OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

Forces, Fields and Energy

2824

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic Calculator

Wednesday 10 June 2009
Afternoon

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **90**.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	10	
2	12	
3	10	
4	15	
5	13	
6	15	
7	15	
TOTAL	90	

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{JK^{-1}\ mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\ kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

refractive index, $n = \frac{1}{\sin C}$

capacitors in series, $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}<c^2>$

radioactive decay, $x = x_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \frac{3H_0^{\,2}}{8\pi G}$

relativity factor, $= \sqrt{(1 - \frac{v^2}{c^2})}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10\lg\left(\frac{I}{I_0}\right)$

Answer **all** the questions.

1 This question is about a nuclear fusion reaction.

(a) Fig. 1.1 shows a deuterium and a tritium nucleus travelling directly towards one another. At a large distance apart, each incident nucleus is travelling at a speed *v*. When they collide and fuse an alpha particle and a neutron are formed. They travel apart as shown. The separation speeds of the alpha particle and neutron are shown in the figure. The mass of each nucleus, in terms of *m*, the mass of a nucleon, is given in the centre of each particle.

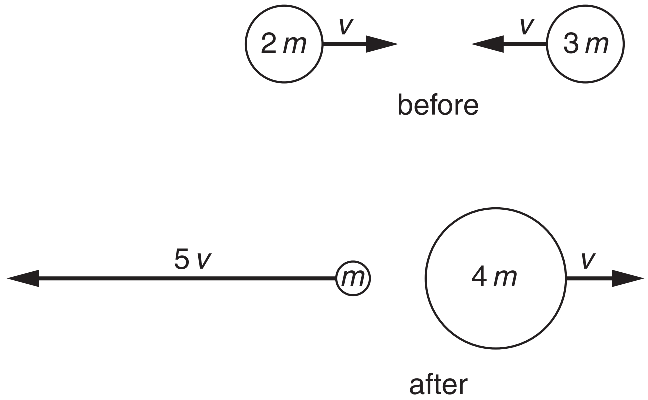

Fig. 1.1

(i) Show that momentum is conserved in the interaction. Work in terms of *m* and *v*.

[2]

(ii) Show that the total kinetic energy of the particles increases by $12\,mv^2$ during the fusion reaction.

[2]

(iii) Compare the increase in total kinetic energy of the particles with the kinetic energy of the neutron and comment.

[2]

(iv) Calculate the increase in total kinetic energy in J of the particles using the data below.

Data:
$m = 1.67 \times 10^{-27}$ kg
$v = 1.19 \times 10^{7}$ m s^{-1}

increase = ... J **[1]**

(b) The total mass of the two nuclei before fusion is 5.029 u. The total mass of the helium nucleus and the neutron is 5.010 u. Show that the energy released in the fusion process is approximately equal to your answer to **(a)(iv)**.

[3]

[Total: 10]

2 **(a)** Define *simple harmonic motion*.

....

....

.... **[2]**

(b) Fig. 2.1(a) shows a simple pendulum suspended from point **P** with the bob at the amplitude of its swing. A student knocks the bob at this instant causing the bob to rotate in a horizontal circle as shown in Fig. 2.1(b).

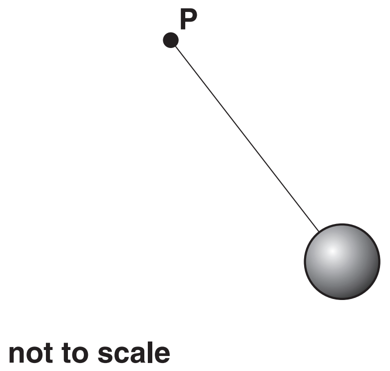

Fig. 2.1(a)

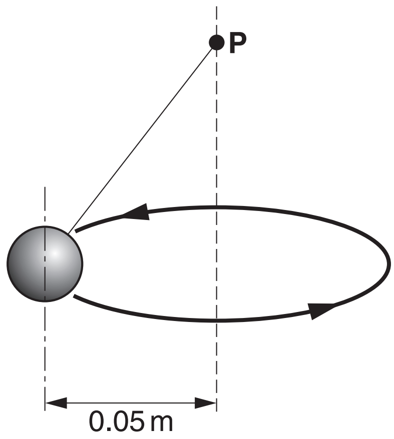

Fig. 2.1(b)

Draw and label arrows on Fig. 2.1(b) to represent the forces acting on the bob. **[2]**

(c) Fig. 2.2 shows a graph of the displacement of the bob against time when it is oscillating as a simple pendulum.

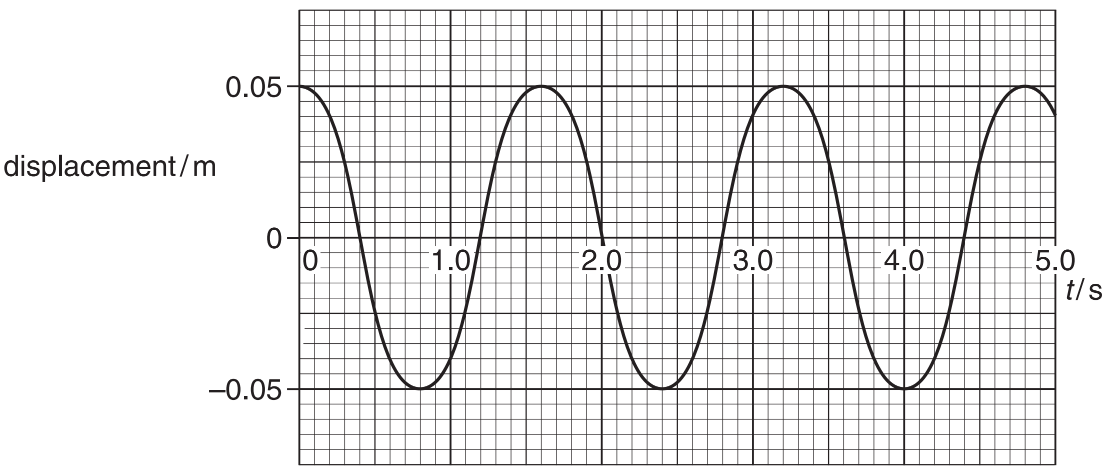

Fig. 2.2

The frequency f of oscillation is related to the length l of the pendulum by the formula

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}\ .$$

Use data from Fig. 2.2 to determine

(i) the length l of the pendulum

l = ... m **[3]**

(ii) the maximum acceleration a of the bob.

a = ... $m\,s^{-2}$ **[2]**

(d) Explain why the circular motion of the conical pendulum has the same frequency as the simple pendulum.

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.... **[3]**

[Total: 12]

3 This question is about orbits around the Sun.

(a) The gravitational force of the Sun, mass M, provides the centripetal force which holds the Earth in a near circular orbit of radius R.

By considering the Earth as an isolated planet moving in a circular orbit show that its speed v is given by the equation $v = \sqrt{\frac{GM}{R}}$.

[3]

(b) A space observatory to monitor activity on the surface of the Sun has been placed in a circular orbit, which is 1% smaller than the orbit of the Earth, as shown in Fig. 3.1.

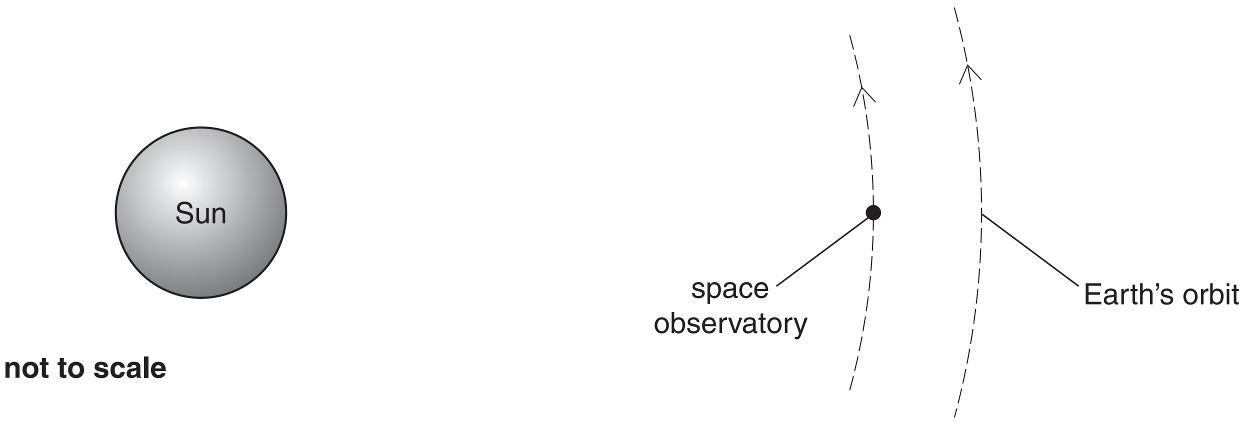

Fig. 3.1

Explain why the equation of part **(a)** predicts that the observatory should orbit the Sun in less than one year.

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.... **[2]**

(c) Fig. 3.2 shows the special case where the Earth and observatory are positioned so that both orbit the Sun in exactly one year.

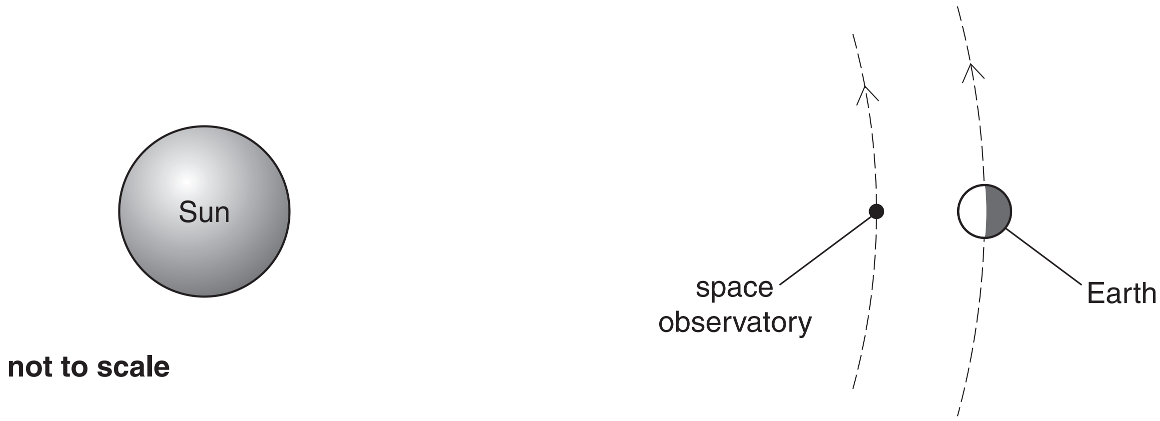

Fig. 3.2

(i) Explain why in this special case the speed of the observatory must be less than the speed of the Earth.

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.... **[1]**

(ii) Draw labelled arrows on Fig. 3.2 to show the directions of the gravitational forces acting on the observatory. Indicate, by length of arrow, which force is larger. **[1]**

(iii) Explain how it is possible for the observatory to have an orbital period of one year. Suggest why this is convenient.

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.... **[3]**

[Total: 10]

4 This question is about charging and discharging a capacitor.

Fig. 4.1 shows a circuit, consisting of two resistors, a capacitor and two milliameters A_1 and A_2, which can be connected to a 12 V supply through a switch **S**. Initially, the switch **S** is open and the capacitor is uncharged.

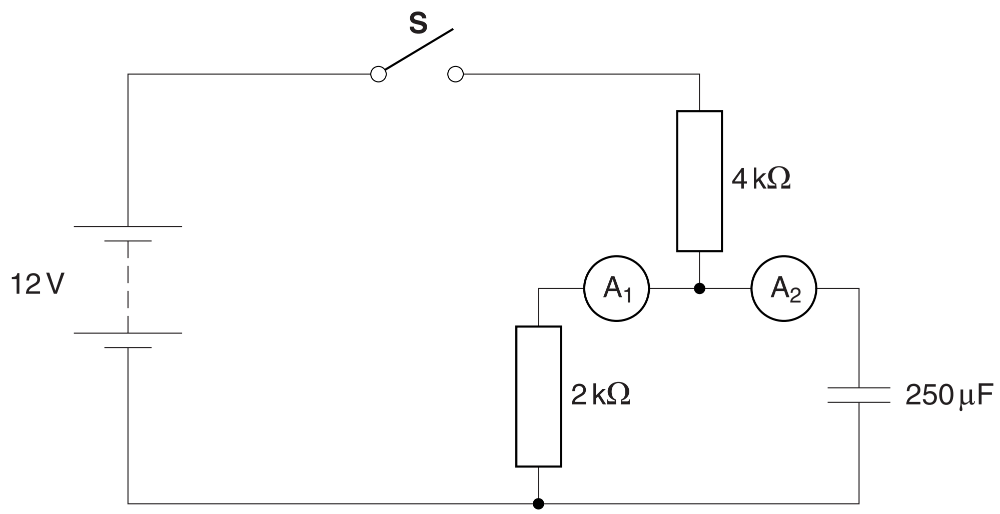

Fig. 4.1

(a) When the switch **S** is closed, explain why the initial current readings are

(i) zero on A_1

....

.... **[2]**

(ii) 3.0 mA on A_2.

....

....

.... **[2]**

(b) After the capacitor has fully charged

(i) state the readings of

1 ammeter A_1 .... mA **[1]**

2 ammeter A_2 .... mA **[1]**

(ii) explain why the voltage across the capacitor is 4.0 V

....

....

.... **[2]**

(iii) calculate the charge Q stored on the capacitor.

Q = ... C **[2]**

(c) The switch **S** is now opened.

(i) State the initial reading of ammeters A_1 and A_2.

.... mA **[1]**

(ii) Calculate the value of the time constant for the decay of charge on the capacitor.

time constant = ... s **[1]**

(iii) Plot a graph on the axes of Fig. 4.2 of the reading I of ammeter A_2 from $t = 0$, when the switch is opened, to $t = 1.5$ s. Label the y-axis with a suitable scale. **[3]**

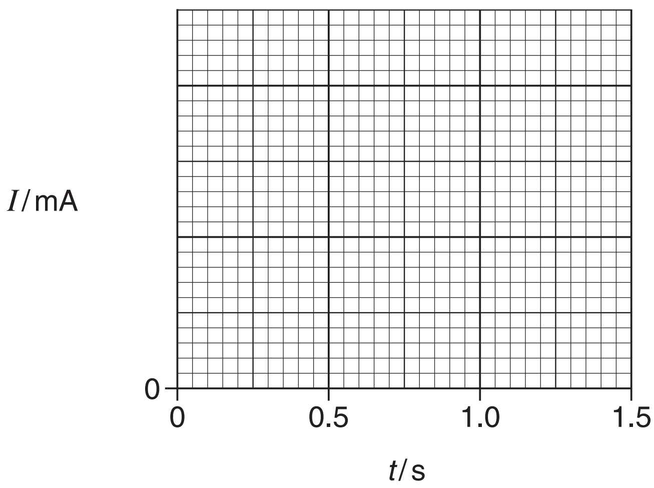

Fig. 4.2

[Total: 15]

5 Fig. 5.1 shows a soft iron ring of variable circular cross-section. It has four coils containing 2, 3, 4 and 5 turns wound around it. The cross-sectional area of the ring is different for each coil.

A d.c. supply is connected across the coil with three turns.

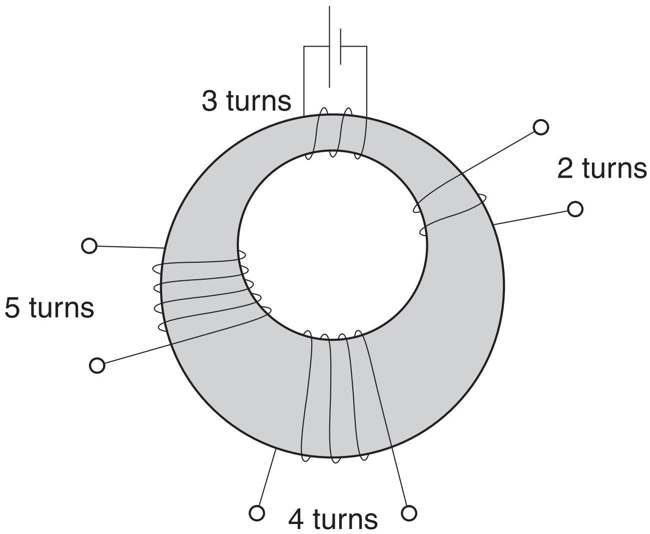

Fig. 5.1

(a) Draw on Fig. 5.1 the complete paths of **two** lines of magnetic flux produced by the three-turn coil when there is a current in it. **[2]**

(b) (i) Explain how *magnetic flux density* is related to *magnetic flux*.

....

....

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.... **[2]**

(ii) State which **one** of the following three quantities,

magnetic flux   magnetic flux density   magnetic flux linkage

is most nearly the same for all four coils in Fig. 5.1. Give a reason for your answer.

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.... **[2]**

(iii) Write down **one** of the **other** two quantities in **(ii)** above. State in which coil this quantity has the largest value. Give a reason for your answer.

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.... **[2]**

(iv) Write down the remaining quantity from **(ii)** above. State in which coil this quantity has the largest value. Give a reason for your answer.

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.... **[2]**

(c) Faraday's law applies to situations where the magnetic flux through a circuit is changing. Use this law to explain why the iron core in Fig. 5.1 heats up when an alternating current is supplied to the three-turn coil instead of a direct current.

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.... **[3]**

[Total: 13]

6 This question is about the radioisotope americium-241 used in smoke detectors. Fig. 6.1 shows a cross-section through a simplified smoke detector mounted on the ceiling.

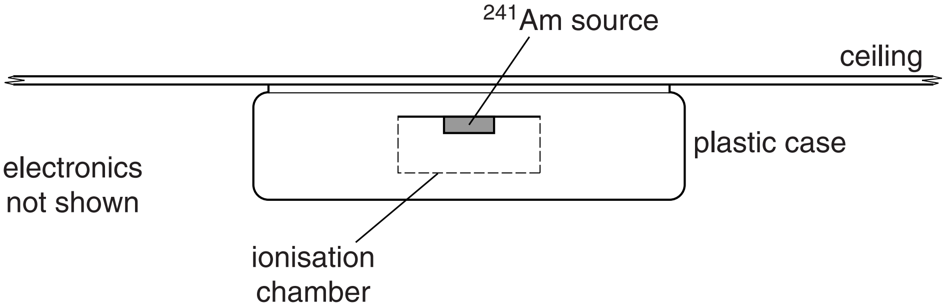

Fig. 6.1

The alpha particles emitted by the americium ionise the air inside the ionisation chamber maintaining a small current in a circuit including the ionisation chamber in series. When smoke enters the chamber the ions are absorbed and the current falls, causing the alarm to sound.

(a) Americium-241 occurs naturally from the decay of plutonium-241 by beta minus emission, or is made artificially by the bombardment of plutonium-240 inside a nuclear reactor. The nuclear equations for each of these processes are shown below with letters substituted for some of the symbols.

$$^{241}_{Z}\text{Pu} \rightarrow {}^{241}_{95}\text{Am} + \beta^-$$

$$^{240}_{Z}\text{Pu} + \text{X} \rightarrow {}^{241}_{95}\text{Am} + \beta^-$$

Write down

(i) the numerical value of the letter Z .... **[1]**

(ii) what Z represents .... **[1]**

(iii) the correct name of particle X. .... **[1]**

(b) A typical smoke detector contains 2.5×10^{-10} kg of americium-241.

(i) Show that the source contains about 6×10^{14} nuclei of americium-241.

[2]

(ii) The half-life of americium-241 is 480 years. Show that its decay constant is about $4.6 \times 10^{-11}\,s^{-1}$.

1 year = 3.15×10^{7} s

[1]

(iii) Calculate the activity of the americium-241 in the smoke detector. Give a suitable unit with your answer.

activity = ... unit .... **[3]**

(iv) Estimate the time it takes for the activity to fall by one percent.

time = ... s **[3]**

(c) Nuclei of americium-241 decay by alpha particle emission. Suggest

(i) why the americium is not a hazard when it is inside the detector

....

.... **[1]**

(ii) how a small speck of the source could be hazardous if it came out of the plastic case.

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.... **[2]**

[Total: 15]

7 In this question, four marks are available for the quality of written communication.

In the first half of the twentieth century physicists had three tools to probe the atom to investigate its structure, namely α-particles, electrons and X-rays.

(a) Describe briefly **one** experiment which was used to determine the size of the atom.

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.... **[5]**

(b) Describe **one** experiment which led to the discovery of the nucleus and to an estimate of its size.

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.... **[6]**

Quality of Written Communication **[4]**

[Total: 15]

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