A S PHYSICS COMPETITION 2007

ONE HOUR PHYSICS COMPETITION PAPER

FRIDAY 9 th MARCH 2007

We hope teachers will set and mark the enclosed paper for their A S 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 9 th March. However if this is not possible, any date during the period 5th – 9 th March will be acceptable. Scripts must be posted in sufficient time to arrive by first class post on Monday 17 th March at the Olympiad Office at the University of Kent at Canterbury. 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 of 35 or more, 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
A S Physics Competition
Electronics Laboratory
University of Kent
Canterbury, Kent CT2 7NT

We will invite the five outstanding Gold Medallists, together with their teachers, to the AS Physics Competition 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 .

A S PHYSICS COMPETITION 2007

ENTRY FORM

Name of teacher ______________________________

School ______________________________

Address ______________________________

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Tel. No. ______________________________

Email ______________________________

TOTAL NUMBER OF ENTRIES ______________________________

Full names and marks of Gold Medallists with 35 or more 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 A S Physics Competition paper and suggestions for possible future challenging questions.

Comments:

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2007 AS PHYSICS COMPETITION CERTIFICATES

All Participating students will receive a certificate. They will be awarded Gold, Silver, Bronze and Participation Medal Certificates, based on their marks, according to the scheme below:

Medal Certificate	Gold	Silver	Bronze	Participation
Mark Range	50 – 35	34 – 25	24 - 15	14 – 0
No. of certs. requested				

Total Number of Entries ☐

NAME OF TEACHER ______________________________

NAME OF SCHOOL ______________________________

ADDRESS OF SCHOOL ______________________________

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Please return to:

Dr Cyril Isenberg
A S Physics Competition
British Physics Olympiad Office
Electronics Laboratory
University of Kent
Canterbury, Kent CT2 7NT

AS COMPETITION PAPER 2007

Total Mark/50

SOLUTIONS

Section A: Multiple Choice

There is only one mark for each correct answer.

1. **C**
2. **D**
3. **B**
4. **B**

5. **B**
6. **A**
7. **D**
8. **C**

Section B: Written Answer

Question 9.

A mass *M* is attached to the end of a horizontal spring. The mass is pulled to the right, 8 cm from its rest position. It is then released so that the mass oscillates to the left and right, with the system gradually losing energy over many cycles.

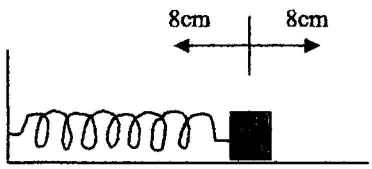

fig. 7

a) State the energy changes that take place over one complete cycle as the mass moves to the left and then back to the right.

Elastic pe → ke → elastic pe → ke → elastic pe

for correct energy changes ✓

for 1 cycle of changes only – no more and no less ✓ [2]

b) The energy stored in a stretched spring is proportional to the square of the extension of the spring. If after some time, the amplitude of the oscillation is reduced to 1 cm, what fraction of the initial energy has been lost? Show your working.

Amplitude reduces from 8 cm to 1 cm

Energy reduces from 64 to 1 unit ✓

So 1/64 left or 63/64 lost ✓ for either answer [2]

c) We will need to use a concept that you have met in radioactivity. State what is meant by the half-life of a radioactive substance.

The time taken for half of the (radioactive) nuclei (allow material) to decay ✓

[1]

d) Now we shall apply this concept to the loss of energy from the oscillating system. The amplitude decays away in the same manner as radioactive decay (exponentially). How many half-lives have passed for the amplitude to reduce to 1 cm?

8 cm → 4 cm → 2 cm → 1 cm ✓

3 half-lives ✓ [2]

e) The period of oscillation does not depend upon the amplitude of the oscillation, being the same for both large and small amplitudes. The period of oscillation is 0.5 seconds. The half-life for the amplitude loss is 5 seconds. How many oscillations have occurred by the time the amplitude has dropped down to 1cm?

10 oscillations per half-life ✓

30 oscillations in 3 half lives ✓ allow ecf [2]

f) The energy is also dissipated away exponentially with time. Using your answer to part (b) for the energy lost, how many energy loss half-lives have passed when the amplitude has reduced to 1 cm?

64 → 32 → 16 → 8 → 4 → 2 → 1 ✓ No ecf allowed

6 half-lives ✓

[2]

/11

Question 10.

a) At the earth's surface, the radiant power received from the Sun normally is 1.3×10^3 W per square metre. The power radiated by the Sun is the same everywhere over the Sun's surface. If the Earth orbits at a distance of 1.5×10^{11} m from the Sun, calculate the total energy radiated away by the Sun each second. (It may be useful to know that the surface area of a sphere is $4\pi r^2$).

Total power $= 1.3 \times 10^3 \times$ area W ✓

$= 1.3 \times 10^3 \times 4 \times \pi \times r^2$ W

$= 3.7 \times 10^{26}$ W $= 4 \times 10^{26}$ W ✓ [2]

b) Although you may not have studied it yet, Einstein produced a famous equation relating mass and energy which we shall use, $E = mc^2$, where E is energy in joules, m is mass in kg, c is the velocity of light in a vacuum ($c = 3 \times 10^8$ m/s). Using your answer to part (a), calculate the mass loss of the Sun due to the energy being radiated away each second.

$3.7 \times 10^{26} \div 9 \times 10^{16} = 4.1 \times 10^9$ kg (/s)

$= 4 \times 10^9$ kg (/s) ✓ allow e.c.f.

$= 4$ million tonnes /s [1]

c) If the mass of the Sun is 2×10^{30} kg, what is the percentage of the Sun's mass that is lost by radiation each year?

$\frac{4 \times 10^9}{2 \times 10^{30}} \times 365 \times 24 \times 3600 \times 100\%$ allow e.c.f.

✓ for 365 x 24 x 3600 seconds in a year

$= 6.3 \times 10^{-12}$ % ✓

[2]

d) Assuming that this rate remains constant, what is the percentage loss of mass of the sun since it was formed, five thousand million years ago?

6×10^{-12} % $\times 5 \times 10^9$ ✓ allow e.c.f.

= 0.03 % ✓

[2]

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Question 11.

The transformer, shown in fig. 9, outputs power at 415 V, along a copper cable 50 m in length, to an electrical machine. The total resistance of the copper conductor (100 m there and back) is 0.0493 Ω at an operating temperature of 60°C. The machine takes a current of 200 A.

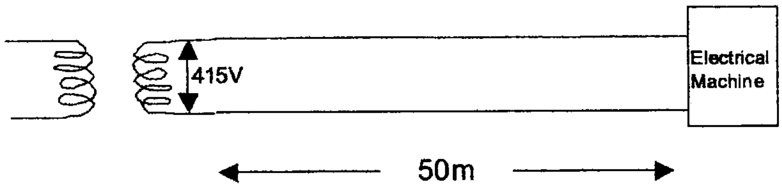

fig. 7

a) What is the total power that the transformer is supplying to the machine and cable?

Power = V x I ✓

= 415 x 200

= 83,000 W ✓ [2]

b) What is (i) the power loss in the cable, and (ii) what percentage is this of the total power supplied?

Power in cable $= I^2 R$ ✓

$= 200^2 \times 0.0493$

= 1972 W = 1.9 kW ✓

Percentage is $\frac{1.9}{83,000} \times 100\% = 2.3 \times 10^{-3}\ \%$ ✓

[3]

c) Often the conductor size is chosen not on the basis of the steady current required, but on the short circuit current that might occur. If in our wiring, a short circuit occurred at the machine end of the cable, a current of 6000 A could be expected. Explain why this current is significantly less than that calculated from the 415 V supply and the 0.0493 Ω resistance of the cable.

The secondary of the transformer also has some resistance ✓

Resistance at the short circuit connection ✓

Do not accept cable heats up [2]

d) If the circuit breaker produces a delay of 0.4 s before it breaks the circuit, calculate the heat energy generated in this short time interval. Assume that the resistance of the wire does not change significantly as it heats up.

Energy converted = V I t ✓

= 415 x 6000 x 0.4

= 996 kJ ✓

[2]

e) The heat energy required to raise the temperature of 1kg of copper by 1°C is called the specific heat capacity of copper. It has the value is 385 $Jkg^{-1}\,°C^{-1}$. We can use a simple formula,

heat energy supplied = mass x specific heat capacity x temperature rise

in order to determine the temperature rise of the copper cable, assuming no heat loss to the surroundings.

Calculate

(i) The mass of copper in the 50 m cable, given that its
cross sectional area = 50 mm^2
density of copper = 8960 kg/m^3

mass = density x volume ✓ accept if used correctly numerically

= 8960 x 50 x 50 x 10^{-6}

= 22.4 kg ✓ [2]

(ii) Calculate the final temperature of the cable after 0.4s, if its initial temperature is 60°C.

996,000 = 22.4 x 385 x temperature rise ✓ allow e.c.f.

Hence temperature rise = 115°C

And so final temperature = 175 °C ✓

Mark acceptable just for the correct temperature rise [2]

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Question 12.

A single uniform underground cable linking A to B, 50 km long, has a fault in it at distance *d* km from end A. This is caused by a break in the insulation at X so that there is a flow of current through a fixed resistance *R* into the ground. The ground can be taken to be a very low resistance conductor. Potential differences are all measured with respect to the ground, which is taken to be at 0 V.

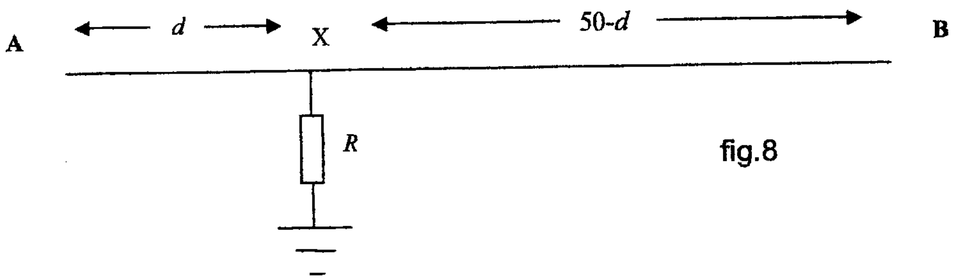

fig.8

In order to locate the fault, the following procedure is used. A potential difference of 200 V is applied to end A of the cable. End B is insulated from the ground, and it is measured to be at a potential of 40 V.

a) What is the potential at X? Explain your reasoning.

40 V ✓

B is at the same potential as X because **no current flows along BX** ✓

[2]

b) What is

(i) the potential difference between A and X?

200 – 40 = 160 V ✓

[1]

(ii) the potential gradient along the cable from A to X (i.e. the volts/km)?

$$\frac{(200-40)}{d} = \frac{160}{d}$$ ✓ allow reciprocal

[1]

c) The potential applied to end A is now removed and A is insulated from the ground instead. The potential at end B is raised to 300 V, at which point the potential at A is measured to be 40 V.

(i) What is the potential at X now?

40 V [1]

(ii) Having measured 40 V at end B initially, why is it that 40 V has also been required at end A for the second measurement?

So that X is at the same potential ✓

and then the same current flows into the ground through R ✓

(and the same currents will therefore flow along AX and BX - see part (e) (✓)) [2]

d) What is the potential gradient along the cable from B to X?

$$\frac{(300-40)}{(50-d)} = \frac{260}{(50-d)}$$ ✓

[1]

e) The potential gradient from A to X is equal to the potential gradient from B to X.

(i) Explain why this is true

Because the same currents flowed along AX and BX ✓

So $I = \frac{V_{AX}}{R_{AX}} = \frac{V_{BX}}{R_{BX}}$ ✓

and R is proportional to length (✓) [2]

(ii) From the two potential gradients that you obtained earlier, deduce the value of *d*.

$$\frac{160}{d} = \frac{260}{(50-d)} \qquad 260\,d = 50 \times 160 - 160\,d$$

Hence $d = 19$ **km** ✓

[1]

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2007 BRITISH ASSOCIATION MEETING

UNIVERSITY OF YORK

100 PHYSICS SCHOLARSHIPS

This year the annual meeting of the British Association for the Advancement of Science will take place at the University of York from 9 – 15 September. On Friday 14 September the Physics and Astronomy Section has devoted the day to popular lectures on particle physics and astronomy.

100 PPARC scholarships worth £40 each for A level students who do not live in York, and £25 for those students residing in York, are available. They will be awarded on a ' first come first served' basis. Students will be required to write a 300 word report of their day at the Festival . Applicants should write or email

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PHYSICS SUMMER SCHOOL

Senior Physics Challenge

This Cambridge University programme, to further skills in Physics and to prepare school students for the transition to University Physics, holds a yearly Summer School in Cambridge. In 2007 it will most likely be from Sunday 1 July to Thursday 5 July. It is for students who will just completing their AS year at school. Attendance is by application and recommendation from the student's school. Further details will appear in mid February – look on http://www-spc.phy.cam.ac.uk/
This website has details of last year's School and will be a good guide to this year's.

Professor Mark Warner
Anson Cheung
Directors, SPC