Name:	
School:	

Total Mark	

BPhO
British Physics Olympiad

2019 Physics Challenge

Time allowed: 1 hour

Attempt all questions

Write your answers on this question paper

You may use a calculator

You may use any standard exam board formula and data booklet

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 10 marks in total).
Questions require a clear explanation of the underlying physics principles.
Allow about 10 minutes for this section.

Section C: Two longer answer questions requiring calculations (worth 30 marks in total).
Questions may be set on unfamiliar topics. Additional information necessary to answer the question will be given in each question.
Allow about 35 minutes for this section.

Useful Constants and Equations

The following useful equation may be unfamiliar to some students:

$\rho = {}^{m}/_{V}$ density = mass ÷ volume

The following constant should be used:

$g = 10\ \mathrm{N/kg}$ gravitational field strength on Earth

Students should note:

The footnote on page 10 is NOT part of the question and students are advised not to spend time reading it during the 1 hour available for the Physics Challenge. The footnote is provided to place the values derived in the question in to context and to avoid suggesting that the derived values agree with the accepted values.

Section A: Multiple Choice Answers

Write the letter corresponding to your chosen answer in the grid below.

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

Question 1

A metal cube has a mass of 5.81kg and is at rest on a table.

The length of one side of the cube is 8.00 cm.

Which row in the table gives the correct values for density of the metal and pressure exerted by the cube on the table top?

	Density of the metal / kg/m^3	Pressure due to cube / Pa
A	11300	9080
B	11300	1510
C	11300	908
D	1510	9080
E	1510	1510
F	1510	908

Question 2

The metal cube in Question 1 is divided into 8 identical smaller cubes.

How does the pressure exerted by a **single** smaller cube on the table top compare to the pressure exerted by the original (larger) cube?

A. Increases by a factor of 4
B. Increases by a factor of 2
C. Stays the same
D. Decreases by a factor of 2
E. Decreases by a factor of 4

Question 3

A snail takes part in a snail race.

The snail completes the 80cm course in 3.0 minutes. What is the average speed of the snail?

A. 27 m/s
B. 0.44 m/s
C. 0.27 m/s
D. 0.013 m/s
E. 0.0044 m/s

Question 4

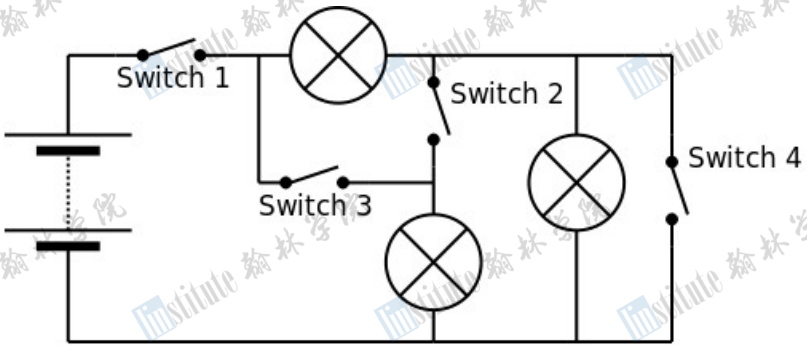
Standard 100 g masses used in physics experiments can be checked using a digital top-pan balance. When a sample of five 100 g masses is checked, the values for five different masses are recorded as 100.6 g, 99.4 g, 99.3 g, 100.5 g and 100.2 g.

When students use any number of 100 g masses in routine experimental work, without measuring the individual masses, the variation in the actual mass is an example of:

A. Calculation error
B. Human error
C. Parallax error
D. Random error
E. Systematic error

Question 5

A student is given a battery pack, several switches and several bulbs, and builds the following circuit:



Which of the following switch combinations will result in all the bulbs being illuminated?

	Switch 1	Switch 2	Switch 3	Switch 4
A	CLOSED	CLOSED	CLOSED	CLOSED
B	CLOSED	CLOSED	CLOSED	OPEN
C	CLOSED	CLOSED	OPEN	OPEN
D	CLOSED	OPEN	OPEN	OPEN
E	OPEN	OPEN	OPEN	OPEN

Question 6

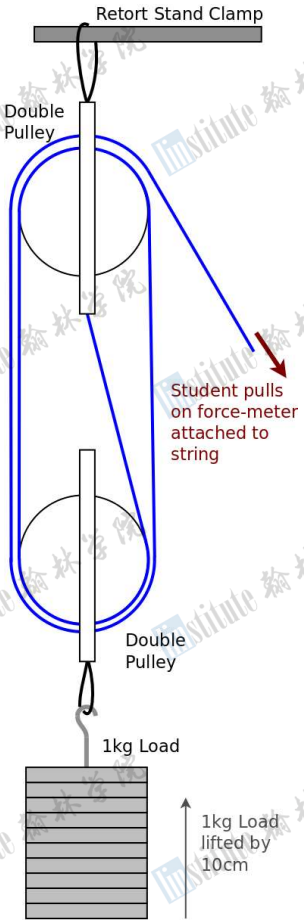
The pictures shows a pulley in a school Physics lab being used to lift a 1.0 kg mass.

When the student pulls the force meter it records a force of 2.6 N.

Moving the force meter 40 cm results in the 1.0 kg mass being raised by 10 cm.

The efficiency of the pulley system is:

A. 100%
B. 96%
C. 74%
D. 25%
E. 3.8%

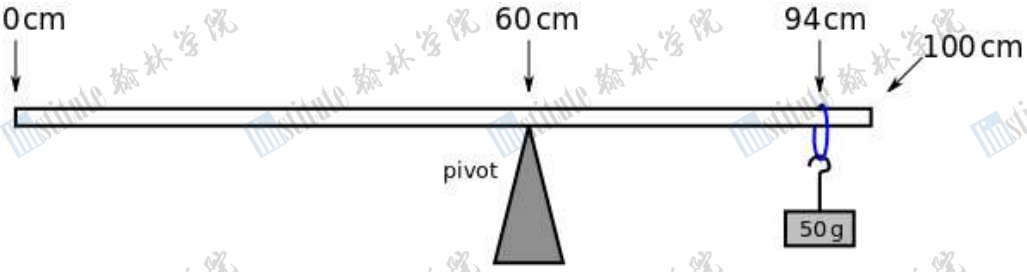


Question 7

A 1 m wooden ruler has been damaged and is no longer uniform.

The mass of the ruler is determined to be 142 g.

The ruler is balanced on a knife edge with a 50 g mass as shown.



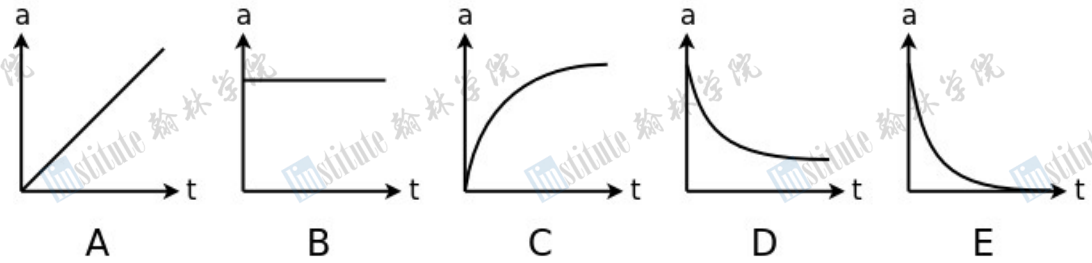
The centre of mass of the ruler is at:

A. The 12 cm mark
B. The 48 cm mark
C. The 50 cm mark
D. The 60 cm mark
E. The 95 cm mark

Question 8

A helium party balloon is released from rest and rises in the air, quickly reaching terminal velocity.

Which of the following graphs is most likely to represent the acceleration of the balloon with time?



Question 9

Radio waves, X-rays and Microwaves are all members of the electromagnetic spectrum.

When listed in terms of increasing frequency, the correct order is:

A. Microwaves, Radio waves, X-rays
B. X-rays, Microwaves, Radio waves
C. Radio waves, Microwaves, X-rays
D. Radio waves, X-rays, Microwaves
E. Microwaves, X-rays, Radio waves

Question 10

As part of a Physics experiment, a tennis ball is dropped in an elevator (a lift).

The time for the ball to reach the floor of the elevator is recorded.

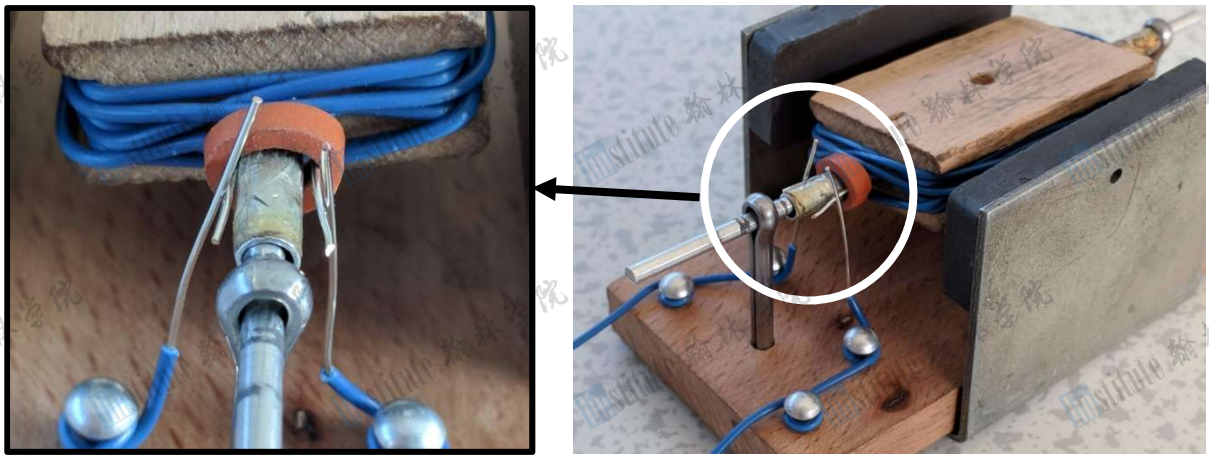
The shortest time will be recorded when the elevator is:

A. Stationary
B. Moving downwards and speeding up
C. Moving downwards at a constant speed
D. Moving downwards but slowing down
E. In freefall

Section B: Short answer questions

Question 11

The photographs show a simple demonstration d.c. electric motor that is used to illustrate how an electric motor works.



Explain the basic principles of a d.c. electric motor

You may annotate the photograph [5 marks]

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Question 12

A student is investigating how a 30 N spring balance works. A 1 kg mass is suspended from the spring balance. The student stands on a table and holds the spring balance stationary.

Whilst holding the spring balance, the student jumps off the table and lands on the floor. A colleague videos the reading on the spring balance throughout the experiment.

An analysis of the video shows that:

- ❑ When the student is standing on the table and the balance is stationary (and not accelerating), the reading is 10 N
- ❑ When the student is falling from the table to the floor, the reading is 0 N
- ❑ When the student lands, the reading is momentarily greater than 10 N

Explain these observations [5 marks]

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Section C: Long answer questions

Question 13

In the early morning of January 21st 2019 a total lunar eclipse was observed across the UK. A lunar eclipse occurs when the Moon enters the Earth's shadow.

(a) **Draw a labelled diagram** (not to scale) to show the relative positions of the Sun, Earth and Moon during a total lunar eclipse.

Explain why a total lunar eclipse is not observed every (lunar) month. [2 marks]

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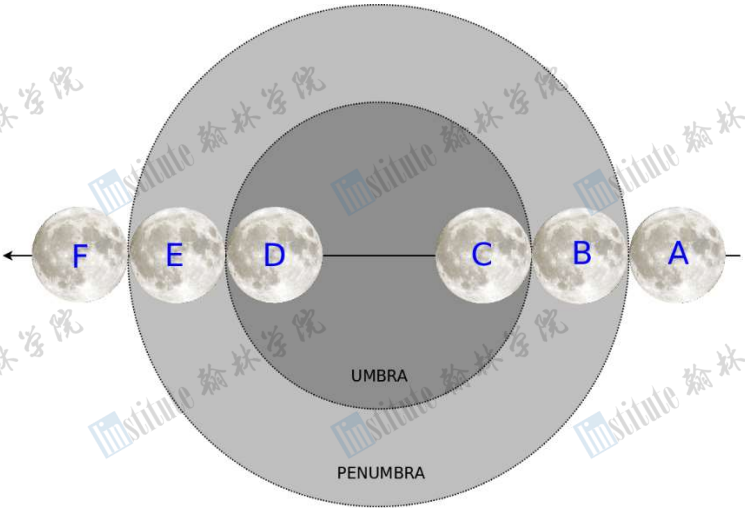
Due to the fact that the Sun is not a point source, the shadow of the Earth on the Moon has an area of complete shadow, called the umbra, surrounded by an area of partial shadow called the penumbra, as shown below.

The diameter of the Earth's shadow (the umbra) at the Moon is 9200 km.



A	Moon enters Penumbra	2:37 a.m.
B	Partial eclipse begins	3:34 a.m.
C	Total eclipse begins	4:41 a.m.
D	Total eclipse ends	5:43 a.m.
E	Partial eclipse ends	6:50 a.m.
F	Moon leaves Penumbra	7:48 a.m.

(Lunar image: free for commercial use, no attribution required)

*** **Note:** Umbra, penumbra and size of the Moon are **NOT** SHOWN TO SCALE in the diagram ***

A partial lunar eclipse occurs when part of the Moon is in the shadow of the Earth (the umbra).

A total lunar eclipse occurs when the Moon is entirely within the umbra of the Earth's shadow.

Assume, in the following questions, that the Moon passed through the widest part of the Earth's shadow during the total lunar eclipse.*

(b) By considering the time interval between appropriate points in the lunar eclipse, **show that** the speed of the Moon* in its orbit as seen from Earth is calculated as approximately 4300 km/h.

[3 marks]

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(c) By considering the time between the appropriate points in the lunar eclipse and the speed calculated previously, **show that** the diameter of the Moon* is approximately 4800 km.

[3 marks]

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(d) Given that the period** of the Moon's orbit is 27.3 days, calculate the distance between the Earth and the Moon.

[3 marks]

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* The lunar eclipse that occurred on 21st January passed completely through the umbra but crossed at an angle just to the North of the ecliptic, meaning that it did not quite pass through the widest part. In addition the motion of the Earth is not taken into account. The values for the speed and size of the Moon and Earth – Moon distance calculated in the question are, as a result, significantly higher than the accepted values.

** The sidereal period, the time taken to complete a 360° path around the Earth relative to the fixed background stars, is approximately 27.3 days. Due to the Earth's own motion in its orbit, the synodic period, the time between successive full moons, is longer at approximately 29.5 days

(e) It is claimed that a thumb, held at arm's length, will almost exactly obscure the full moon.

By estimating the size of your thumb and the distance between your eye and your thumb at arm's length, discuss the validity of this claim.

[4 marks]

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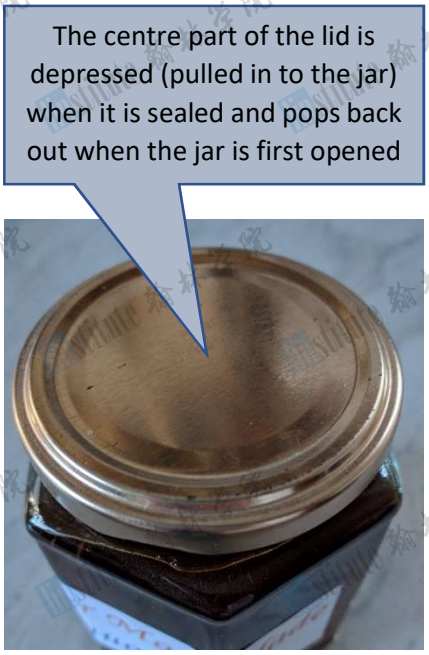
Question 14

Glass food jars have a 'safety seal' to guarantee that the jar has not been opened since manufacture. The metal lid has a depression which "pops" or "clicks" when the jar is opened.

The safety seal works by having a lower pressure inside the jar. The greater atmospheric pressure keeps the metal lid depressed. When the jar is opened the pressure inside the jar increases and the lid snaps back into its original shape making the characteristic popping sound.

Assume atmospheric pressure is 101 kPa



(a) The force required to "pop" or depress a jam jar lid with a centre part diameter of 4.0 cm is found to be 13 N.

Show that the pressure required to depress the lid is about 10 kPa

[2 marks]

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(b) An empty jam jar is gently heated in an oven to a temperature of 80 °C. The lid is put on tightly to make an air tight seal and the jam jar allowed to cool from 80 °C. The safety seal "pops" down and is fully depressed when the jam jar reaches a temperature of 38 °C.

Using the result from part (a), **calculate** the pressure inside the jam jar at 38 °C.

[2 marks]

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(c) The pressure of a gas becomes zero when the temperature falls to absolute zero. Use the results of the experiment with the jam jar to **estimate** a value for the absolute zero of temperature.

[4 marks]

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(d) State one assumption necessary to be able use the results of the experiment to calculate the value of absolute zero.

[1 mark]

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(e) The experiment is repeated but this time the jam jar is half full of jam. **Explain** whether or not this change affects the temperature at which the safety seal pops down.

[3 mark]

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(f) The accepted value for absolute zero is -273 °C. Therefore, one or more of the values determined experimentally must have been incorrect.

By thinking about how the measurements might have been made, **suggest** which of the measurements in the experiment is most likely to have caused the difference between the value calculated in part (c) and the accepted value. **Explain** whether the measurement suggested was too low or too high.

[3 marks]

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END OF PAPER

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