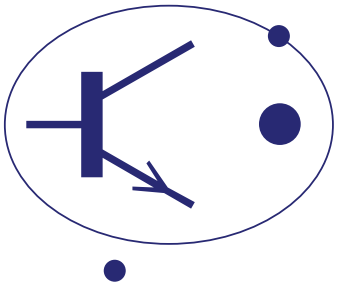
Name	
School	

TOTAL MARK	

BRITISH PHYSICS OLYMPIAD



2010 Physics Challenge

Time allowed: 1 hour

Attempt all questions. Write your answers on this question paper.

You may use any calculator.

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

Section A: Ten multiple choice questions worth 1 mark each (worth 10 marks in total).
Allow about 10 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 calculation (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 about 40 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										

1. The Earth is a distance of 1 Astronomical Unit (1 AU) from the Sun.
In these units the speed of the Earth in its orbit around the Sun is:

A. 1.00 AU / year

B. 2π AU / week

C. 0.017 AU / day

D. 0.26 AU / hour

E. 1.99×10^{-7} AU / min

2. A radioactive isotope with a short half life can be added to a batch of paint.
The paint is stirred thoroughly and the activity of different samples is then measured to ensure they have been properly mixed.

A radioisotope with a half life of 6 hours and an initial activity of 800 Bq is added to 500 litres of paint. If the paint is mixed evenly then after one day the activity of 1 litre of paint should be:

A. 133 Bq

B. 50 Bq

C. 1.6 Bq

D. 0.2 Bq

E. 0.1 Bq

3. The specific heat capacity (SHC) of a material is defined as the amount of energy required to raise the temperature of 1 kg of the material by 1°C.

When 1000 J of thermal energy is transferred to 200 g of material X the temperature increases by 4 °C. When 2000 J of thermal energy is transferred to 100 g of material Y the temperature increases by 8 °C.

The ratio of their specific heat capacities, SHC of X : SHC of Y is:

A. 4 : 1

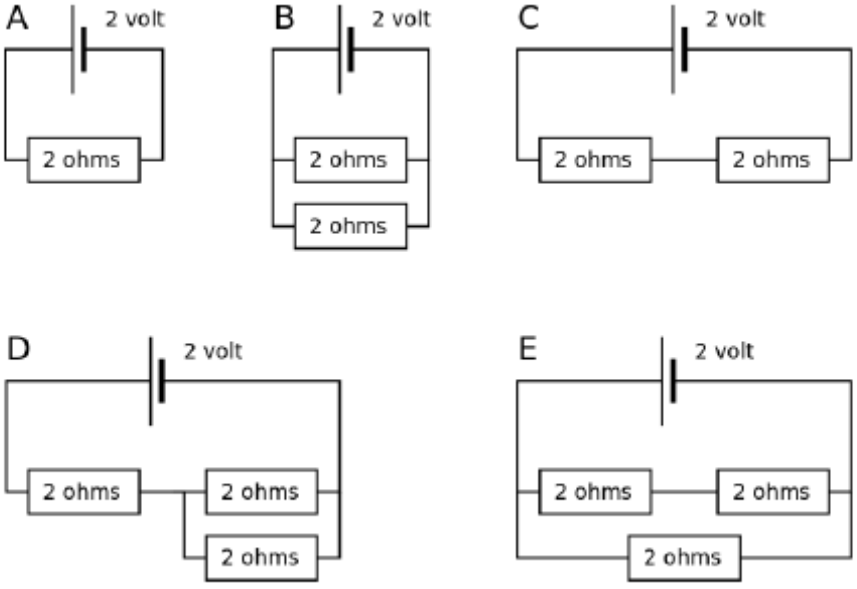
B. 2 : 1

C. 1 : 1

D. 1 : 2

E. 1 : 4

4. Consider the circuits shown below.
In which circuit is the current flowing through the cell the largest?



5. The 3rd floor observation deck of the Eiffel tower is about 280 m above street level. Assuming that the acceleration due to gravity is 10 m/s^2 and that air resistance can be ignored, the speed of a coin dropped off the observation deck when it hits the street below is:

A. 280 m/s

B. 75 m/s

C. 28 m/s

D. 10 m/s

E. Cannot be determined without knowing the mass of the coin

6. Microwaves and radiowaves can both used to transfer data from one place to another. The advantage of using microwaves is that they:

A. are not diffracted

B. travel faster

C. can transfer more information per second

D. have a longer wavelength

E. are not absorbed by the atmosphere

7. A current carrying conductor (i.e. a wire) in a magnetic field experiences a force.
Which of the following factors does NOT affect the **size** of the force.

A. The size of the current

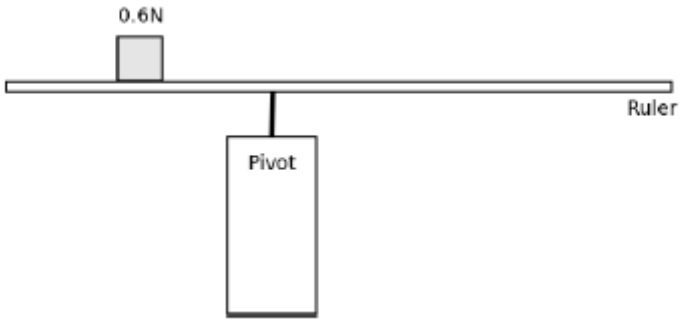
B. The strength of the magnetic field

C. The angle between the conductor and the direction of the magnetic field

D. The length of the conductor in the magnetic field

E. The direction of the current

8. A uniform ruler is 100 cm long. A 0.6 N weight is placed at the 80 cm mark.
The ruler is balanced in equilibrium on a pivot placed at the 60 cm mark.



The weight of the ruler is:

A. 1.2 N

B. 1.0 N

C. 0.6 N

D. 0.5 N

E. 0.3 N

9. A frictionless trolley accelerates down a smooth straight sloping runway.
When the mass of the trolley is doubled, the acceleration:

A. Doubles

B. Increases a bit but does not double

C. Stays the same

D. Decreases a bit but does not halve

E. Halves

10. To measure the value of a fixed resistor, readings of voltage and current can be taken and the resistance calculated from these.

The method likely to give the most accurate answer is:

A. Carefully take a single reading of V and I and use the equation V = IR to calculate resistance.

B. Take several different readings of V and I, calculate R for each and take an average.

C. Take several different readings of V and I, plot a graph of V against I and find R from the gradient

D. Assume that the value stated by the manufacturer is accurate as they have obviously tested all their resistors

E. Look it up on the internet

Section B: Short answer questions

11. Heat loss from a house can be reduced by using double glazing.
Explain how double glazing reduces heat loss from a warm room to the colder outside environment.

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12. An electric light bulb is connected to a suitable power supply.
The current flowing through the bulb quickly rises to a maximum when the power supply is first connected but then falls to settle at a lower constant value after a short time.
Explain why the constant current flowing in the bulb is less than the maximum value.

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Section C: Longer questions

13. Free fall and air resistance

A package is dropped from rest from a very tall tower and then, after some time, a parachute opens to slow the package down.

Initially the parachute is closed and the whole package is approximately a sphere of radius 50 cm and mass 40 kg.

As the package falls through the air, the drag force increases as the velocity increases and, eventually, the package achieves its terminal velocity.

The drag force (D) acting on the package is given by the equation:

Drag force = constant (k) x cross sectional area (A) x velocity (v) squared

$$D = k A v^2$$

where: $k = 0.7\ Ns^2/m^4$

A is the cross sectional area of the sphere

(i.e. the area of a circle of the same radius)

v is the velocity

(a) Show that the terminal velocity of the package before the parachute opens is approximately 27 m/s.

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(b) Without further calculation, state **and** explain how the terminal velocity would be affected if the 40 kg package had a higher density than the package considered in (a).

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The package considered in part (a) is travelling at its terminal velocity when the parachute is opened.

Assume the stated drag formula also applies to the parachute when it is open.

(c) Estimate the area of the parachute needed to reduce the terminal velocity of the package to 10 m/s.

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(d) Calculate the resultant force acting on the package and parachute immediately after the parachute opens (assume the parachute opens instantly so that the parachute is initially moving at 27 m/s).

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(e) In the space below draw an acceleration-time graph for the package from the moment it is released from rest until after the parachute opens and it achieves a final terminal velocity of 10 m/s.
Include a scale on the acceleration axis to show all significant values.
It is not necessary to indicate a scale on the time axis.

[4]

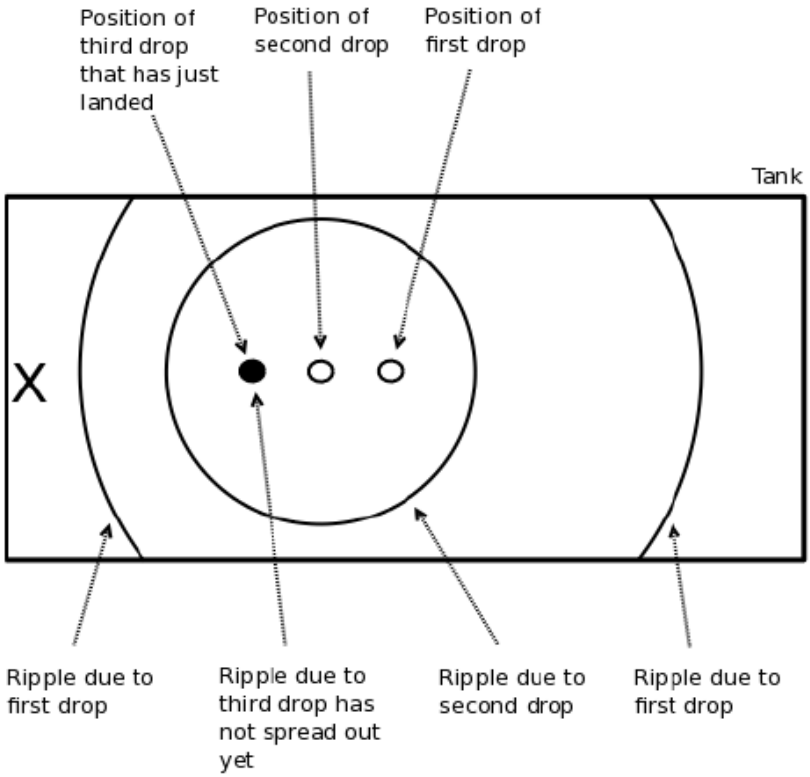
14. Sound from a moving car

A group of students investigates how the sound from a moving car appears to change its frequency (pitch) compared to when the car is stationary.

They use a model where water drops from a source moving at a constant speed cause ripples to spread out on the surface of a tank of still water.

In the model the ripples that spread out represent the sound waves from the moving car.

The diagram shows the position where three drops landed and the position of the ripples due to the first two drops. The third drop has only just landed and so the ripple has not spread out yet.



The ripples travel at speed v = 9.0 cm/s
The source moves at speed c = 4.0 cm/s
The drops occur every half second

(a) State the frequency at which the drops are released

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(b) Show that the time interval between successive ripples arriving at point X is 0.28 s

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(c) State the frequency of the waves arriving at point X

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When a car is stationary the horn has a frequency of 300 Hz.
When the car moves at 5.00 m/s towards an observer the horn appears to have a slightly higher frequency.

(d) By calculating the time period of the sound and referring to the model described previously, estimate the frequency of the horn that the observer hears.
(speed of sound = 340 m/s)

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15. Distance to the Sun

The distance from Earth to the Sun can be accurately calculated by measuring the distance from Earth to Venus when exactly half of Venus is visible as seen from Earth.
The angle between Venus and the Sun as seen from Earth is then measured.

(a) Draw a labelled diagram to show the relative positions of Earth, Venus and the Sun when exactly half of Venus is visible from Earth.

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(b) State the angle between a line drawn from the Sun to Venus and a second line drawn from Earth to Venus. (i.e. the angle between Earth and the Sun as seen from Venus)

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(c) The distance to Venus is measured by accurately timing how long it takes a radar beam to bounce off Venus and return to Earth.

Given that the speed of the radar beam is 2.9979×10^8 m/s and the 'echo' of the radar signal is detected 692.43 s after being transmitted, show that the distance to Venus is 103.79×10^6 km.

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(d) Suggest a reason why the distance to the Sun cannot be measured using radar.

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Astronomical angles are measured in fractions of a degree called minutes and seconds.

1 degree = 60 minutes of angle
1 minute = 60 seconds of angle

The angle between the Sun and Venus is measured to be:

46 degrees 12 minutes 49 seconds (46° 12' 49")

(e) Express the angle in decimal form

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(f) Calculate the distance from Earth to the Sun in km

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[**End of Questions**]