AS COMPETITION PAPER 2007

Total Mark/50

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 calculator.

Allow about 10 minutes for section A.

The gravitational field strength on the earth is 9.8 N/kg

Section A: Multiple Choice

Circle the correct answer to each question. There is only one mark for each correct answer.

1. Two trucks tow a third one by means of inextensible ropes and a pulley attached to them (fig. 1). The accelerations of the two trucks are a_1 and a_2. What is the acceleration of the third truck that is being towed?

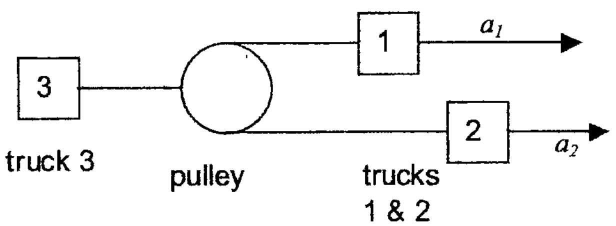

fig. 1

A. (a_1+a_2) B. (a_1-a_2) C. $\frac{(a_1+a_2)}{2}$ D. $\frac{(a_1-a_2)}{2}$

2. A piece of ice floats in a glass filled with water. The ice contains a small stone, so that when the ice has all melted, the stone sinks to the bottom of the glass. What will happen to the level of the water in the glass, firstly as the ice melts, and secondly as the stone is released from the ice and sinks to the bottom?
The water in the glass will

A. remain the same then rise B. rise and fall C. fall then remain the same D. remain the same then fall

3. A stone, thrown vertically into the air from ground level, returns to the ground in 4 seconds due to the constant gravitational force acting upon it (ignore air resistance). If the stone is thrown up at twice the initial speed, the time taken to return to the ground will now be

A. 6s B. 8s C. 12s D. 16s

4. A 20 Ω resistor is connected to an AC power supply with a voltage output that varies from 4V to –2V at equal time intervals as shown on the graph below. What is the average heating power dissipated in the resistor?

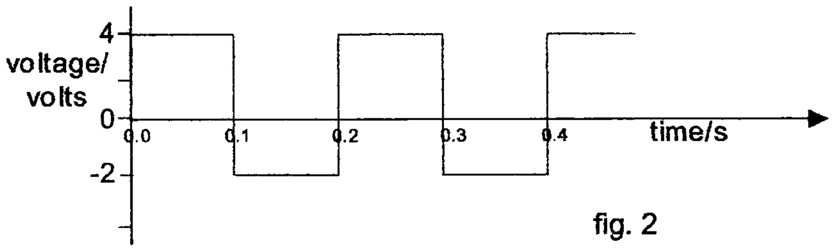

fig. 2

A. 0.2W B. 0.5W C. 0.8W D. 1.0W

5.

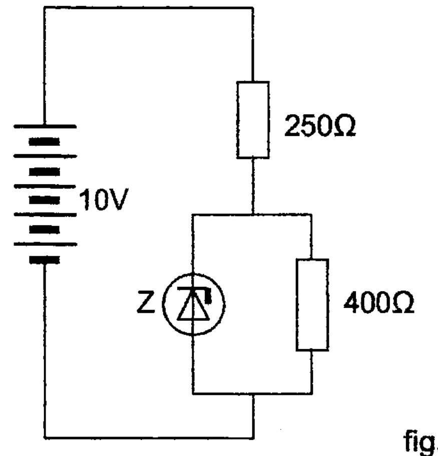

fig. 3

A 10 V battery, with negligible internal resistance, is connected to two resistors of resistance 250 Ω and 400 Ω and to the component Z as shown. Z is a device which has the property of maintaining a potential difference of 5 V across the 400 Ω resistor. The current through Z is

A. 2.9 mA B. 7.5 mA C. 12.5 mA D. 15.4 mA

6. A small mass, M, is given an initial velocity v_0, and it slides from A to B via two possible paths; either down the shallow dip X or over the hump Y, both of which are the same shape but inverted. Friction is to be ignored. Along which path does the mass take the shortest time to slide from A to B?

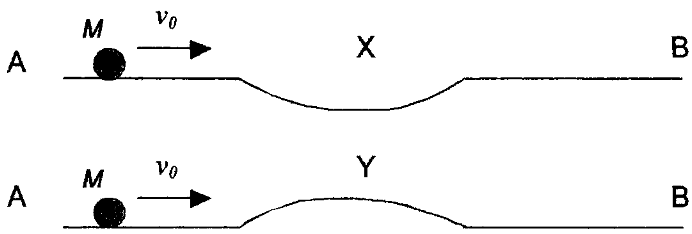

fig. 4

A. Via X B. Via Y C. You cannot say D. Same time taken

7. A thin rectangular block of glass, of thickness t, has a beam of light passing through it along a normal to a face, as shown in fig. 5. The light wave travels at a slower speed in glass than in air. The ratio of the extra number of waves introduced within the length t when the glass is in place, to the number of waves within the same length t in air, is given by

λ = wavelength in air

The **refractive index,** $n = \dfrac{\text{speed of light in air}}{\text{speed of light in glass}}$

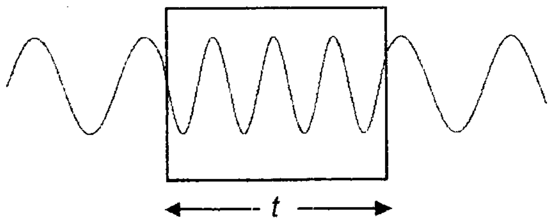

fig. 5

A. (n-1) B. $\dfrac{1}{(n+1)}$ C. $\dfrac{n}{(n+1)}$ D. $\dfrac{(n-1)}{n}$

8. A narrow beam of light is incident normally upon a thin slit, and the light that passes through is spread out by diffraction. The thin slit is then immersed in a container of water. The beam of light is shone through the water and is again at normal incidence to the slit. The spread of the diffracted beam of light in water will be

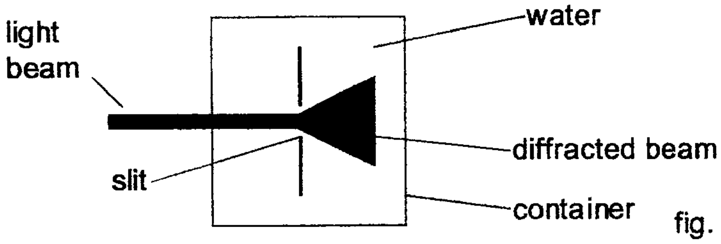

fig. 6

A. The same as in air B. Diffraction will not occur in water C. Less spread out than in air D. More spread out than in air

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.

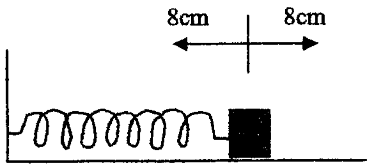

fig. 7

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.

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____ [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.

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____ [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.

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____ [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?

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____ [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 1 cm?

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____ [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?

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____ [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 $4\pi r^2$).

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____ [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.

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____ [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?

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____ [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?

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/7

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.

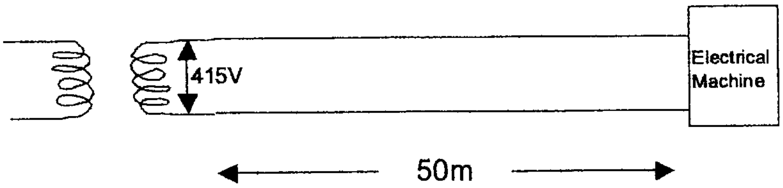

fig. 7

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

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____ [2]

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

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____ [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.

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____ [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.

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____ [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 $Jkg^{-1}\,{}^{o}C^{-1}$. 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

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____ [2]

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

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____ [2]

/13

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.

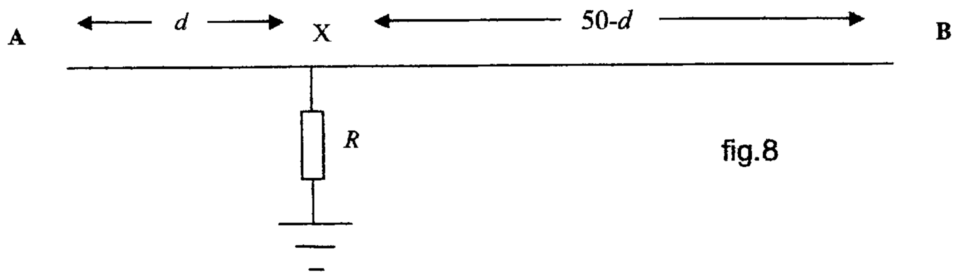

fig.8

In order to locate the fault, the following procedure is used. A potential difference of 200V 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 40V.

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

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____ [2]

b) What is

(i) the potential difference between A and X?

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____ [1]

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

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____ [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?

______________________________ [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?

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______________________________ [2]

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

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______________________________ [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

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______________________________ [2]

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

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/11