AS CHALLENGE PAPER 2014

Name	
School	

Total Mark/50

Friday 14th March

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.

You may use any public examination formula booklet.

Allow no more than ***10 minutes*** *for* ***section A.***

Section A: Multiple Choice

Circle the correct answer to each question. Write your answers in the table at the end of the multiple choice questions on page 3.

Each question is worth 1 mark. There is only one correct answer to each question.

1. A steel ball bearing is dropped onto a concrete floor and rebounds to 80% of its initial height. The percentage of the kinetic energy lost in the collision is.

   A. 80% B. 64% C. 36% D. 20%

2. An air molecule of mass 5.0 x 10^{-26} kg and moving with a speed of 500 ms^{-1} has a kinetic energy of about

   (e = 1.6 x 10^{-19} C)

   A. 1 eV B. 0.4 eV C. 40 meV D. 4 meV

3. The Moon takes 2 minutes to sink below the horizon at the equator when observed at night (about the same time as the Sun takes to set). If the radius of the Earth is 6400 km and the radius of the Moon is 1700 km, what is the angular size of the Earth when observed from the Moon?

   A. 3.8^o B. 3.5^o C. 1.9^o D. 0.3^o

4. A bubble is made from a soap film of uniform thickness enclosing a spherical volume of air. If the diameter of the bubble is trebled, the thickness of the soap film, t, will become

   A. t/27 B. t/9 C. t/4 D. t/3

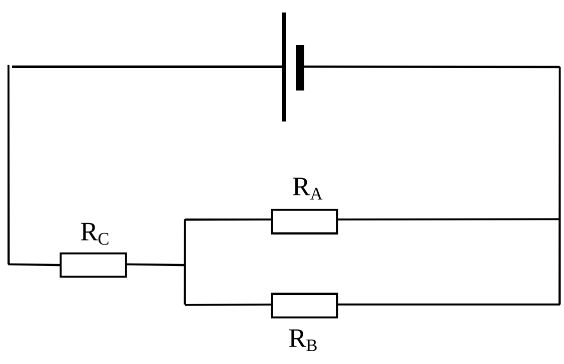
5. The radius of the Sun is 6.9 x 10^5 km and that of the Earth is 6400 km. Approximately how many rigid earth spheres could be fitted into the interior of the sun?

A. 100　　B. 1200　　C. 10000　　D. 10^6

6. An incompressible liquid flows through a pipe which has a section with a narrower bore. What is the speed of the liquid and the volume rate of flow in the narrow section compared to the wider section of the pipe?

	Speed of flow / $m s^{-1}$	Volume rate of flow / $m^3 s^{-1}$
A	Slower	Same
B	Faster	Less
C	Faster	Same
D	Slower	More

7. In the circuit shown below, the power converted in R_A is 1 W. The value of R_A is R, that of R_B is 2R and R_C is 2R. How much power is supplied by the cell?



A. 3W　　B. 4W　　C. 6W　　D. 8W

8. The neutral point between the Earth and the Moon is the point where the gravitational pull of the Moon is equal to the gravitational pull of the Earth. If the energy a 1000 kg spacecraft needs in order to reach the neutral point from the Earth is 6.0×10^{10} J and to reach the neutral point from the Moon is 0.25×10^{10} J, what is the minimum energy needed to send a 1 kg rock from the Moon to the Earth?

A. 0.25×10^{7} J B. 5.75×10^{7} J C. 6.0×10^{7} J D. 6.25×10^{7} J

Answers

Qu 1	Qu 2	Qu 3	Qu 4	Qu 5	Qu 6	Qu 7	Qu 8

Section B: Written Answers

Question 9.

The intensity of radiation received at the Earth from the Sun is about 1.4 kWm^{-2}. The faintest stars in the Milky Way Galaxy have intensity at the earth of about 10^{-20} of the solar intensity. At what distance away should a 100 W bulb be placed in order to produce the same intensity as the faintest stars?

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Question 10.

a) A column of fluid of density ρ and cross sectional area A, fills a measuring cylinder to a depth h, as shown in figure 1. Show that the pressure, P at the bottom is given by the expression $P = \rho g h$.

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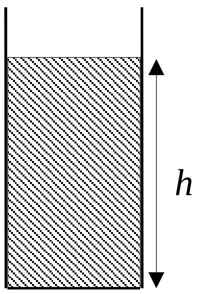

Figure 1. Measuring cylinder filled with liquid to a height, *h*.

b) Explain why this formula is inapplicable to determining the height of the earth's atmosphere if the pressure at ground level is known.

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A simple hydraulic system is represented by two wide pipes connected together by a narrow bore tube, with the system containing an incompressible liquid, water.

Resting on top of the water are two steel discs of masses 2.00 kg and 1.00 kg, which provide a seal, but have negligible friction with the pipes. The cross sectional areas of the pipes are in the ratio of 2:1, as shown in figure 2.

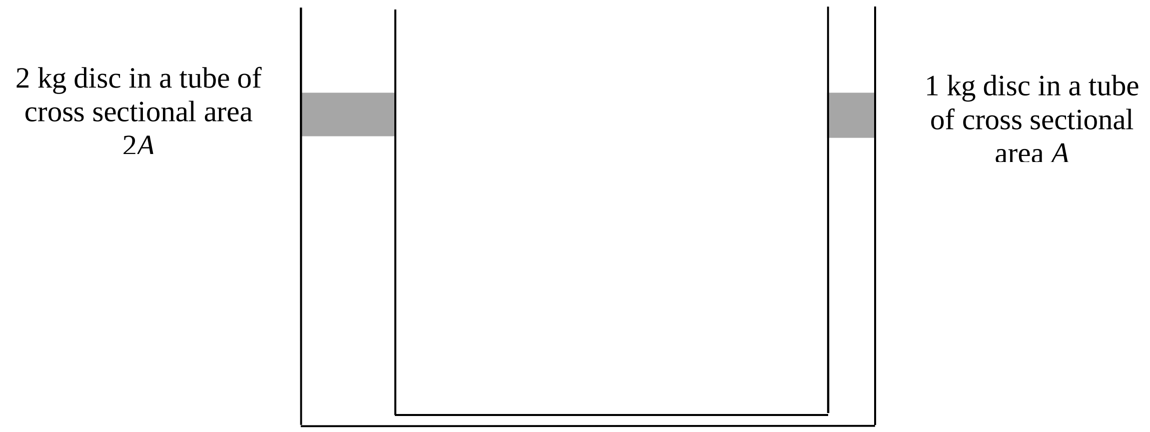

Figure 2. Water filled pipes with 2 kg and 1 kg masses providing the seals.

c) If the discs have the initial positions shown in figure 2, in which they are level, explain what determines these positions, since the weights on the two sides are clearly quite different.

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d) If the 1 kg disc on the right hand side is pushed down the tube a little way, explain what would happen when it is released. Would it remain where it is, would it rise or would it continue to sink?

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e) If a small tube was connected as shown in figure 3, would the discs remain in their initial positions? Explain your answer.

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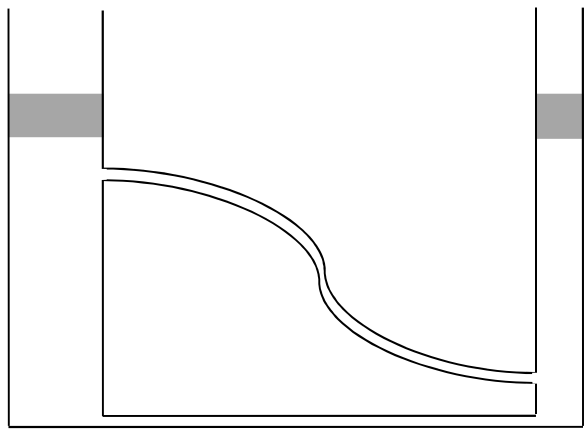

Figure 3. Small bore tube connecting the pipes at different heights.

f) Returning to figure 2, the left hand disc is now replaced by a 1.00 kg steel disc of thickness *x*, so that the two steel discs on each side are of equal mass. If the water level height difference becomes stable at 50.0 cm, calculate *x*, the thickness of the left hand steel disc.

density of steel is 7.8 g cm^{-3}
density of water is 1.0 g cm^{-3}

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g) Hence calculate the cross sectional area of the left hand pipe.

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Question 11.

The Earth was formed as a molten body at a temperature of about 4000 K. It has cooled down since its formation and the surface is now at a temperature of 300 K.

a) State, with a brief reason for your answer, the processes by which heat is transferred from deep within the Earth to the surface.

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b) Similarly, state and justify which processes transfer heat away from the surface of the earth into space.

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A formula for the rate of cooling of a hot sphere can be derived and it depends on the surface temperature, *T* of the sphere, the area of the surface, *A*, the nature of the material making up the sphere and the nature of the surface. Lord Kelvin applied this idea to the cooling of the Earth.

The cooling time is given by the formula

$$t_{cool} = \frac{Nk}{\sigma A}\left(\frac{1}{T_f^3} - \frac{1}{T_i^3}\right)$$

where T_i is the initial temperature of the hot earth and T_f is the final temperature of the Earth (taken to be 300 K at the present time), *N* is the number of atoms in the sphere, A, k and σ are constants whose values are:

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
k = 1.38×10^{-23} J K^{-1}
surface area of the earth, $A = 5.1 \times 10^{14}$ m^2

In order to calculate the time taken for the earth to cool, we should know the initial and final temperatures.

c) The initial temperature of the earth was at least the temperature of molten rock.

(i) Explain why the exact value is of little importance for the calculation of t_{cool}.

(ii) Write down an approximate version of the formula which does not include the initial temperature.

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(iii) Calculate *N*, the number of atoms making up the earth, given the typical mass of an atom is 6 x 10^{-26} kg, the radius of the Earth is 6400 km, and the average density of the earth is 5500 kg m^{-3}.

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(iv) Calculate t_{cool} and express your answer in years.

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(v) Comment on the numerical answer you have obtained.

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Question 12.

A rigid rod, of length 4ℓ and of negligible mass, has two masses *m* and 2*m* attached at positions ℓ and 4ℓ respectively, measured from the right hand end of the rod, as shown in figure 4.

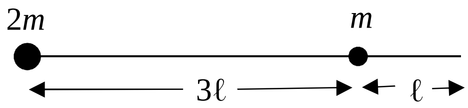

Figure 4. Horizontal rod with masses 2*m* and *m* attached.

a) Calculate the distance, *x*, of the centre of mass of the rod from the right hand end.

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b) The rod is released from rest in the horizontal position.

(i) Describe the motion of the rod as it falls.

(ii) Calculate the speed of the centre of mass of the rod when it has fallen through a height *x*. (Work in symbols and do not substitute for *g*).

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The rod is now attached to a hinged support at the right hand end, so that it will swing down like a pendulum when released, as shown in figure 5.

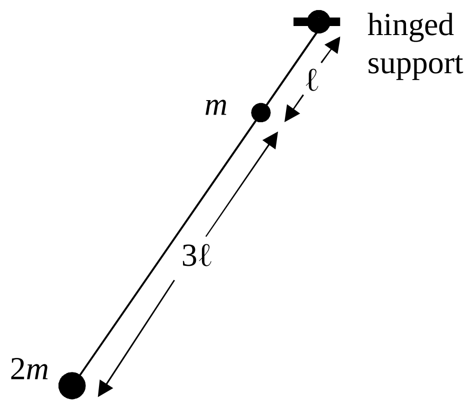

Figure 5. Light pendulum rod with the two masses attached.

c) The rod is released from rest in the horizontal position. When the centre of mass has fallen by the distance, x, the rod will be vertical. Since the centre of mass has fallen through the same distance as in (b), explain why it will not have the same speed as calculated in part (b).

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d) Calculate the speed of the centre of mass when the rod has swung to a vertical position.
Hint: express the speed of each falling mass as $v = r\omega$ where ω is the angular velocity of the rod (change of angle over time) and r is the distance from the pivot. The masses will have the same value of ω, which can be obtained.

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