AS CHALLENGE PAPER 2013

Name	
School	
Town & County	

Total Mark/50

Time Allowed: ***One hour***

Attempt as many questions as you can.

Write your answers on this question paper.

Marks allocated for each question are shown in brackets on the right.

You may use any calculator.

You may use any public examination formula booklet.

Allow no more than ***10 minutes*** *for* **section A.**

The gravitational field strength on the Earth is 9.8 N kg^{-1}

Section A: Multiple Choice

Circle the correct answer to each question. Write your answers in the table at the end of the multiple choice questions on page 3.

Each question is worth 1 mark. There is only one correct answer.

1. Two charges A and B of +3 nC and -2 nC respectively are placed close together in a vacuum, as shown below.

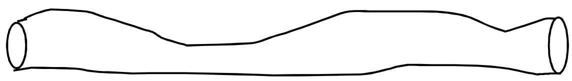
A. The force on A is greater than the force on B

B. The force on B is greater than the force on A

C. The force on A is in the same direction as the force on B

D. The force on B is in the opposite direction to the force on A

2. A long thin wire shown below has a varying cross section.



The hottest part of the filament is at:

A. all points are the same

B. it depends upon the current

C. the thickest part

D. the thinnest part

3. A mass is dropped from the roof of a building and it passes a tall window some distance below. The mass travels at speeds v_t and v_b as it passes the top and bottom of the window frame. Ignore air resistance. It is travelling at the average of these two speeds at:

A. the midpoint of the window

B. above the midpoint of the window

C. below the midpoint of the window

D. depends upon the height of the window

4. A small mass slides horizontally with energy E on a frictionless surface between two rigid walls. On each collision with a wall, the mass loses ½ of its kinetic energy. How many collisions with the wall occur before the speed of the small mass falls by a factor of 8?

A. 3

B. 4

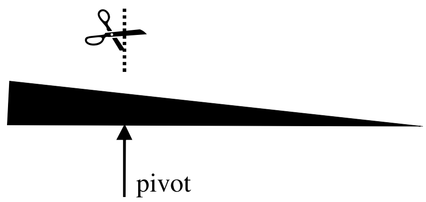
C. 6

D. 8

5. An electron is accelerated from rest through 1.5×10^{3} V. The charge on an electron is 1.603×10^{-19} C and its mass is 9.10939×10^{-31} kg. the speed of the electron will be

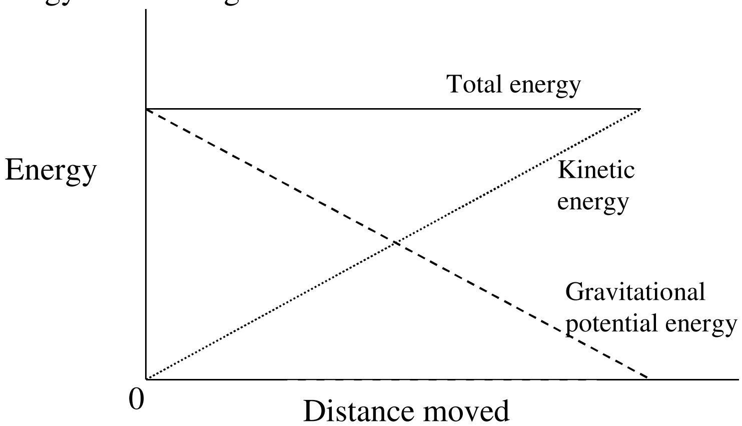
A. 2.3×10^{6} m s^{-1} B. 22.98×10^{6} m s^{-1} C. 23×10^{6} m s^{-1} D. 230×10^{7} m s^{-1}

6. A wedge shaped beam of uniform density wood balances on a pivot. If the wedge is cut in half vertically at the balance point, and each half is weighed on a balance,



A. the left hand half has a greater mass
B. the right hand half has a greater mass
C. the two halves could have the same or have different masses
D. the two halves must have the same mass

7. The graphs below show the kinetic energy, gravitational potential energy, and total mechanical energy of a moving mass.



Which best describes the motion of the mass?

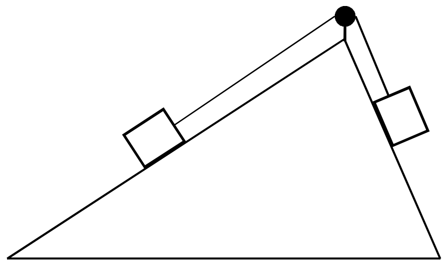
A. accelerating on a flat horizontal surface
B. sliding up a frictionless slope
C. falling freely under gravity
D. being lifted at a constant velocity

8. A red laser pen produces monochromatic light of a wavelength of 633 nm. How many photons per second are produced by a 1 mW laser if all of the energy goes into producing the red light photons? The energy of a photon is given by $E = hf$.

$$c = 3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$$
$$h = 6.6 \times 10^{-34}\ \mathrm{Js}$$
$$1\ \mathrm{nm} = 10^{-9}\ \mathrm{m}$$

A. 3.2×10^{18} B. 3.2×10^{15} C. 7.8×10^{27} D. 3.2×10^{33}

9. Two identical masses are shown hanging from a light string passing over a pulley of negligible friction. There is no friction between the masses and the slopes which are at different angles. The masses are released from rest.



A. The masses remain at rest B. The masses slide off to the left C. The masses slide off to the right D. The masses move to a balanced position

10. If a 1.5 V cell is to be recharged, each electron must be supplied with a minimum energy of

A. 1.5 eV B. 1.5 J C. 9.5×10^{18} eV D. 9.5×10^{18} J

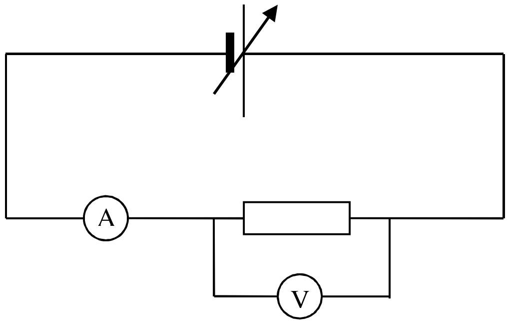
Answers

Qu 1	Qu 2	Qu 3	Qu 4	Qu 5	Qu 6	Qu 7	Qu 8	Qu 9	Qu 10

Section B: Written Answers

Question 11.

A simple circuit is set up as shown below. A resistor, which is an *ohmic* device, is connected to a variable power supply, and a current I flows through it.
The power supply is adjusted so that the potential difference in volts measured across the resistor varies as $V = 4 + 2t$ where t is the time measured in seconds from the moment the supply is turned on.



a) Why does the equation for V only work when t is measured in seconds?

____

____ [1]

b) What does the term *ohmic* mean for the resistor?

____

____ [1]

c) What would be the potential difference across the resistor at the end of 6 seconds?

____

____ [1]

d) If $R = \frac{V}{I}$, and the resistance of the resistor is 8.0 Ω,

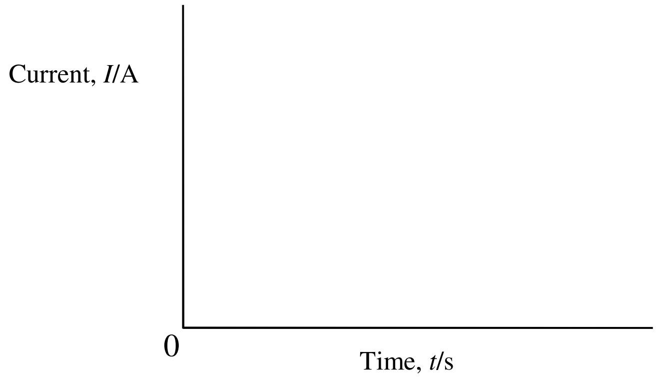
i. What current would be flowing after 6 seconds?

____

ii. Write down the equation for the current after time t.

____ [2]

e) Sketch a graph of the current against time for the first 6 seconds.
(include key values on the axes but it does not need to be accurately plotted)



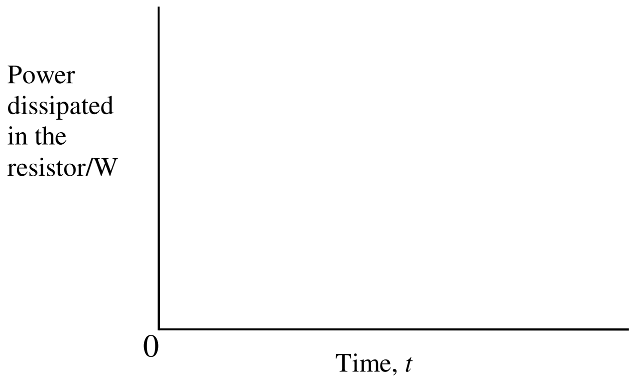
[1]

f) From the graph or otherwise, calculate how much charge flows through the resistor in the first 6 seconds.

____

____ [2]

g) Sketch a graph of the power against time for the resistor for the first 6 seconds.
(include key values on the axes)
On the graph what feature corresponds to the energy dissipated in the resistor?



[2]

h) The resistor will burn out when the power dissipated reaches 50 W. For how many seconds will the resistor survive in the circuit?

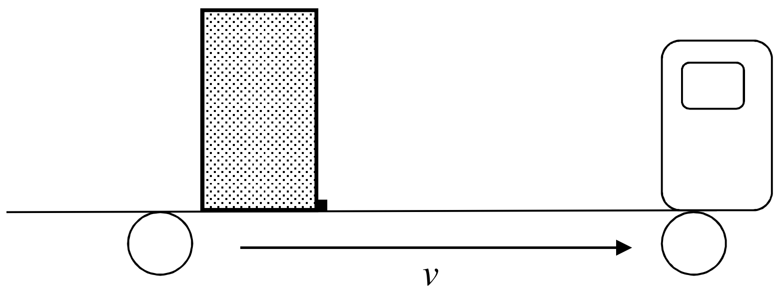
____

____ [2]

/12

Question 12.

A wardrobe filled with clothes is loaded onto a furniture van and driven along a straight road at a steady speed v. We will model the filled wardrobe as a solid rectangular block of uniform density. The van halts very rapidly, but smoothly (no conversion of mechanical energy into heat) so that the wardrobe just topples over. There is a small block to stop it sliding forwards.



a) On the right of the block sketched in figure 3, sketch in the model block at the moment of toppling over. Mark on the centre of gravity. When it is at the point of toppling, what energy change has taken place?

____

____ [2]

b) The height of the wardrobe is 2 m and its width is 1 m. By considering the energy change, calculate the minimum speed of the van for the wardrobe to topple over.

____

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____

____

____ [4]

c) If the van is going at a very high speed, it can halt with a long stopping time without the wardrobe toppling over. However, an extremely short stopping time should be avoided as the shock to the wardrobe will cause mechanical energy to be lost as heat. The question says "the van halts very rapidly". What physics time scale would be relevant to make the toppling example valid?

____

____

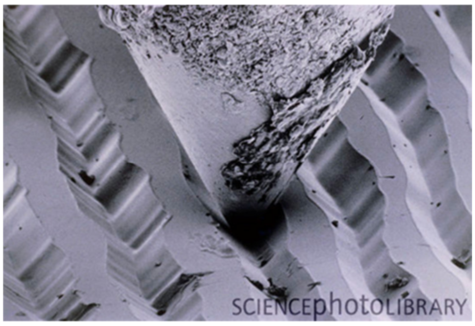
____ [2]

/8

Question 13.

A vinyl LP record is played by a stylus (a needle) being slotted into a groove on the record, with the stylus being vibrated by wavy variations in the width of the groove as shown in the picture below.

LP diameter about 30 cm



Stylus needle in a groove

a) The radius of an outer groove on the LP is 14.6 cm and the rate of rotation is 33⅓ revolutions per minute. Calculate the speed of the stylus in the groove.

____

____ [2]

b) If the frequency of vibration of the stylus is 8.0 kHz, which will produce an audible note of that frequency, calculate the size of one wavelength in the groove.

____

____ [2]

c) At the centre of the LP the radius of the groove is 2/5 of the outer groove radius. What is the size of a wavelength in the groove corresponding to 8.0 kHz?

____

____ [1]

d) If the speed of sound in air is 330 $m\,s^{-1}$, what is the wavelength in air of the note being played?

____

____ [1]

e) If the room was filled with a denser gas such as carbon dioxide, comment on whether you would expect any change to the frequency of the note that you would hear.

____

____ [1]

/7

Question 14.

An astronaut undertaking a spacewalk faces many dangers, one of which is overheating. The glare of the sun on one side of the suit, with the intense cold of space on the other side of the suit, can produce extreme temperature differences, whilst the heat generated by the astronaut inside the suit is at least as much of a problem.

We can estimate how long he could survive if his internally generated heat energy is not removed. For a 75 kg astronaut generating 240 W through his exertions, his temperature will rise rapidly and he will be unable to function when his core temperature increases to about 40.5 ^{o}C from the normal 38.5 ^{o}C.

We can assume that his body is mainly water, which has a specific heat capacity, c, of 4200 J kg^{-1} ^{o}C^{-1}. The energy supplied, ΔE, is related to the temperature rise, $\Delta\theta$, and mass, Δm, through

$$\Delta E = mc\Delta\theta$$

a) Calculate the amount of energy required to raise his body temperature by 1 ^{o}C.

____

____

____

____ [2]

b) What is the rate of increase of his body temperature due to his exertions?

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____ [2]

c) How long will it take the astronaut to become unable to function due to his temperature rise?

____

____ [1]

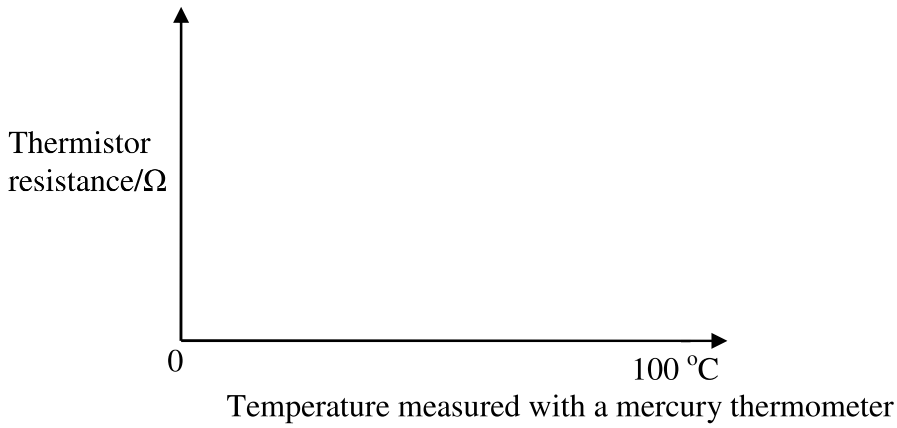
/5

Question 15.

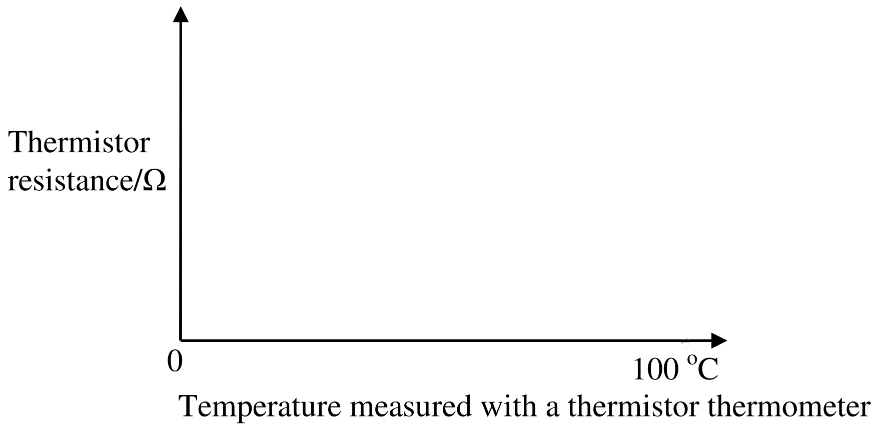
To calibrate a mercury-in-glass thermometer (an ordinary glass thermometer with a column of mercury), it is placed in ice-water and 0 ^{o}C is marked on the glass stem at the end of the mercury column. It is then placed in boiling water and 100 ^{o}C is marked on the glass stem. One hundred equal divisions are then marked on the glass stem between these two *fixed points* to form a linear centigrade scale.

A thermistor has a resistance which decreases as the temperature increases, rapidly at first and then, at low resistance, less rapidly. A thermistor thermometer is calibrated by placing it in ice-water; its resistance is 1020 Ω. When placed in boiling water its resistance is 154 Ω.

a) Sketch on the axes (include key values on the axes), how the resistance of a thermistor varies with temperature measured with a mercury thermometer.



b) Sketch on the axes (include key values on the axes), a linear temperature scale for the thermistor using the temperatures and resistances at the two *fixed points*.



[4]

c) If the thermistor scale is taken to be linear, what is the change of resistance per 1 ^{o}C between 1020 Ω and 154 Ω?

____

____ [1]

d) When the thermistor is used to measure your body temperature, the resistance is found to be 292 Ω. What change of resistance occurs when the thermistor is warmed up to body temperature from 0 ^{o}C?

____

____ [1]

e) From your answers to (b) and (c) calculate the temperature of your body using the thermistor temperature scale. Comment on your answer.

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____ [2]

/8

END OF PAPER