PHYSICS CHALLENGE 2007

ONE HOUR 15 MINUTE PHYSICS COMPETITION PAPER

FRIDAY 2 nd MARCH 2007

We hope teachers will set and mark the enclosed paper for their final year GCSE students, or equivalent students in Scotland. Xerox copies of the paper should be produced for your students. The solutions and marking scheme are attached. It is intended that the paper should be taken on Friday 2 nd March. However if this is not possible, any date during the period 3 rd – 9 th March will be acceptable. Scripts must be posted in sufficient time to arrive by first class post on Monday 12 th March at the Olympiad Office at Leicester. Any scripts arriving after this date cannot be considered for an award. There is no charge for entering the competition.

After the scripts have been marked please send those scripts with marks exceeding 41 , the scripts of the Gold Medal Certificate students to be considered for the award of a book prize, together with the entry form ,which is on the following page, and request for certificates to:

Dr Cyril Isenberg
Physics Challenge Competition
British Physics Olympiad Office
Department of Physics and Astronomy
University of Leicester
University Road, Leicester LE1 7RH

We will invite the ten outstanding Gold Medallists, together with their teachers, to the Physics Challenge Presentation Ceremony at The Royal Society in London on Thursday 26 April 2007. Prizes and certificates will be despatched to all medallists, who are not amongst those invited to the Presentation, in May. Teachers are requested to complete the certificates, according to the scheme specified on the last page, and present them to their students .

PHYSICS CHALLENGE 2007

ENTRY FORM

Name of teacher _____

School _____

Address _____

_____

Tel. No. _____

Email _____

TOTAL NUMBER OF ENTRIES _____

Full names and marks of Gold Medallists with more than 41 marks (first name followed by surname) to be considered for the award of a book prize.

NAME	TOTAL MARK	NAME	TOTAL MARK

Please complete and return the request for certificates at the end of this booklet.

TEACHERS' COMMENTS

We welcome comments concerning questions in this Physics Challenge paper.

Comments:

Total Mark

2007 PHYSICS CHALLENGE

Name:	
School:	
Town:	**COUNTY**

Time Allowed: One hour and 15 minutes

Attempt all questions.
Write your answers on this question paper.
Marks allocated are shown in brackets on the right; total 60.
You may use any calculator.

Allow 15 minutes for Section A, 35 minutes for the three questions of Section B, and 25 minutes for the question in Section C.

You may take the strength of Earth's gravity to be 10 N/kg.

Section A: Multiple Choice

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
0 (example)			✓	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

1. The energy required to lift a 5kg bag of potatoes onto a shelf 1.5m off the floor in a supermarket is approximately

A 7.5 J
B 50 J
C 75 J
D 112 J

2 The Earth's gravitational field is stronger in Britain than in Brazil. 100kg of sugar is to be loaded on board ship in Brazil. You will get the highest weight reading on the scales when the sugar is unloaded in Britain, if

A the Brazilian port loads 100kg of sugar using Brazilian scales, and the British port uses British scales
B both ports use Brazilian scales
C both ports use British scales
D the Brazilian port uses British scales, and the British port uses Brazilian scales.

3 A special kind of ruler can be used to measure reaction times. You position the 'zero' mark between your friend's first finger and thumb. Without warning, you let go of the ruler, and your friend has to grab it as soon as possible. You can read the reaction time from labelled marks on the ruler. The marks are separated from each other by 0.01s intervals of ' falling' time. This means that

A each mark is the same distance from the one before it
B the marks get closer together as you go away from the zero
C the marks get further apart as you go away from the zero
D as you go away from the zero, the marks get closer together then further apart again.

4. The car of a frictionless lift is exactly balanced by its counterweight when it is empty. The motor is perfectly efficient, but does not generate useful electricity when the lift slows down. The electrical energy used when lifting a person from the ground to the tenth floor of a building does NOT depend on

A the maximum speed reached by the lift
B the mass of the person in the lift
C the mass of the lift car plus passenger
D the height of each floor of the building

5. Two warthogs have equal kinetic energy when running at top speed. One runs 5% faster than the other. This means the mass of the faster one is roughly

A 5% less than the slower one
B 10% less than the slower one
C 2.5% less than the slower one
D 5% more than the slower one

6. A secret agent has to pick up a vital document at exactly 11am.The journey involves 32km on roads where the average speed is 80km/hr, and 6.6km on roads where the average speed is 50km/hr. The journey must start begin at
   A 10:16
   B 10:24
   C 10:28
   D 11:32

7. Woodpeckers measure frequency in rattles and time in pecks. The frequency in rattles is equal to the number of waves made during each peck. If one rattle is the same as 20Hz, one peck is
   A 20s
   B 1.0s
   C 0.02s
   D 0.05s

8. A cricket match must not be continued if the light level falls below 180 lux. Lux are units of light intensity. At 180 lux, the resistance of a light dependent resistor (LDR) is 1.5kΩ. You construct a circuit for use by an umpire with the LDR, a 9V battery and an ammeter all connected in series. One day the ammeter reads 10mA. Should the game continue?
   A Yes, because the current is higher than that expected at 180 lux
   B Yes, because the current is lower than that expected at 180 lux
   C No, because the current is higher than that expected at 180 lux
   D No, because the current is lower than that expected at 180 lux.

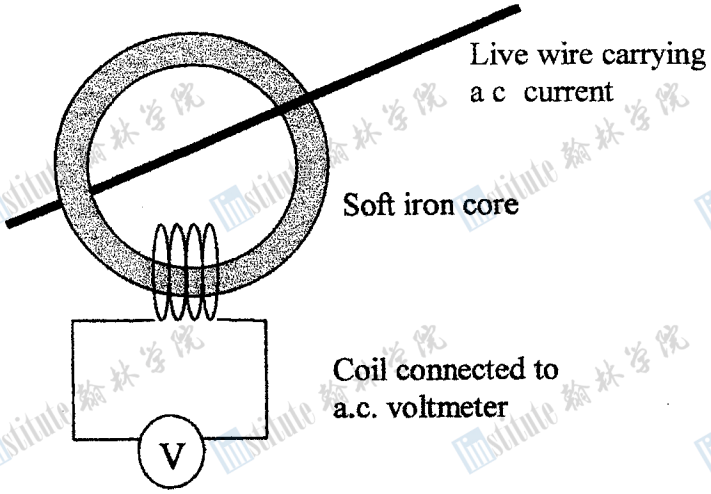
9. A residual current device (RCD) is a type of circuit breaker which has saved many lives. It is incorporated into the main switch in many modern fuse boxes, and turns the power off if a current of more than 30mA flows through a fault (or a person) to earth. It can tell that this is happening when
   A the current in the neutral wire is more than 30mA
   B the current in the neutral wire is greater than that in the live wire
   C the current in the live wire is greater than that in the neutral wire
   D the current in the live wire is greater than that in the earth wire.

10. The Moon takes 27 days to complete one orbit round the Earth. The Earth takes 24 hours to rotate once about its own axis. Observers on Earth always see the same side of the Moon. This means that a person on the side of the Moon facing the Earth will
   A never experience night
   B never experience day
   C will experience night and day in 24 hour cycles (like on Earth)
   D will experience night and day in 27 day cycles

[10 marks]

Section B: Written Answer

1. Electricians can measure the current flowing in a cable without disconnecting it. They do this using a 'clamp ammeter'. The device is shown in the diagram.



a) Why does the voltmeter show a reading when there is a current in the mains cable?

[2]

b) If the current in the cable doubles, what do you expect to happen to the reading on the voltmeter? Give your reason.

[2]

c) Would this device work in another country where the electricity network operates on direct current (d.c.)? Explain.

[3]

d) Could you use this device to measure the current flowing in a neutral wire? Explain.

[2]

2. A mechanic uses a hydraulic car lift to raise a car which requires a new exhaust. The mass of the car is 900kg. The car is driven onto a metal grid, which is supported by four columns in a rectangular arrangement. Hydraulic fluid enters cavities in the columns, and the car is lifted 2m.

a) Calculate the force exerted by each of the four columns on the supporting grid. State any assumptions.

[3]

Each of the supporting columns is cylindrical, with a cylindrical cavity inside each. The cavity has a cross-sectional area of $20cm^2$.

b) Calculate the minimum pressure of the hydraulic fluid required to lift the car.

[3]

c) The hydraulic fluid for all of the columns is compressed in another cylinder by a pump. This 'master cylinder' has a cross sectional area of $1cm^2$. Calculate the force exerted on the cylinder by the pump in order to lift the car.

[3]

d) If the pump broke down, could the mechanic operate the master cylinder with physical force? Explain.

[2]

e) Assuming the fluid to be incompressible, calculate the volume of fluid which would need to be pumped into the master cylinder to make the car rise by 2m.

[3]

3. This question is concerned with stretching springs. A loaded spring is mounted vertically as shown in Figure 1. h_1 is the height of the bottom of the load from the bench.

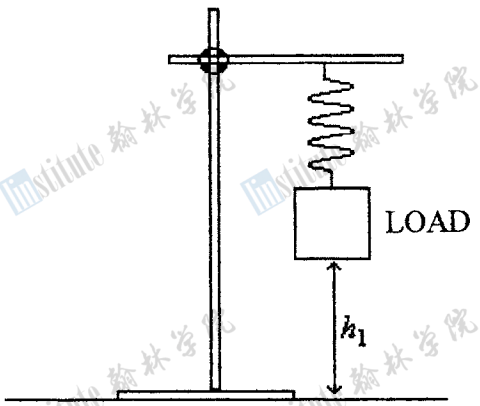


Figure 1

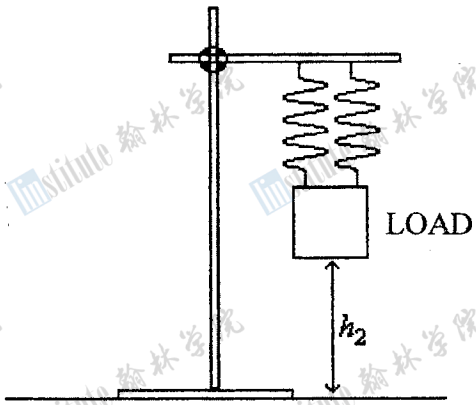
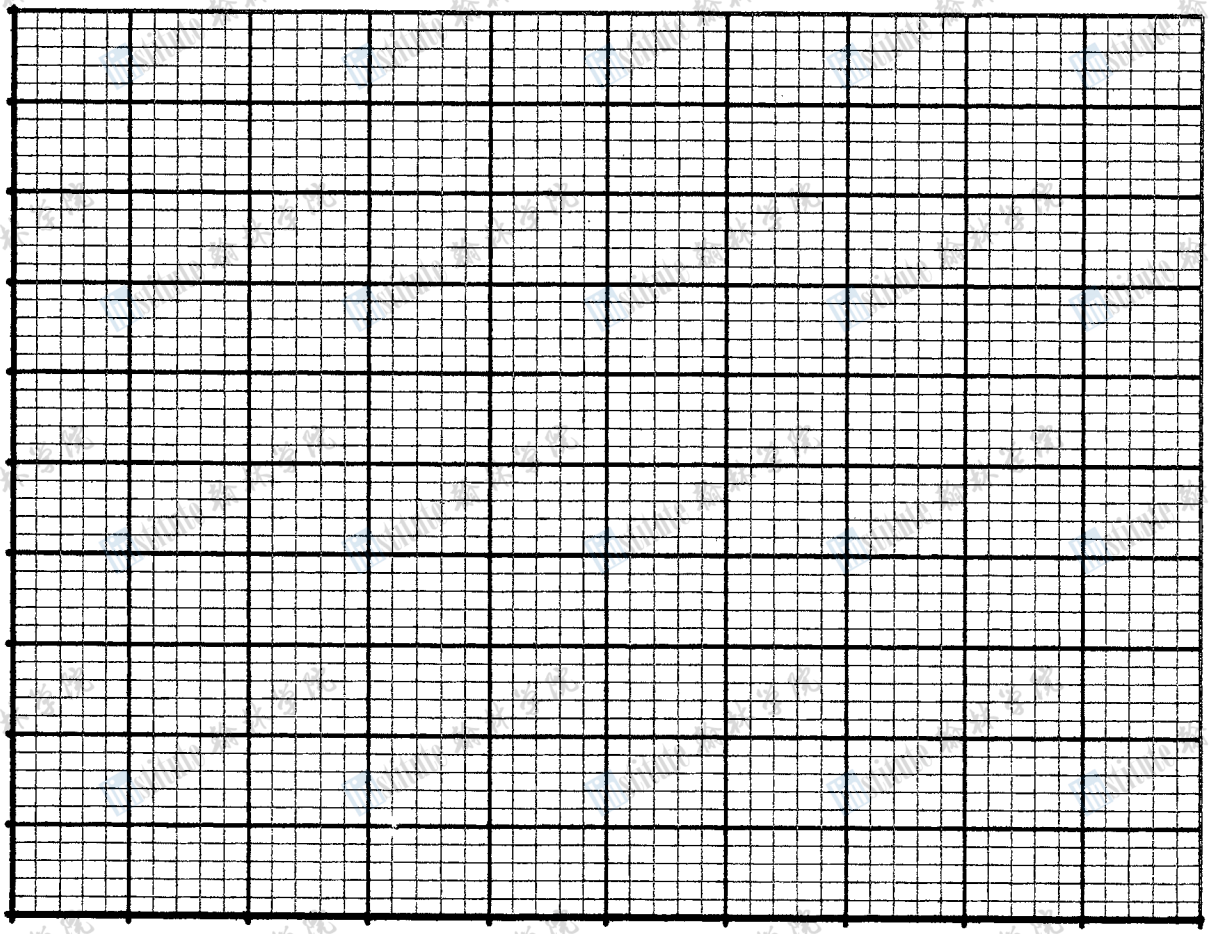


Figure 2

A student measures h_1 for different loads. All loads are cubes of equal dimensions, but are of different densities. The measurements are shown in the table:

Load/N	h_1/mm
1.00	184
2.00	179
3.00	173
4.00	168
5.00	162

a) Plot a graph of h_1 (y-axis) against Load (x-axis). You should use a scale for h_1 of 140 mm – 190 mm, and a scale for Load of 0N – 10N.



[5]

b) What is the meaning of the intercepts on the axes?

[3]

c) Use your graph to calculate the *change in Load* which gives a *change in* h_1 of 1 mm. Show your working.

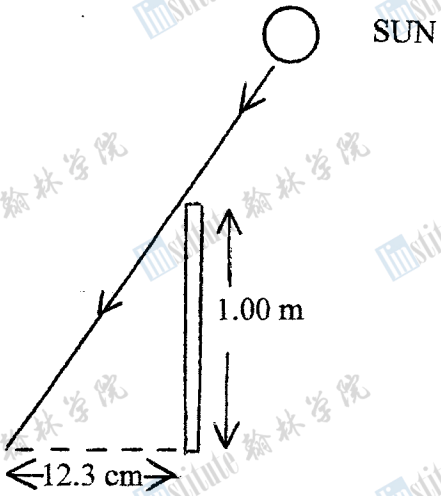
[2]

In Figure 2 a similar experiment is performed with springs identical to the spring in Figure 1. The two springs are effectively sharing the load.

d) On your graph, draw a line that would represent the data for the experiment in Figure 2. What is the value of h_2 when the load is 10 N ? [3]

Section C: Written Answer

Eratothsenes, in about 300 BC, determined the circumference of the Earth from available data. He discovered that at Syrene, S, the Sun was directly overhead at noon on a certain day of the year. At exactly the same time, on the same day, of the year, Eratothsenes measured the angle between the Sun's rays and the vertical at Alexandria, A, 800 km due North of Syrene. He did this by measuring the length, 12.3 cm, of the shadow cast by a vertical pole 1.00 m in length:



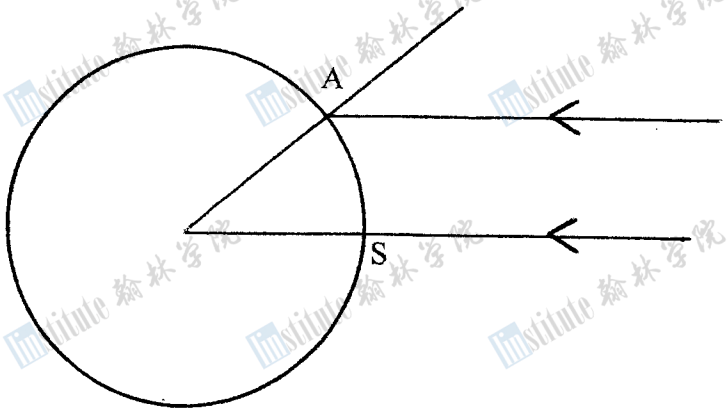
The diagram is not to scale.

a) Show that the angle the Sun's rays make with the vertical is about 7.0°.

[3]

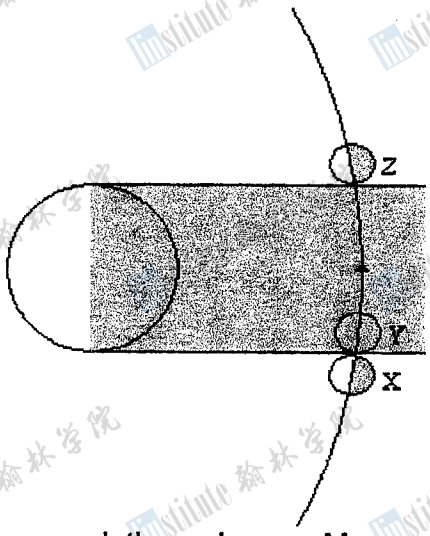
b) From the information above, show that the circumference of the Earth, C, is about 4.1×10^4 km.

HINT: Study the following diagram indicating Syrene, S, and Alexandria, A.



[3]

Later Aristarchus of Samos (310 – 230 BC) also determined, approximately, the size and distance of the Moon. During an eclipse of the Moon, the Moon passes through the Earth's shadow:



It was observed that the Moon moved through *one* Moon diameter (measured against the background stars) in one hour (i.e. from position X to position Y in the diagram). It was also observed that the Moon took approximately 2.5 hours to pass through the Earth's shadow region, during which time the full Moon was obscured from view (i.e. from Y to Z).

c) Calculate the width of the shadow region in terms of the Moon's diameter.

[2]

d) Assuming, as is clear from the diagram, that the shadow region of the Earth is equal to *one* Earth diameter, show that the diameter of the Moon is about 5.2×10^3 km.

[2]

Let us use the results of parts (a) – (d) to determine the distance to the Moon. It turns out that a coin 0.8cm in diameter held 0.88 m from the eye just blots out the Moon.

e) Calculate the ratio of the coin's distance from the eye to the coin's diameter.

[1]

f) Calculate the distance from the Moon to the observer with the coin.

[3]

End of Questions