

Name:	
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Total Mark	
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2012 Physics Challenge

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

Q1

The mass of a 250 ml conical flask is 128.30 grams. A vacuum pump is used to remove the air from the flask. The mass of the evacuated flask is now measured to be 128.00 grams. ($1 \text{ m}^3 = 1000 \text{ litres}$).

The best estimate of the density of air is:

- A 0.0000012 kg/m^3
- B 0.0012 kg/m^3
- C 0.012 kg/m^3
- D 0.12 kg/m^3
- E 1.2 kg/m^3

Q2

The specific heat capacity of a metal block is measured by using a small electrical heater and measuring the corresponding change in temperature. The specific heat capacity of the block is given by the equation:

specific heat capacity = Energy transferred / (mass x change in temperature)

All of the measurements needed are shown below.

Which of the readings will cause the greatest uncertainty in the final answer?

- A Mass of block = $1.2000 \text{ kg} \pm 0.1 \text{ g}$
- B Voltage of heater = $12.0 \text{ V} \pm 0.1 \text{ V}$
- C Current through heater = $4.0 \text{ A} \pm 0.1 \text{ A}$
- D Rise in temperature = $30 \text{ }^\circ\text{C} \pm 1 \text{ }^\circ\text{C}$
- E Time heater used for = $10 \text{ minutes} \pm 2 \text{ seconds}$

Q3

Assuming no energy is transferred (i.e. lost) from the metal block during the heating process, the best estimate for the specific heat capacity of the metal as measured in question 2 is:

- A $24000 \text{ J / (kg } ^\circ\text{C)}$
- B $960 \text{ J / (kg } ^\circ\text{C)}$
- C $800 \text{ J / (kg } ^\circ\text{C)}$
- D $13.3 \text{ J / (kg } ^\circ\text{C)}$
- E $1.3 \text{ J / (kg } ^\circ\text{C)}$

Q4

A wave on a long spring has a frequency f , a wavelength λ and a velocity v . The tension in the spring changed. A new wave on the spring has three times the frequency and twice the wavelength. The wave speed is now:

- A $6v$
- B $3v$
- C $2v$
- D v
- E $1/6 v$

Q5

Consider two bulbs, X and Y, and a battery. The bulbs operate at the same voltage i.e. they light normally when each, in turn, is connected to the battery. The bulbs are connected in series with the battery. Bulb X is brighter than bulb Y.

The bulbs are now connected in parallel with the battery.

Which of the following statements is correct?

- A** Both bulbs have the same brightness
- B** Bulb X is brighter
- C** Bulb Y is brighter
- D** Which bulb is brighter cannot be determined without knowing the battery voltage
- E** Which bulb is brighter cannot be determined without knowing the current

Q6

Three small metal cubes each have a mass of 20 g.

One cube is Aluminium (density = 2.7 g/cm^3), one is Brass (density = 8.5 g/cm^3) and one is Lead (density = 11.4 g/cm^3).

Which cube, when dropped into a beaker of water, will result in the greatest rise in the water level?

- A** All will cause the same rise in water level
- B** Aluminium
- C** Brass
- D** Lead
- E** Depends which one is dropped in first

Q7

An electric sports car with a mass of 600 kg starts from rest and accelerates to achieve a velocity of 30 m/s in 7 seconds. Assuming the motors and transmission are perfectly efficient, the average power transferred from the batteries during this time is approximately:

- A** 270 kW
- B** 130 kW
- C** 64 kW
- D** 39 kW
- E** 1 kW

Q8

200 g of a radioactive isotope is prepared for medical use and has an initial activity of 6000 Bq. The isotope has a half-life of 32 hours and decays to produce another isotope that is not radioactive. A 5 g sample of the isotope is delivered to a clinic and is administered to a patient exactly 4 days after being produced. At this time the activity of the sample is approximately:

- A** 30000 Bq
- B** 750 Bq
- C** 50 Bq
- D** 19 Bq
- E** 4 Bq

Q9

In a domestic electrical circuit, there is an Earth wire included as a safety precaution to prevent the user from receiving an electric shock. Which of the following statements correctly describe the operation of the earth circuit?

- i) If a fault occurs, where the live wire touches the earthed metal case of the appliance, a large current flows along the Earth wire and blows the fuse
- ii) If a person is electrocuted, the extra current flowing through the person blows the fuse
- iii) If the Neutral wire is damaged, the Earth wire allows the circuit to continue to function

- A** (i) only
- B** (ii) only
- C** (iii) only
- D** (i) and (ii) only
- E** (i), (ii) and (iii)

Q10

A gas in a syringe is compressed slowly. No gas escapes and the temperature of the gas does not change. Which of the following statements correctly explain why the pressure of the gas increases?

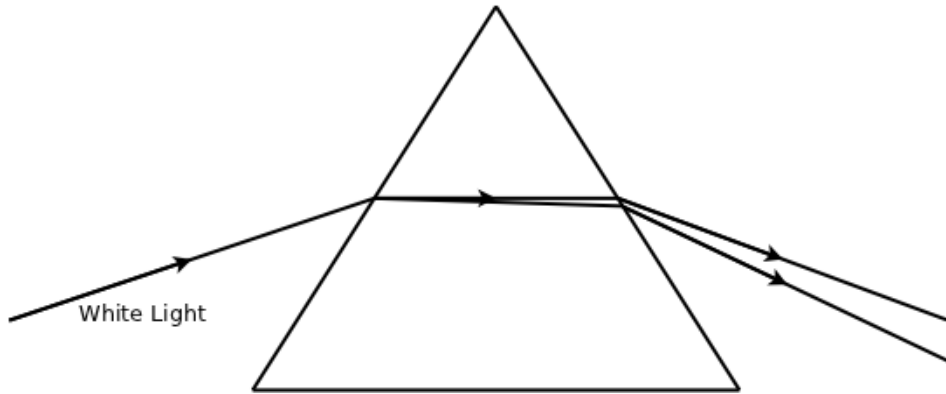
- i) The particles of the gas move faster and hit the walls of the syringe harder
- ii) The particles of the gas hit the walls of the syringe more often
- iii) The particles of the gas have less space and collide with each other more often

- A** (i) only
- B** (ii) only
- C** (iii) only
- D** (i) and (ii) only
- E** (ii) and (iii) only

Section B: Short Answer Questions

Q11

White light disperses when passed through a prism, as shown below:



Explain why the white light is split up into the different colours of the visible spectrum.

[4 marks]

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Q12

Explain why an electrical transformer works using alternating current but does not work using direct current.

[4 marks]

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Section C: Longer Answer Questions

Q13

Mechanics of a bouncing Rubber Ball.

A rubber ball falls vertically and bounces on a hard floor. If the ball hits the floor at velocity v , it rebounds with a velocity $0.9v$ i.e. it rebounds with 90% of the impact velocity.

(a) The ball is dropped from a height of 1.0 m.

Using conservation of energy or otherwise, show that the velocity of the ball as it hits the floor for the first time is approximately 4.5 m/s.

[2 marks]

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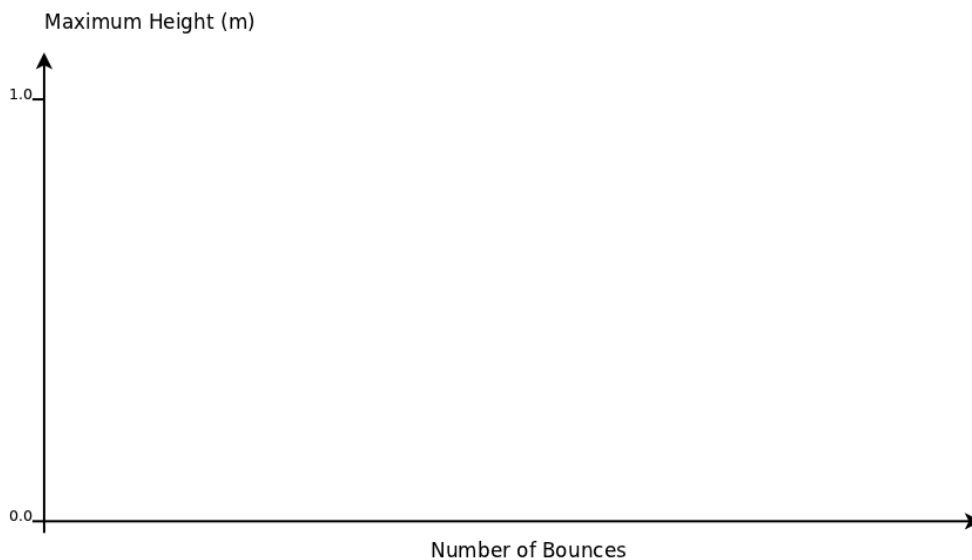
(b) Calculate the maximum height the ball achieves after the first bounce.

[3 marks]

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(c) Consider a graph of maximum height achieved after each successive bounce. Use the axes below to sketch the shape of the graph. No further calculations are expected.

[3 marks]



(d) Explain why the time between successive bounces decreases.

[3 marks]

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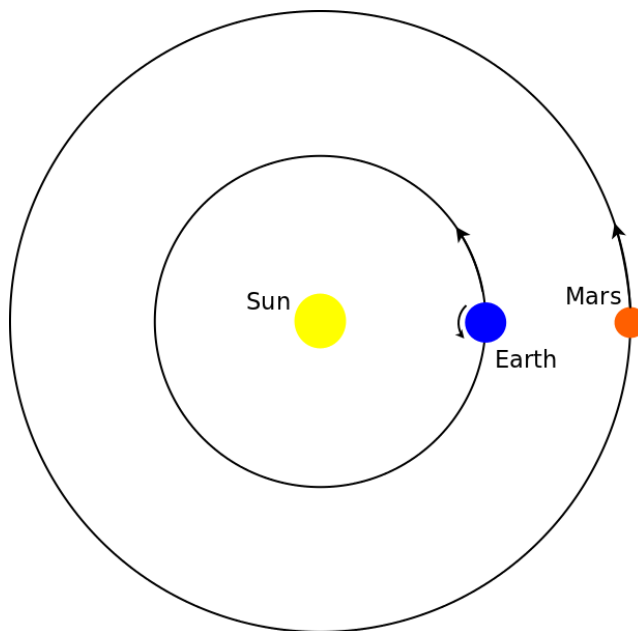
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Q14

Relative motion of Mars.

Data:	Distance of Earth from the Sun:	149 million kilometres (1.49×10^{11} m)
	Distance of Mars from the Sun:	228 million kilometres (2.28×10^{11} m)
	Length of one Earth Year:	365 earth days

The diagram, which is most certainly not to scale, shows the orbits of the Earth and Mars about the Sun.



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

[2 marks]

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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.

$T^2 \propto R^3$ or $T^2 = kR^3$ T = time for one orbit
R = radius of orbit
k = constant

(b) Using the data for Earth, calculate the value of the constant, k, and state the appropriate units.

[3 marks]

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(c) Hence, calculate the orbital period and the orbital speed of Mars.

[3 marks]

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(d) Consider the situation shown in the diagram above, when the sun, Earth and Mars are in line and Earth and Mars are on the same side of the sun. As seen from Earth, Mars will appear to move over the next few nights, relative to the background stars. State **and** explain which direction (East to West or West to East) Mars will appear to move.

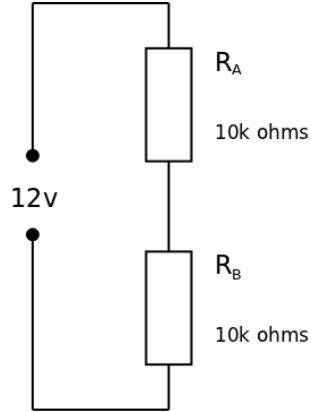
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Q15

Using a voltmeter with a potential divider.

A simple potential divider is made from two $10\text{ k}\Omega$ resistors as shown.
The combined resistance of the two $10\text{ k}\Omega$ resistors in series is $20\text{ k}\Omega$.



(a) Show that the current in the circuit is 0.6 mA .

[2 marks]

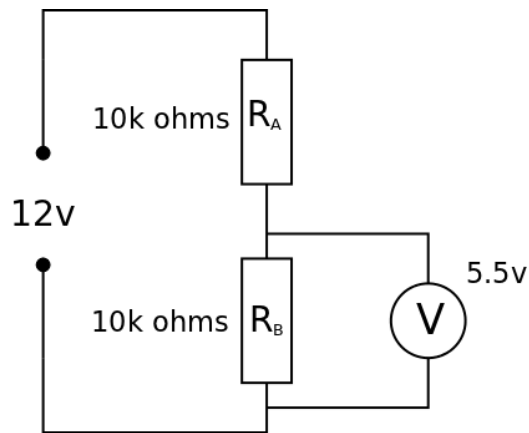
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(b) Show that the potential difference across the bottom resistor, R_B , is 6 volts.

[2 marks]

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A voltmeter is now added in parallel with the bottom resistor. The reading on the voltmeter is only 5.5 volts – less than the expected value. This is because the voltmeter has a finite resistance and therefore some current flows through the voltmeter.



(c) Calculate the potential difference across the top resistor, R_A , with the voltmeter connected as shown in the diagram above.

Hence calculate the current flowing through the top resistor, R_A .

[2 marks]

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(d) Knowing the potential difference across the bottom resistor, R_B , calculate the current through **only this resistor**.

[1 mark]

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(e) Hence, calculate the resistance of the voltmeter.

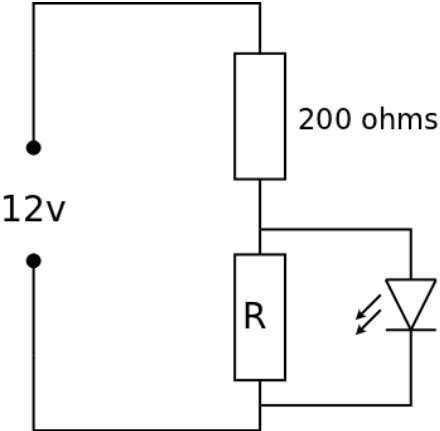
[2 marks]

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(f) A similar potential divider is now used to provide the correct voltage for an LED (Light Emitting Diode) although the resistors have lower values and the resistors are not the same as each other.



If the LED requires an operating voltage of 2 volts and a current of 20 mA, calculate a suitable value for the unknown resistor R.

[3 marks]

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END OF PAPER