PHYSICS CHALLENGE 2006

ONE HOUR GCSE PHYSICS COMPETITION PAPER

FRIDAY 3 rd MARCH 2006

We hope teachers will set and mark the enclosed one hour paper to 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 enclosed. It is intended that the paper should be taken on Friday 3 rd March. However if this is not possible any date during the period 4 th – 10 th March will be acceptable. Scripts must be posted in sufficient time to arrive by first class post on Monday 13 th March at the Olympiad Office in Leicester. **Any scripts arriving after this date cannot be considered for an award. There is no charge for entering the Physics Challenge.**

After the scripts have been marked, please send those scripts with marks exceeding 35, together with the completed entry form and request for commendation certificates, to:

Dr Cyril Isenberg
Physics Challenge
British Physics Olympiad Office
Department of Physics and Astronomy
University of Leicester
University Road
Leicester LE1 7RH
(Tel: 01227 823768)

The scripts will be moderated and grouped into gold, silver and bronze medal catagories for the award of prizes and certificates.

We will invite the fifteen top gold medallists, together with their teachers, to the Physics Challenge Presentation Ceremony at The Royal Society in London on Thursday 27 th April 2006. Prizes and certificates will be despatched to medallists, who are not amongst those invited to the Presentation Ceremony, in May. Teachers should complete the certificates and present them to their students.

PHYSICS CHALLENGE 2006

Total Mark	* Marks

Name	
School	
Town & County	

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 type of calculator.

Allow 10 minutes for Section A, 30 minutes for the first four questions of Section B, and 20 minutes for the final question.

The gravitational field strength on the Earth: 10 N/kg
The acceleration due to gravity on the Earth: 10 m/s^2

Section A: Multiple Choice.

Tick the box, which contains the correct answer to each question.

1. One of the Apollo astronauts dropped a hammer on the Moon where the acceleration due to gravity is 1.7 m/s^2. If it took 1s for the hammer to hit the surface of the Moon, what was its average speed during that second?

A. 0.85 m/s	B. 1.7 m/s	C. 3.4 m/s	D. 4.9 m/s	E. 9.8 m/s

2. Beavers measure the energy needed to drag a tree trunk to a dam. The dragging force is measured in grunts, the distance in steps. The energy needed is measured in

A. grunt step^2	B. steps/grunt
C. grunt steps	D. grunts/step
E. grunts	

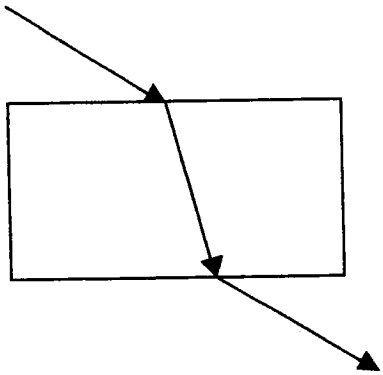
3. A Martian measures a hammer on Earth, and then repeats the measurements on Mars. Which will be **different**?

A. The mass	B. The weight	C. The density	D. The volume	E. The length

4. A double-decker bus is in danger of being blown over on a very windy day. To make it more stable the driver should ask the passengers to

A. Spread out evenly over the bus	B. Lie down and spread out evenly over the bus
C. All go downstairs	D. All go upstairs
E. Winch the engine upstairs	

5. The diagram below shows a ray of light entering a glass block. Which statement is **false**?



A. The light travels more slowly in the glass than in air.	B. The light ray is bent towards the normal to the surface as it enters the glass.
C. The light has a lower frequency in the glass than in the air.	D. The wavelength of the light is smaller in the glass than in the air.
E. The phenomenon depicted here is called refraction.	

6. One of the following forces does **no** work. Which is it?

A. A teacher push-starting his car.	B. The brakes slowing a car down.
C. A vice, holding a piece of wood ready for sawing.	D. Your weight, as you fall from a diving board.
E. A mass hanging on a spring	

7. The count rate from a radioactive source is measured at one minute intervals. The results are recorded as follows:

time/s	0	60	120
count per second	16883	4120	1020

What is the approximate value of the half-life?

A. 20 s	B. 30 s	C. 40 s	D. 50 s	E. 60 s

8. A 20kg table top is to be supported by four 2kg legs. Adjacent legs are held together by a horizontal 1kg strut at a height of 10cm above the floor. The force exerted by each leg on the floor will be approximately

A. 50 N	B. 60 N	C. 70 N	D. 80 N	E. 100N

9. An object of weight 20 N drops from rest to the ground 10 m below. It strikes the ground with force of about

A. 10 N	B. 20 N	C. 40 N	D. 200 N	E. can't be determined from this information

10. A government agency drops an 800kg car onto a concrete surface to simulate a crash at 31m/s (70mph). Assuming that the air resistance can be neglected, and that the gravitational field strength is 9.8N/kg, from what height should the car be dropped?

A. $0.5\times800\times31^2$	B. $0.5\times800\times31^2\div9.8$	C. $0.5\times9.8\times800\times31^2$	D. $0.5\times31^2\div9.8$	E. $0.5\times31\div9.8$

Section B: Written Answer

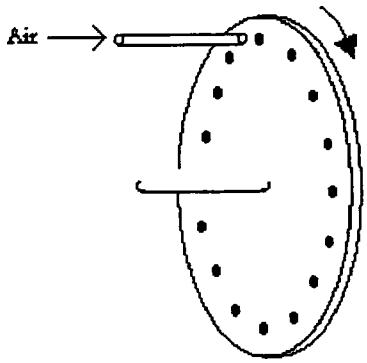
11. A truck (with a faulty handbrake) starts from rest and rolls down a slope of constant gradient. After the truck has rolled 50 m along the slope the speedometer reads 36 km/h. Calculate the gradient of the hill (you may neglect friction and other losses).

_____

_____

_____

_____ [3]



12. The diagram above shows the basic idea behind a disk siren. It consists of a disk in which there are 16 equally spaced holes, all at the same distance from its axle. When a jet of air is directed at the holes and the disc is rotated at a particular constant rate, the frequency of the note produced is 320 Hz.

(a) Calculate the frequency of the note produced when a disk containing 24 holes is rotated at 4/3 times the rate.

_____

_____

_____ [2]

(b) How does the sound of this note compare with the sound of the original note?

_____ [1]

(c) Explain how a sound is produced by the siren.

_____

_____ [2]

13.

In a spiral accelerator, a particle is accelerated 10,000 times through the same potential difference of 10 kV.

Calculate the energy acquired by

(a) an electron

_____

_____ [1]

(b) a proton

_____

_____ [1]

(c) an oxygen nucleus (an oxygen atom stripped of all its electrons)

_____

_____ [1]

(Don't worry about the construction of the accelerator – all that matters is that the particle traverses 10 kV 10,000 times.)

You might find the following data helpful:

Charge on the electron = -1.6×10^{-19} C

Atomic number of Oxygen = 8.

14.

When investigating a road accident the police found that a car had crashed through the side of a road bridge over a motorway. The bridge was 20 m above the motorway and the point of impact of the car with the ground was found to be 50 m in front of the point where the car left the bridge. The speed limit on the road bridge was 50 km/h. You may neglect air resistance.

(a) Calculate the time it takes the car to fall 20 m.

_____

_____ [2]

(b) What distance would the car cover at 50 km/h in this time?

_____

_____ [1]

(c) Does the information given indicate that the car was exceeding the speed limit when it crashed?

_____ [2]

15.

If there is no cloud cover, the intensity of sunlight on the surface of the Earth is approximately 1kW per square metre directly facing the Sun.

a) A solar cell is 30% efficient and has an area of $10m^2$. It generates an output of 230V. What is the maximum current you could draw from it?

_____

_____

_____

_____ [3]

b) The solar cell is installed on a roof, directly pointing at the Sun. A few hours later, it no longer points directly at the Sun – in fact it would need to be rotated by 20° to point directly at the Sun. What is the total solar energy falling upon it in two minutes?

_____

_____

_____

_____ [3]

c) A passing, light-fingered, alien sees your nice Solar Panel, steals it, and takes it home to Venus The Earth is 1.50×10^{11} m from the Sun, whereas Venus is typically 2/3 of this distance from the Sun. Assuming that the thief's family install their panel, assume on a cloudless part of their planet (not easy) pointing directly at the Sun – will it collect more or less solar energy each minute than it would on Earth? Explain your answer. You may assume that its efficiency is not affected by the horrendous climate.

_____

_____

_____

_____ [3]

d) Estimate the output power of the solar cell when installed facing the Sun on Venus.

_____

_____

_____

_____ [2]

16.

A particularly important quantity in the physics of solids and liquids is the energy required to change the state of one kilogram of a substance without change in temperature. For example, 1 kg of water requires a very large quantity of energy to change its state at 100 °C from liquid to gas, some 2.3 MJ. Indeed, this large energy is released when steam condenses back into 1 kg of water at 100 °C. It is the reason why scalding by steam can be a very serious injury.

A beaker of water is placed on a mass balance and an immersion heater is used to heat the water. A voltmeter measures the potential difference across the heater to be 240 V. An ammeter measures the current through the heater to be 8.3 A. When the water starts to boil a stopwatch is started and the mass balance reading M is recorded at 10 s intervals.

The results are below:

t/s	*M*/g
0	168
10	159
20	151
30	142
40	133
50	124
60	116
70	107

(a) On the graph paper provided, plot a graph of this data and use it to calculate the *rate of reduction in mass* of the water as it boils. Show all your working. [5]

(b) Use your value for the *rate of reduction of mass* to calculate the energy required to change the state of one kilogram of water at 100 °C.

_____

_____

_____

_____ [2]

(c) 0.9 kg of water at 0 °C is heated by bubbling through it a jet of steam at 100 °C. What is the temperature of the water when 0.1 kg of steam has condensed?

[6]

Additional information: The energy required to *raise the temperature* of 1 kg of water by 1 °C is 4200 J.