2009 Physics Challenge

Total Mark

Name:	
School:	
Town:	

Time Allowed: One 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). Allow about 40 minutes for this section.

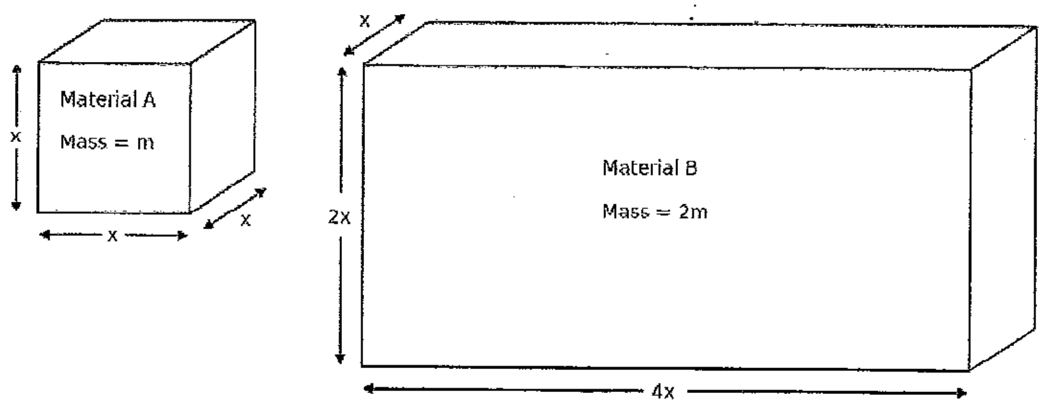
Total 50 marks; mark allocations for each sub-section are shown in brackets.

Section A: Multiple Choice Questions

Tick the box in the grid which contains the correct answer to each question.
The first row has been done as an example if the answer to question zero were C

Question	A	B	C	D	E
0 (example)			✓		
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

1. A cube of material A has sides length x and a mass m.
A block of material B has mass 2m and dimensions of x, 2x and 4x as shown.

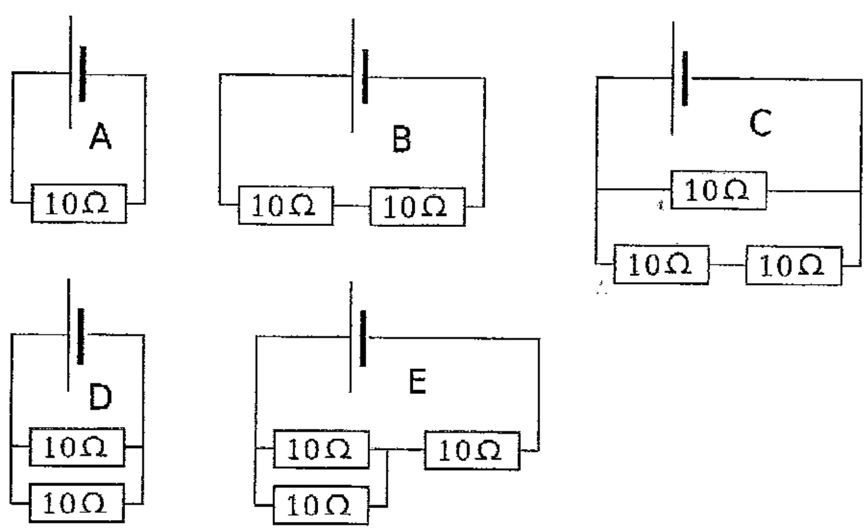


The density of material B is:

A. Four times that of material A
B. Twice that of material A
C. The same as material A
D. Half that of material A
E. Quarter that of material A

2. The 5 circuits shown all contain a 2v cell (with no internal resistance) and various combinations of 10Ω resistors.

In which circuit is the greatest power dissipated?



3. A student investigates how easily beta particles, from a radioactive source, are absorbed by aluminium. Using a Geiger-Mueller tube they measure how many counts are detected in 100 seconds for various different thicknesses of aluminium. The student finds that it is difficult to accurately determine the number of counts due to the beta particles since they are rather "drowned out" by the effect of background radiation. They want to increase the ratio of "counts due to the source" to "counts due to the background radiation".

Which of the following measures would ***not*** help?

A. Reduce the distance between the beta source and the detector from 20cm to 5cm.
B. Increase the time taken for the measurement from 100 seconds to 1000 seconds
C. Place the entire apparatus within a lead-lined box.
D. Use a source with higher activity (one which emits more beta particles per second)
E. Use a detector that only detects beta particles

4. A generator is connected to an oscilloscope so that the peak output voltage and the frequency can be measured. The generator is initially operated so that it makes 600 revolutions per minute which produces a peak output voltage of 2.0 v at a frequency of 10Hz. When the generator is then operated at 1200 revolutions per minute the output voltage and frequency will be:

	Peak voltage	Frequency
A.	greater than 2 v	20 Hz
B.	greater than 2 v	5 Hz
C.	Exactly 2 v	10 Hz
D.	Less than 2 v	20 Hz
E.	Less than 2 v	5 Hz

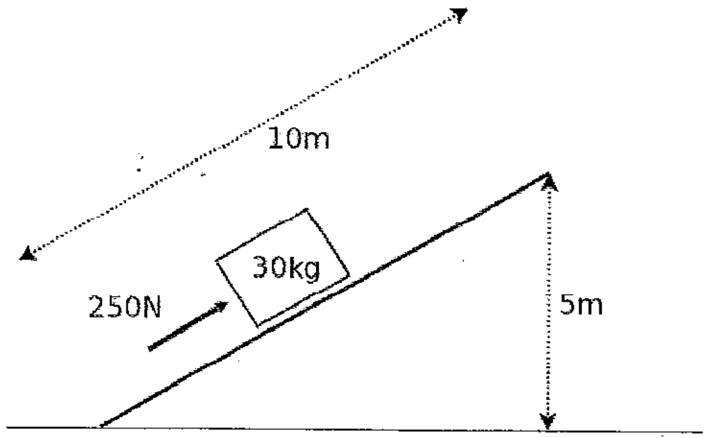
5. Car tyre pressures are often measured in units of psi (pounds force per square inch) which is not the same as the standard unit of pressure, the Pascal (where $1Pa = 1N/m^2$). Given that 1.00 inch ≡ 2.54 cm and 1.00 pound force ≡ 4.45 N, then a tyre pressure of 36.0 psi is equivalent to a standard pressure of:

A. 14.2 Pa
B. 63.1 Pa
C. 160 Pa
D. 6310 Pa
E. 248000 Pa

6. A student pushes a box of mass 30kg up a slope at a constant velocity.

They exert a constant force of 250N over the entire 10m length of the slope. The slope is inclined as shown in the diagram.

The amount of energy dissipated due to friction is:



A. 1000 J
B. 1500 J
C. 2500 J
D. 3000 J
E. 7500 J

7. When a light beam containing both red and blue light is shone through a prism it can be made to disperse (split into separate colours) due to the refraction of the light. Which of the following statements is ***true***?

A. The speed of the red light is greater than the speed of blue light in the prism.
B. The frequency of the red light is higher than the frequency of the blue light.
C. The material of the prism has a lower refractive index for blue light than for red light.
D. The wavelength of the red and blue light increases inside the prism.
E. Before entering the prism, red light travels faster than blue light.

8. A 3.00kW electric kettle can bring 1.00 litre of cold tap water, initially at 15.0°C, to the boil in 2.00 minutes. (For cold water, $1cm^3$ has a mass of 1g).

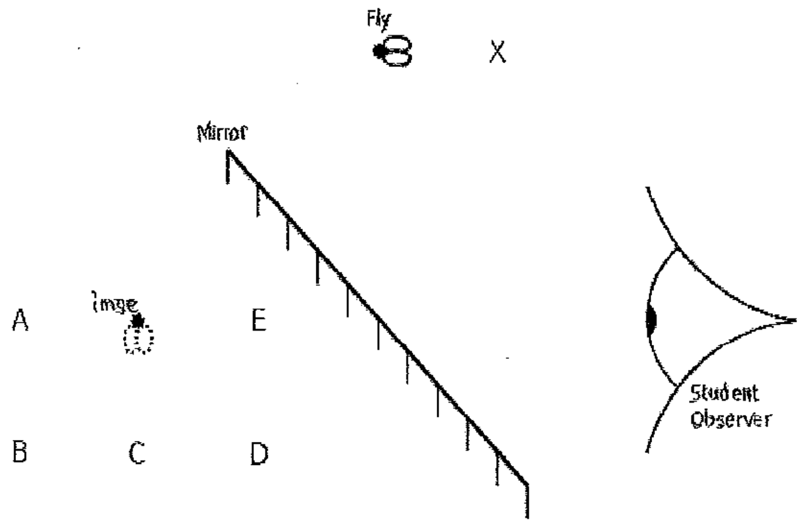
This suggests an approximate value for the specific heat capacity of tap water of:

A. 24000 J/kg/°C
B. 4240 J/kg/°C
C. 4180 J/kg/°C
D. 71.0 J/kg/°C
E. 4.24 J/kg/°C

9. A student observes the image of a fly in a plane mirror.

The fly then moves to the position marked X.

Where does the image of the fly move to?



10. A cannon fires a cannonball of mass m vertically upwards with an initial velocity v and it achieves a maximum height h.

A second cannon now fires a different cannonball of mass 2m vertically upwards with an initial velocity of 2v.

The second cannonball achieves a maximum height of:

A. 8h
B. 4h
C. 2h
D. h
E. h/2

Section B: Short answer questions

Question 11.

It can be demonstrated in a science laboratory that a **charged** plastic rod can be used to pick up small **uncharged** objects such as scraps of paper or pieces of polystyrene.

Explain clearly how a positively **charged** plastic rod is able to attract a small **neutral** object.

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Question 12.

Consider a sample a radioactive isotope that decays to produce a stable isotope.

Explain why the **activity** of the sample reduces over a period of time.

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Section C: Longer Questions

Question 13:

A space rocket is launched vertically from the surface of the Earth.

When the rocket is launched it has a mass of 746 tonnes (1 tonne = 1×10^3 kg) and produces a thrust of 11.95 MN.

a) Calculate the initial acceleration of the rocket

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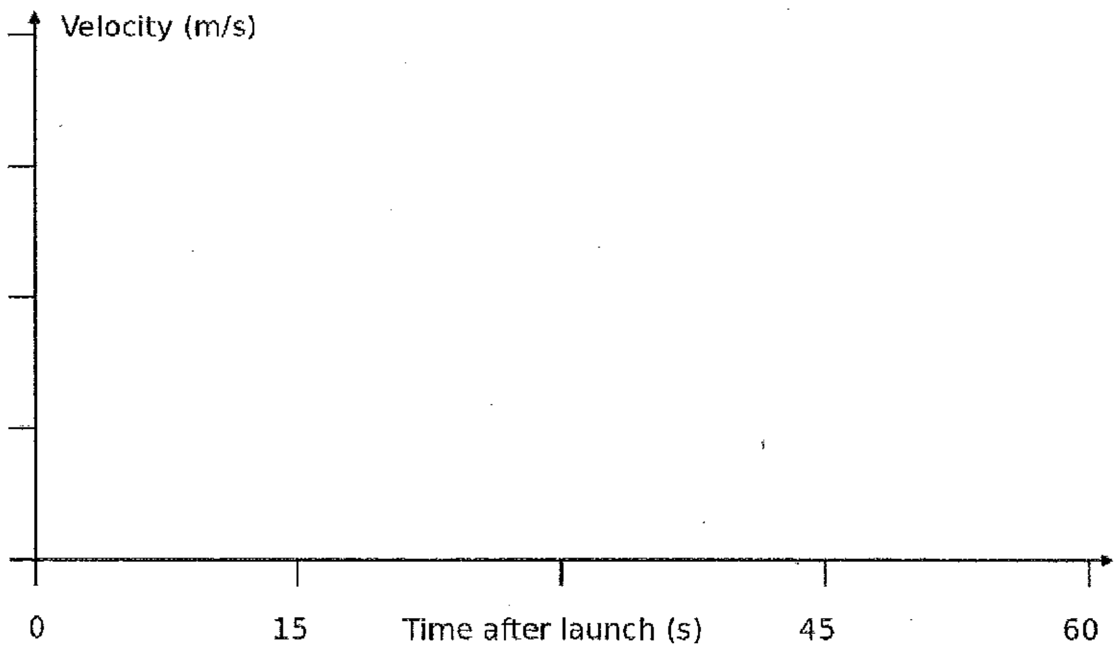
b) On the axes below, plot a velocity – time graph for the first 60s of the rocket flight. Label the velocity axes with an appropriate scale.

Assume the rocket starts from rest and the acceleration remains constant. [2]



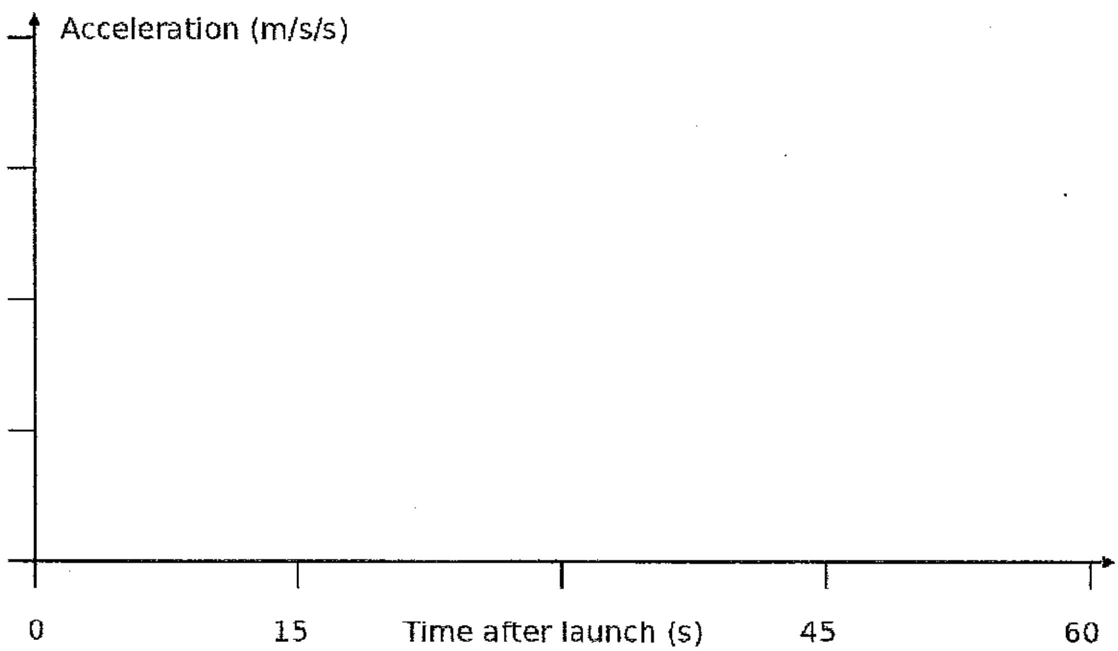
c) In reality the rocket burns 2235 kg of fuel per second and so the overall mass of the rocket reduces, this affects the acceleration.

On the axes below sketch an acceleration - time graph for the first 60 seconds of the rocket flight taking into account the reduction in mass.

(Your sketch graph should clearly show the shape of the graph and pass through approximately the right points but does not have to be a completely accurate plot).

Label the acceleration axes with an appropriate scale.

Assume that the thrust remains constant through-out this period. [3]



d) The actual acceleration of a rocket, 60 seconds after launch, does not quite agree with the simple theoretical value. Suggest one factor, other than thrust or mass, that may also affect the actual acceleration.

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e) Due to the rotation of the earth, a rocket already has kinetic energy, even before it is launched. It is often advantageous to launch a rocket from as close to the equator as possible so that the rocket benefits as much as possible from this kinetic energy.

Given the following:

- The European Spaceport, in French Guiana, is at a latitude of 5.3° North of the equator
- NASA's launch facilities, at Cape Canaveral, are at a latitude of 28.3° North of the equator
- The radius of the earth is 6400 km

Show that rockets launched from Europe's Spaceport benefit from about 27% more kinetic energy at take-off than a similar rocket launched from Cape Canaveral. [3]

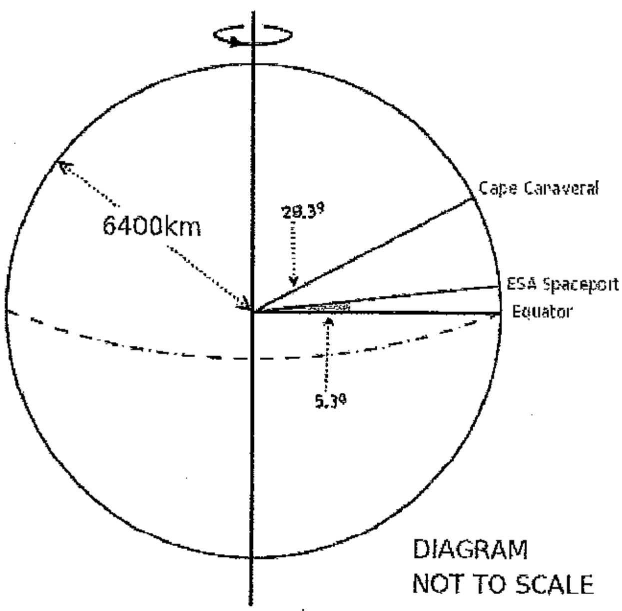

DIAGRAM
NOT TO SCALE

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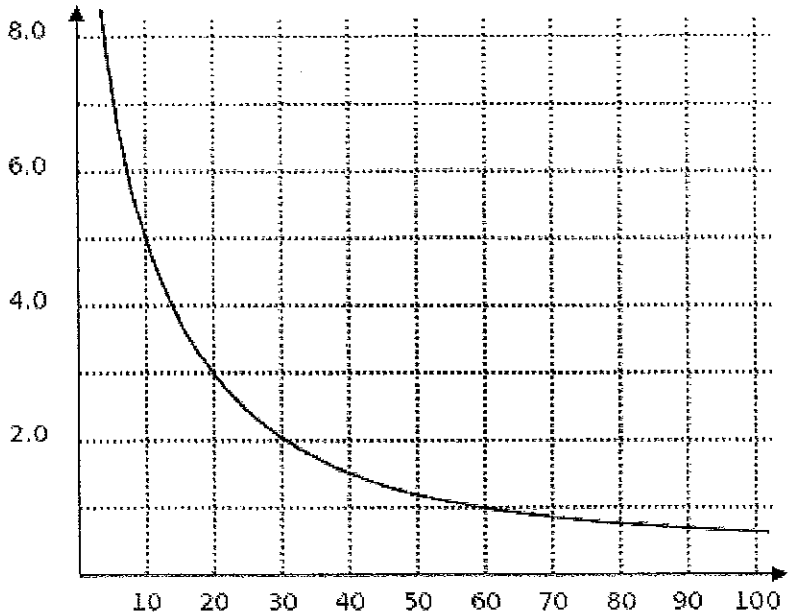
Question 14.

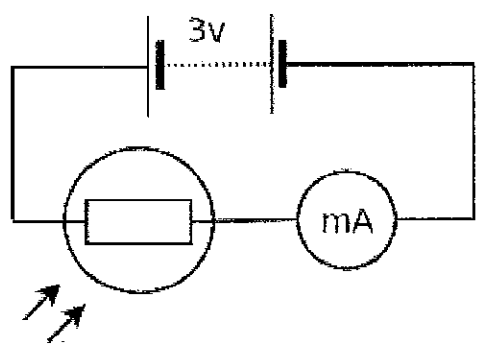
A student constructs a light meter from a light dependant resistor (LDR).

The resistance of the LDR changes with light level, as shown below.



a) The first circuit the student tries is made from a 3.0v battery and an ammeter as shown.

Assume the battery and ammeter have zero resistance.



Calculate the reading on the ammeter when the light level is 10 lux.

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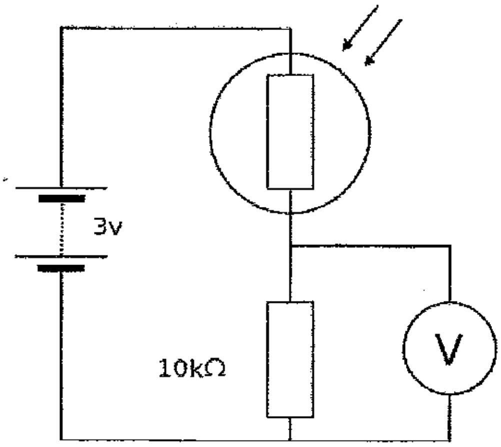
b) The student finds that in bright light the current is too high and the battery goes flat too quickly.

To overcome this problem, a new circuit is constructed from two resistors and a voltmeter, as shown.

Assume the voltmeter has an infinite resistance.



i) Show that, when the light level is 10 lux, the current in the circuit is 0.2 mA.

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ii) Hence calculate the reading on the voltmeter when the light level is 10 lux.

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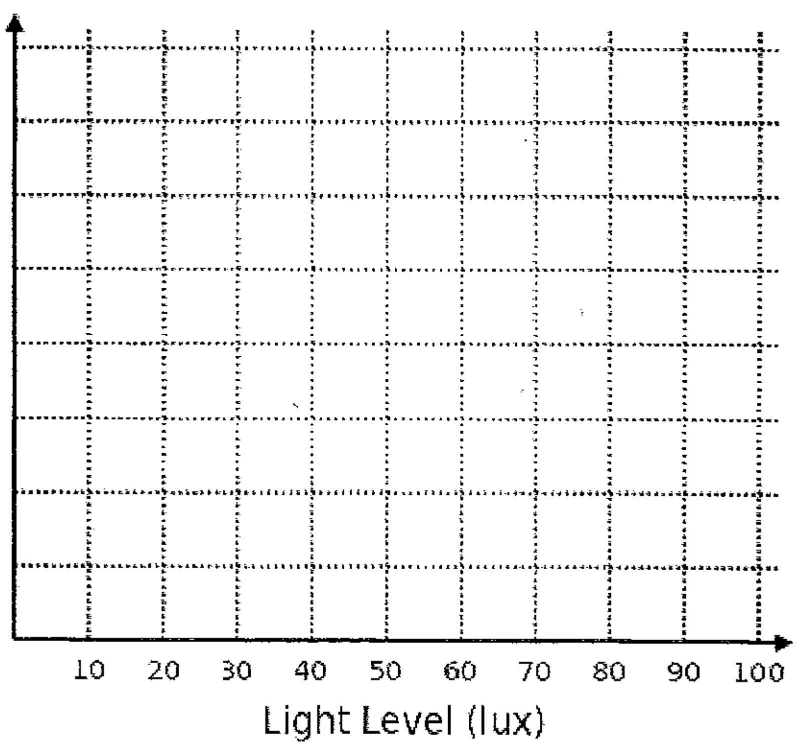
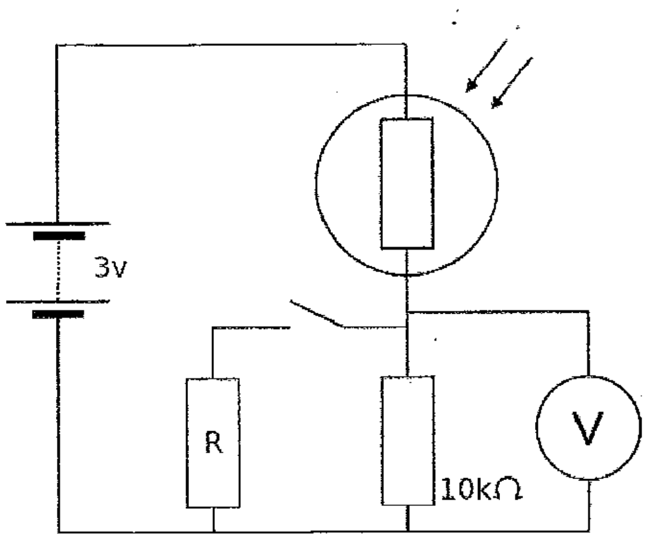
c) On the axes shown, sketch a graph of voltage versus light level for the circuit shown above. Add an appropriate scale to the voltage axes. [3]



d) The student modifies the circuit, to that shown in the diagram below, with an unknown resistor R:



When the light level is 60 lux and the switch is closed the voltmeter reads 1.0v.

i) Calculate the value of R.

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ii) Explain carefully why the student might wish to alter the circuit in this way.

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Question 15.

Some students investigate the amount of energy available from solar radiation.

a) For their first investigation they use a children's outdoor paddling pool which is 4m in diameter and 20cm deep. Cold water is allowed to flow in to one side of the pool at a rate of 20 litres per minute, and the same amount of water overflows from the other side of the pool (1 litre ≡ 1kg of water). The water in the pool mixes evenly so that it is all heated by the energy from the sun and the pool is in thermal equilibrium.

On a good sunny day, the sun provides energy to raise the temperature of the water between entering and leaving the pool - that is, the water flowing out of the pool is warmer than the water flowing in.

The students measure the temperature rise to be 3°C.

i) Given that the specific heat capacity of water is 4200 J/kg/°C, calculate the energy from the sun, received by the 20 litres of water, between entering and leaving the pool in one minute.

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ii) Therefore, calculate the solar **power per square metre** falling on the surface of the pool.

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iii) Suggest why the value calculated in (a)(ii) is likely to be too low.

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b) For their second investigation, the students use an electrical (photovoltaic) solar cell connected in a simple circuit, as shown. The solar cell is placed in the **same** sunlight as in the first investigation.

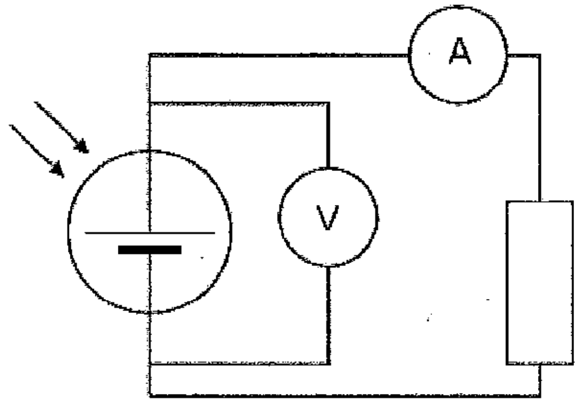
In this investigation the following measurements were made:

Dimension of solar cell = 15 cm x 15 cm

Current in circuit = 200 mA

Voltage across solar cell = 7 v

(Recall P = V x I)



Photovoltaic
Solar Cell

i) Calculate the **power per square metre** generated by the solar cell.

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ii) Assuming that the value for the solar power per square metre, calculated in (a)(ii), is the correct value and that it is the same for the solar cell, calculate the efficiency of the solar cell.

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c) The students find the following facts about solar radiation on earth:

- The power per square meter is also known as intensity (I).
- Above the atmosphere, the intensity (I) of the solar radiation is about $1.4kW/m^2$.
- The intensity of the solar radiation (I) is related to the power output (P) of the sun by the equation $I = P / 4\pi r^2$ where r is the distance between the earth and the sun.

Given that $r = 150 \times 10^6$ km, calculate the power output of the sun.

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d) Finally the student researches the use of photovoltaic solar panels to generate electricity for satellites.

i) Assuming that the electrical solar panels of a satellite in orbit around the Earth are 40% efficient, calculate the surface area of the solar panels required to produce an electrical output power of 200W. (Recall $I = 1.4kW/m^2$)

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ii) Calculate the surface area of similar solar panels needed to generate 200W of power for a similar satellite in orbit around Jupiter at a distance of 780×10^6 km from the sun.

(Hint: Calculate the intensity of solar radiation for $r = 780 \times 10^6$ km)

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