below is a circuit diagram showing the rheostat being used in a circuit.



As the sliding contact is moved along the wire, the output voltage (V_{out}) changes in proportion to the length of the coil wire between the two points of contact ie points X and Y.

Assume that the wire is evenly wound along the coil.

ci) What would you expect the output voltage to be at the half way point?

……..(1 mark)

ii) Where would the sliding contact need to be to get an output of 4.5 V? Be as specific as you can.

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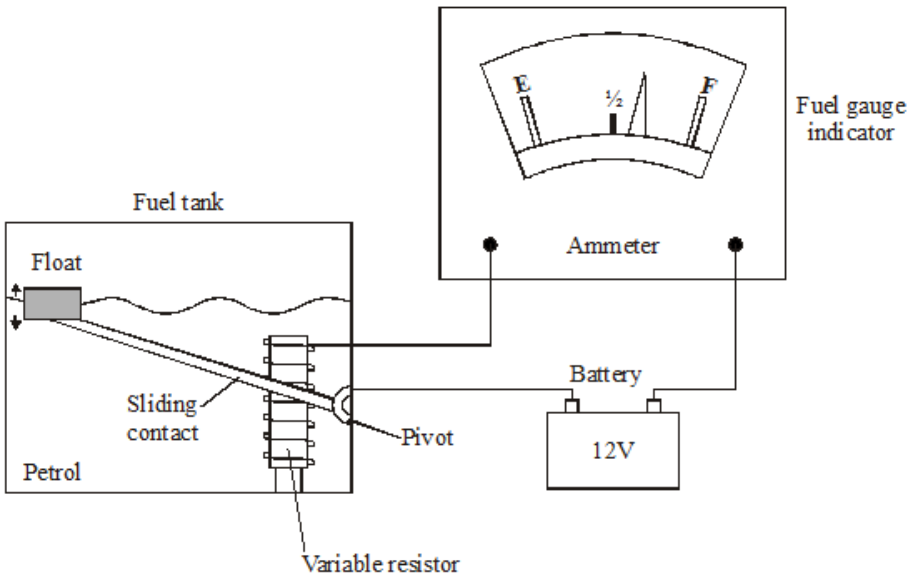
(2 marks)

The diagram below shows the fuel gauge assembly in a car.

- The sliding contact touches a coil of wire and moves over it.
- The sliding contact and the coil form a variable resistor (similar to the rheostat in the question above).
- The sliding contact is connected to a float via a pivot.
- The fuel gauge indicator is an ammeter.
- When the petrol level changes, the resistance of the circuit changes. This in turn affects the current (higher resistance means lower current)
- This causes the pointer in the fuel gauge indicator to move.



d) How will the current in the circuit change as the amount of petrol in the tank falls?

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(1 mark)

Explain your answer.

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(2 marks)

Q3 You may find the following information useful for this question:

Circumference of a circle = 2πr where r is the radius

Weight (in N) = mass (in kg) x gravitational field strength (in N/kg)

Gravitational field strength = 10 N/kg on the Earth's surface

The height that you can jump depends inversely on the gravitational field strength. So if the field strength doubles, the height halves.

ai) If the Olympic games were held on Mars (gravitational field strength= 3.8 N/kg) in a large dome to provide air to breathe, what would happen to the **Olympic record** for:

Weight lifting – **circle the correct answer**

It would increase it would stay the same it would decrease

Explain your choice

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(2 marks)

ii) High jump – **circle the correct answer**

It would increase it would stay the same it would decrease

Explain your choice

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(2 marks)

iii) Throwing the javelin – **circle the correct answer**

It would increase it would stay the same it would decrease

Explain your choice

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(2 marks)

iv) The 100m race – **circle the correct answer**

It would increase it would stay the same it would decrease

Explain your choice

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(2 marks)

The diagram shows the orbits of the Earth and Mars around the Sun.

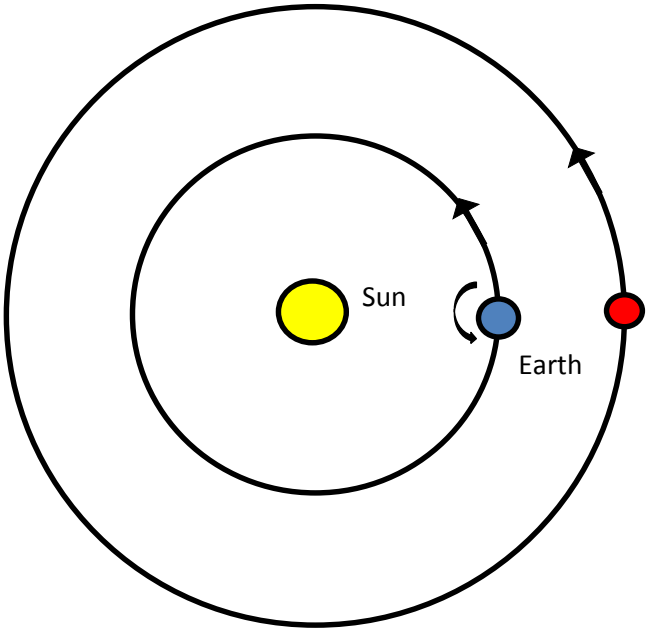

Diagram not to scale

Data:		
	Distance of Earth from the Sun:	1.49×10^{11}m
	Distance of Mars from the Sun:	2.28×10^{11}m
	Length of one Earth year:	365 days.

bi) Using the data given above, and assuming that the orbit is circular, show that the orbital speed of the Earth around the Sun is approximately 29 700 m/s.

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(3 marks)

ii) Convert this speed into km/hr

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(3 marks)

In 1619 Johannes Kepler published his third law of planetary motion which stated that the square of the period of the orbit (time to go round the sun) was proportional to the cube of the radius of the orbit around the sun.

Mathematically this is expressed as:

$$T^2 = k R^3$$

Where T = time for one orbit in seconds

R = radius of orbit in metres

K = a constant

c) Using the data for the Earth, calculate the value of the constant k.

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(2 marks)

d) Suggest a possible unit for k.

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(1 mark)

e) Using the same value of k, calculate the orbital period (ie T) for Mars.

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(2 marks)

f) Hence, calculate the orbital velocity of Mars (in m/s)

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(3 marks)

END OF EXAMINATION

Total 60 marks