PHYSICS CHALLENGE 2003

A GCSE ONE HOUR PHYSICS OLYMPIAD COMPETITION PAPER

FRIDAY 7th MARCH 2003

We hope teachers will set the enclosed 1 hour paper to their final year GCSE students or the equivalent in Scotland. Xerox copies of the paper should be produced for the students. Solutions with marking scheme are enclosed. It is intended that the paper should be taken on Friday 7th March. However, if this is not possible, any date during the weeks of 25th February until 11th March will be acceptable. Scripts must be posted in sufficient time to arrive by first post on 14th March. **Any arriving after that date cannot be considered for an award.**

There is no charge for entering the Competition

After you have marked the scripts, please send those scripts with marks exceeding 30 together with the completed form overleaf to:

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

They will be scrutinised and grouped into gold, silver and bronze medal categories for the award of prizes and merit certificates.

We hope to invite fifteen students, the top gold award winners, together with their teachers, to the Presentation Ceremony at The Royal Society in London on Thursday 1st May 2003. Certificates and over a hundred prizes will be despatched to those students who have produced exemplary scripts but are not amongst the top gold award winners. All students who obtain above 30 marks will receive a certificate. These will be sent to their teacher who is asked to enter the student's name on each certificate. We have asked for your e-mail address so that results can be sent to you more quickly.

Should it not prove possible for your students to enter the Physics Challenge Competition in March, you could still consider setting the paper to them later in the academic year.

PHYSICS CHALLENGE 2003

ENTRY FORM

Name of Teacher _____

School _____

Address _____

_____

Tel No _____

e-mail address _____

BLOCK LETTERS PLEASE

Full names of Students with more than 30 marks (first name followed by surname).

	Mark		Mark

FURTHER ENTRIES CAN BE ATTACHED

Teachers' comments concerning the questions on the Physics Challenge paper will be gratefully received by the organising committee. Should you welcome the opportunity to help with the preparation of future years' papers, please indicate below.

Comments:

_____

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Would you like to help with the preparation of Physics Challenge Papers in future years?

☐ Yes ☐ No

PHYSICS CHALLENGE
2003

Time allowed: one hour

Attempt as many questions as you can. It is often helpful to include diagrams in your explanations.

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

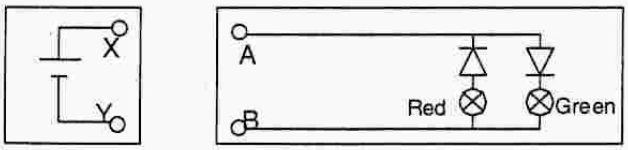
1. A Boeing 737 has a mass of 58,000kg and reaches a take-off speed of 285km/h at the end of the runway after 30s of acceleration. It has two engines, each capable of producing a thrust of 90,000N. Calculate the acceleration in m/s^2, assuming it is uniform, and the force required to produce it. Explain why your answer does not match the thrust data for the engines. [4]

2. Comets usually travel on highly elliptical orbits around the Sun. They travel much faster when closer to the Sun than they do when they are further away. Why is this? [4]

3. The specific heat capacity of a substance is defined as the energy required to raise 1 kg of the substance by 1 °C.
   (a) A kettle with a power rating of 2.0 kW takes 1.4 minutes to raise the temperature of 500g of water from 20 °C to 100 °C. Calculate the specific heat capacity of water. [3]
   (b) Some hot water is added to three times its mass of water at 10 °C and the resulting temperature is 20 °C. Calculate the temperature of the hot water. [3]

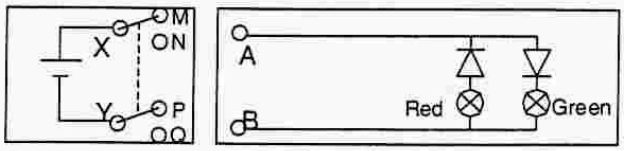
4. The diagram below shows a 'traffic light' system. A cell is connected to terminals X and Y.

   (a) Explain how you connect the circuit to light the red lamp, and how you connect it to light the green lamp. [4]



(b) You can switch the red to green by connecting a DPDT (double pole double throw) switch into the circuit as shown below. This type of switch is shown in the diagram below. With the switch in the UP position, X is connected to M, and Y to P. When the switch is flicked DOWN, X is connected to N, and Y to Q.

Show how to connect M, N, P and Q to the traffic light in order that UP lights the red light, and DOWN lights the green one. [2]



(c) To what would you connect the traffic light circuit to light both lamps at once? [1]

5. (a) Define the *moment of a force* about a point. [2]

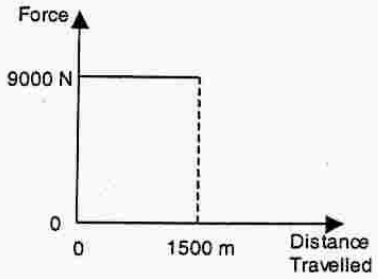
(b) Describe how you would use a metre rule, a 100 g mass and some thread in order to find the mass of an apple. [2]

(c) A uniform metre rule of weight 0.9 N is suspended horizontally by two vertical loops of thread *A* and *B*, placed at 20 cm and 30 cm from its ends respectively. Find positions on the rule at which a 2 N weight must be suspended:

(i) to make *A* become slack; [4]

(ii) to make *B* become slack. [2]

6. The graph below shows the force on a truck as its engine accelerates it from rest. It reaches full speed after travelling 1500m. The truck's mass is 30 000kg. In this question, friction may be neglected.



(a) What is the acceleration of the truck? [2]

(b) What is the area under the line on this graph? What are the units of this 'area'? [2]

(c) Sketch a graph of the velocity (on *y* axis) as a function of time (on the *x* axis). [4]

(d) Compare your answer in part (b) to the kinetic energy of the truck after it has reached full speed. [2].

7. In an experiment in a ripple tank, plane water waves are produced with a frequency of 20 Hz. The waves travel at a speed of 40 cm/s through a gap in a barrier of width 1 cm.

(a) Calculate the wavelength of the waves. [2]

(b) Draw a diagram to show how the waves would spread through the gap. [2]

(c) Draw a diagram to show what happens when the gap is made 4 cm wide. [2]

(d) A hand-held stroboscope is used to observe the experiment. Such a stroboscope may easily be constructed out of a disc with 10 slits in it, equally spaced around its circumference. If you observe the waves through the rotating disc, you will see them several times a second. Explain why the waves look stationary under a stroboscope rotating at 2 Hz. [3]

(e) Describe what you would see if you were to observe the experiment through the stroboscope rotating at a frequency of:

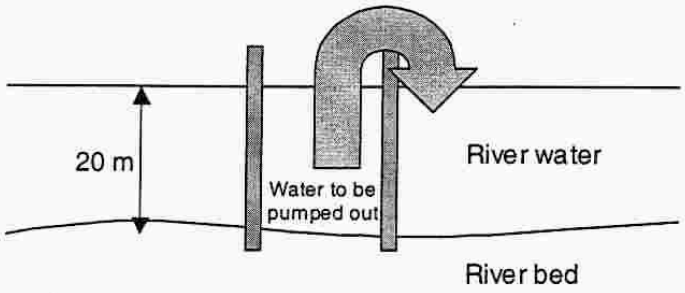
(i) 1 Hz; [1]

(ii) 4 Hz; [1]

(iii) 1.9 Hz. [1]

(f) Suggest why, in cine films, wheels sometimes seem to rotate backwards on forward-moving vehicles. [3]

8. Before a new bridge can be built over an estuary, coffer dams are sunk into the river bed, as shown in the diagram below. Each dam is, in effect, a large tube. The water then needs to be pumped out. Concrete can then be poured in to form the supports for the bridge.



If the river is 20m deep, and the cross sectional area of the coffer dam tubes is $10m^2$, work out the energy needed in order to pump the water out. Take the density of river water to be 1025 kg/m^3, and the Earth's gravitational field strength (g) as 9.81 N/kg. You may assume that you have perfectly efficient pumps available. [6]

PHYSICS CHALLENGE

COMMENDATION CERTIFICATE

Students whose scripts have not been submitted but have obtained 20, or more, marks will receive a Commendation Certificate. Teachers should apply on the form below.

PHYSICS CHALLENGE CERTIFICATES

NO. OF CERTIFICATES REQUESTED: ☐

NAME OF TEACHER: .....

NAME OF SCHOOL: .....

ADDRESS OF SCHOOL: .....

.....

.....

Please return this slip to:

Dr. C. Isenberg,
Physics Challenge
BPhO Office
Department of Physics & Astronomy
University of Leicester
University Road
Leicester LE1 7RH

British Physics Challenge – February 2003

Mark Scheme and Solutions

Total mark for each question is given in the extreme right column. Equivalent valid working should gain equal credit to the solution presented below. Incorrect units should not be penalized the first time, but then one mark should be deducted for a second offence. No further marks should be deducted for incorrect units. Use a similar procedure for inappropriate significant figures, that is, the use of more than 3 in a final answer.

1.		Take-off speed = 285 km/h = 2.85×10^5 m ÷ 3600s = 79.2 m/s	[1]	
		Acceleration = 79.2 m/s ÷ 30 s = 2.64 m/s^2	[1]	
		Force required for this accn. = 5.8×10^4 × 2.64 = 153 kN	[1]	
		Capability of two engines = 2 × 90 kN = 180 kN		
		Any valid reason, for example friction, air resistance.	[1]	[4]
2.		*Either*:		
		Higher gravitational potential energy when furthest from Sun	[1]	
		Total energy constant for motion	[1]	
		Therefore lower kinetic energy when furthest from Sun	[1]	
		Therefore slower when furthest from Sun	[1]	[4]
		Or:		
		Any reference to ice-skater spinning faster when arms drawn in, *or* similar 'angular momentum' phenomenon	[1]	
		Reference linked to situation of a comet in an orbit	[1]	
		some form of mention of absence of tangential forces	[1]	
		Explanation in terms of angular momentum	[1]	[4]
3.	(a)	Energy transferred = 2000W × 84s = 168 kJ	[1]	
		Mass 500g = 0.5 kg, and temperature change = 80°C	[1]	
		Specific heat capacity = 168 kJ ÷ (0.5 kg × 80°C) = 4.2 kJ/kgK	[1]	
	(b)	Appropriate statement of conservation of energy. e.g. energy same for heating just hot water as heating all to 20°C	[1]	
		Formation of equation: for example if mass of hot water is m, and hot water temperature is T then $mT + 10\times3m = 20\times4m$,	[1]	
		thus T = 80–30 = 50, therefore hot water is at 50°C.	[1]	[6]
4.	(a)	RED lamp: connect X to B, and A to Y.	[2]	
		GREEN lamp: connect X to A and Y to B	[2]	
	(b)	Connect M to B, and P to A	[1]	
		Connect N to A, and Q to B	[1]	
	(c)	Alternating Current supply (or just 'ac')	[1]	[7]
5.	(a)	Moment = Force × Distance to pivot	[1]	
		Distance must be measured perpendicular to force	[1]	3
	(b)	Appropriate apparatus and procedure	[1]	
		Explanation of how mass of apple would be calculated.	[1]	

Question continued over the page.

5.	(c)i	Taking moments about B	[1]	
		Taking 0.9N force acting through centre of ruler	[1]	
		Forming correct equation, e.g. 20cm × 0.9N = x × 2N	[1]	
		Answer: 9cm towards the end from B (or 21cm from end)	[1]	
	ii	Taking moments about A:		
		Forming correct equation, e.g. 30cm × 0.9N = x × 2N	[1]	
		Answer: 13.5cm towards the end from A (or 6.5cm from end)	[1]	[10]
6.	(a)	Acceleration = Force ÷ Mass = 9 kN ÷ 30 000kg = 0.3 m/s^2	[2]	
	(b)	Area under graph = 9000 × 1500 = 1.35×10^7	[1]	
		Units of 'area' = newtons × metres = Nm or joules (J).	[1]	
	(c)	Straight line graph through origin for accelerating period	[1]	
		Straight horizontal line after acceleration finished	[1]	
		Final speed (from $v^2 = 2as$ = 2×0.3×1500) is 30 m/s	[1]	
		Time taken (from 1500 = ½ a t^2 or 30 = 0.3 t) is 100s.	[1]	
	(d)	Area under graph = work done = energy transferred = kinetic energy given to truck	[2]	[10]
		If kinetic energy is calculated correctly, but no effective comparison is made, then award one mark.		
7.	(a)	40 = 20 × λ, so λ = 2 cm.	[2]	
	(b)	Semi circular wavefronts coming from gap	[1]	
		Distance between wavefronts constant	[1]	
	(c)	Wavefronts with curved edges, but with straight part in centre	[2]	
	(d)	2Hz rotation rate implies 20 slits per second	[1]	
		this is same as frequency of wave	[1]	
		wave will have moved 'one peak further on' in the time	[1]	
	(e)i	Wave looks stationary.	[1]	
	ii	Peak becomes trough, then peak again...	[1]	
	iii	Wave appears to move 'backwards' – in fact each peak moves 95% of the way forward to next peak's position.	[1]	
	(f)	Cine film involves succession of still images	[1]	
		Spokes of wheel move between successive images	[1]	
		If spokes move *almost* to next spoke's position during the frame time, then eye will perceive this as backward motion	[1]	[15]
8.		Mass of water to be removed = 20×10×1025 = 2.05×10^5 kg	[2]	
		Water needs to be lifted 10m on average	[2]	
		Energy needed = mgh = 2.05×10^5 × 9.81 × 10 = 20.1 MJ	[2]	[6]
		Total mark for paper		**[62]**
		Calculate percentages as if total mark were 60. **Therefore a candidate scoring 30 marks would be given 50%.**		