Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL

1420U30-1

S18-1420U30-1

PHYSICS – A2 unit 3
Oscillations and Nuclei

MONDAY, 4 JUNE 2018 – AFTERNOON

2 hours 15 minutes

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1.	9	
	2.	12	
	3.	8	
	4.	8	
	5.	8	
	6.	19	
	7.	16	
Section B	8.	20	
	Total	100	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space use the continuation page(s) at the back of the booklet taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.

Section **A**: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 minutes on this section.

Section **B**: 20 marks. Comprehension. You are advised to spend about 40 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **4***(b)*.

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SECTION A

Answer **all** *questions.*

1. *(a)* A car travels at a constant speed of 45.0 km h^{-1} around a curve in the road with a radius of 80 m.

(i) Explain why the car is accelerating. [2]

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(ii) Calculate the angular velocity of the car (in rad s^{-1}) as it travels around the curve. [2]

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(iii) Calculate the acceleration of the car and state its direction. [3]

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(b) Discuss how the application of science enables cars to travel safely around curves. [2]

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2. Kinetic theory for an ideal gas gives an expression that can be written as:

$$pV = \frac{1}{3}\, nN_A m\overline{c^2}$$

(a) State the meaning of the terms: [2]

(i) m ....

(ii) $\overline{c^2}$ ....

(b) Defining both symbols, explain what quantity is given by nN_A. [3]

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(c) The product of pressure and volume for an ideal gas may also be expressed as $pV = nRT$. Show in clear steps that the total translational kinetic energy of one mole of the gas is $\frac{3}{2}RT$. [4]

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(d) An ideal monatomic gas, initially at a pressure of 115 kPa and temperature of 294 K, expands at constant pressure from a volume of $2.20 \times 10^{-3}\,\text{m}^3$ to $2.60 \times 10^{-3}\,\text{m}^3$. Calculate the change in the internal energy of the gas. [3]

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3. *(a)* Give the definition of the *specific heat capacity* of a material. [1]

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(b) An insulating flask contains 0.6×10^{-3} m^3 of water at 19.5 °C. A volume 1.6×10^{-3} m^3 of boiling water at 100.0 °C is poured into the flask.

(specific heat capacity of water, c = 4 200 J kg^{-1} °C^{-1}; density of water, ρ = 1 000 kg m^{-3})

(i) Determine the final temperature of the water in the flask. [3]

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(ii) Calculate the heat lost by the boiling water. [3]

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(iii) Justify the statement that no work is done on/by the boiling water as it cools. No further calculations are needed. [1]

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4. *(a)* A fission nuclear reaction for uranium is:

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + 3^{1}_{0}\text{n}$$

The masses of the nuclei are:

mass of $^{235}_{92}\text{U}$ = 235.01 u

mass of $^{92}_{36}\text{Kr}$ = 91.90 u

mass of $^{141}_{56}\text{Ba}$ = 140.89 u

mass of $^{1}_{0}\text{n}$ = 1.01 u

1 u = 931 MeV

Calculate the energy released in this nuclear reaction. [2]

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(b) Explain carefully the relevance of the **binding energy per nucleon** curve to nuclear fission and fusion. [6 QER]

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5. *(a)* Radon gas decays by emitting α-particles. It has a half-life of 3.8 days. Calculate the **percentage reduction** in the activity of a sample of radon after 12 days. [4]

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(b) A student makes the following measurements for a radioactive source using the indicated absorber between the source and detector.

Absorber	Counts per minute
none	1 004
sheet of paper	597
2 mm of aluminium	23
15 cm of lead	27

Explain these observations. [4]

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6. *(a)* A load of 0.150 kg is attached to the lower end of a light vertical spring of stiffness (spring constant) 7.50 N m^{-1}. The system is initially in equilibrium. A student raises the load vertically through a distance of 0.095 m and releases it so that it oscillates.

Determine:

(i) the extension of the spring when the system is in equilibrium; [2]

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(ii) the period of oscillation. [2]

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(b) The student notices the amplitude of oscillation decreasing and records the following amplitudes.

Oscillation number (n)	Amplitude (A) /m
0	0.095
10	0.062
20	0.043
30	0.029
40	0.019
50	0.014
60	0.009

She comments that "the rate of decrease of amplitude is larger at the start of the experiment than at its end". Justify the statement using the data from the table. [2]

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(c) She expects that the measured amplitude of oscillation can be described by the equation:

$$A = A_0 e^{-\frac{n}{N}}$$

where A_0 is the initial amplitude, n is the oscillation number and N is a constant for the experiment that describes the decay of the amplitude.

(i) Justify that A_0 is the amplitude when n = 0. [1]

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(ii) By considering the amplitude when n = 30 use the equation to determine a value for N. [2]

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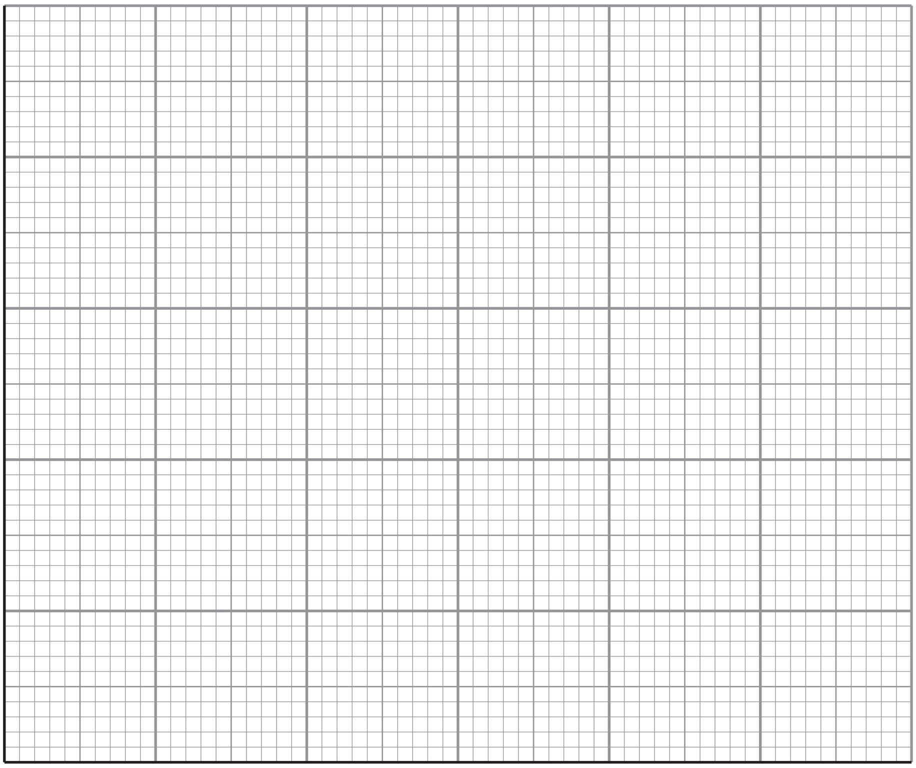
(d) The student decides to check the validity of the equation.

(i) Complete the third column in the table. The first four rows have already been completed. [1]

Oscillation number *(n)*	Amplitude *(A)* / m	$\ln\left(\frac{A_0}{A}\right)$
0	0.095	0
10	0.062	0.43
20	0.043	0.79
30	0.029	1.19
40	0.019	
50	0.014	
60	0.009	

(ii) Plot $\ln\left(\frac{A_0}{A}\right)$ (y-axis) as a function of the oscillation number (x-axis) and draw a line of best fit. [3]



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(iii) Explain whether or not your graph is in agreement with the equation $A = A_0 e^{-\frac{n}{N}}$. [2]

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(iv) Use the graph to determine a value for N. [3]

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(v) Explain which of the two values obtained for N is expected to be the more accurate, the value in part *(c)*(ii) or *(d)*(iv). [1]

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7. *(a)* A pendulum oscillating with simple harmonic motion consists of a small 0.05 kg mass oscillating at the end of a string of length 4.0 m. The displacement x in metres at time t can be written as:

$$x = 0.25 \cos \omega t$$

(i) Show that the angular velocity, ω, is approximately 1.57 rad s^{-1}. [2]

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(ii) Calculate the maximum speed of the mass. [2]

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(iii) Show that the kinetic energy (E_k) of the mass, in joules, may be written as: [2]

$$E_k = 3.8 \times 10^{-3} \sin^2 1.57t$$

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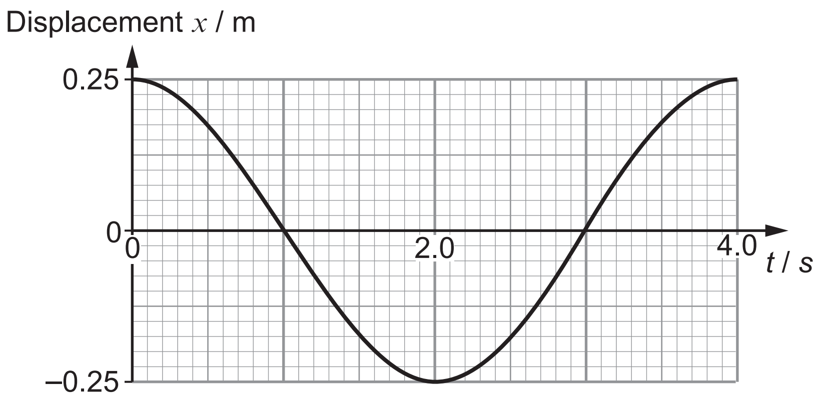
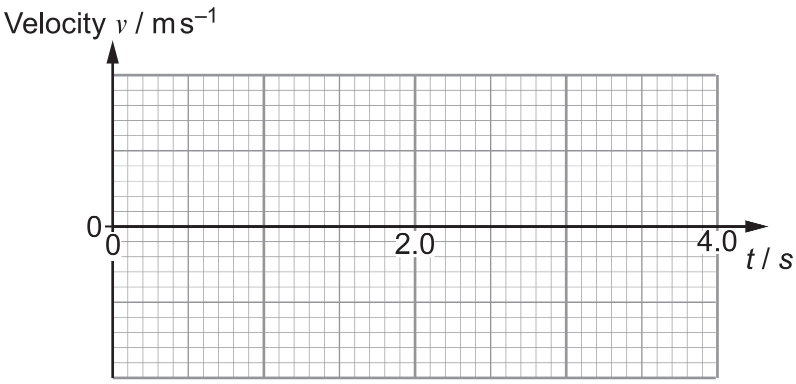
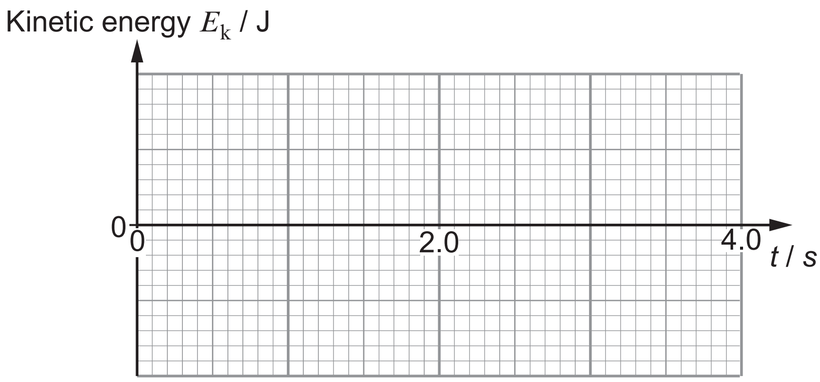
(iv) The displacement-time curve for the pendulum is shown for a time interval of one period i.e. 4.0 s. Draw curves for velocity, v, and E_k on the axes below for the same interval of time. Indicate values on your axes for v and E_k. [4]







(v) Determine the maximum height reached by the pendulum mass above the level of its lowest point. [2]

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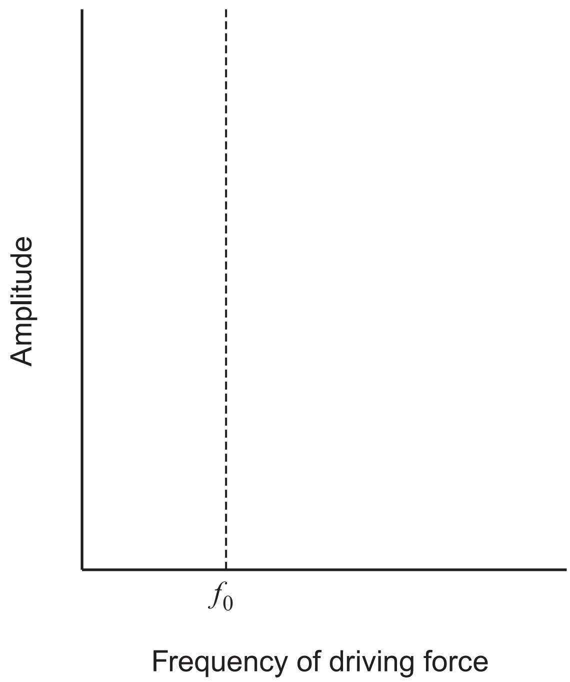
(b) A system that can oscillate may be driven by an external sinusoidal force.

(i) Sketch the amplitude of a lightly damped system as the frequency of the driver is increased. The natural frequency f_0 of the system is indicated. Label the curve **X**. [1]



(ii) Name the effect seen near the frequency, f_0. [1]

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(iii) Sketch a second curve on the **axes above** for an identical oscillating system that is damped to a greater extent. Label the curve as **Y**. [2]

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SECTION B

Answer **all** *questions*

Read through the following article carefully.

Freely adapted from:

The Physics of Optical Fibres
By Justino Luis Moreno

Paragraph

Basically, an optical fibre is just a piece of glass along which you send light. A similar procedure was first demonstrated not with glass but with water flowing from a spout in 1840 by scientists Daniel Colladon and Jacques Babinet. Babinet later published his work in an article entitled "On the reflections of a ray of light inside a parabolic liquid stream". This effect can be reproduced quite easily in a school lab using the apparatus shown in Figure 1. 1

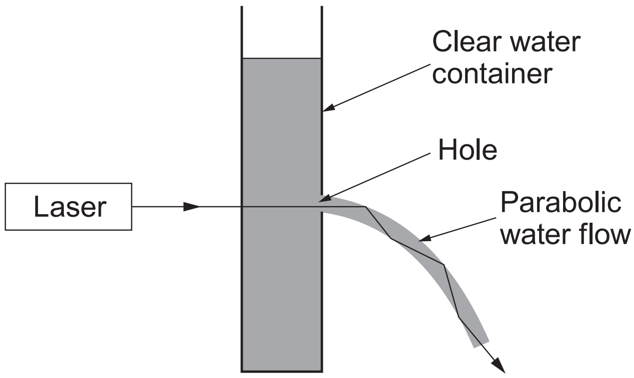

Figure 1

Although this set up is pleasing to the eye and is the basis of some water features, it isn't much use for international telecommunication! A standard optical fibre is shown in Figure 2 along with a ray of light entering it. 2

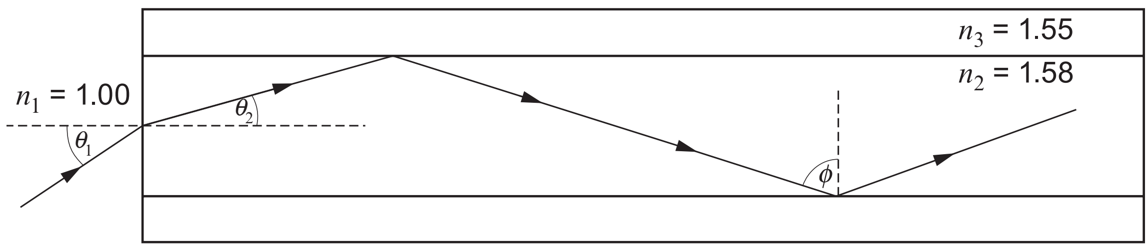

Figure 2

This ray of light is repeatedly reflected along the length of the optical fibre. If the entrance angle (θ_1) is small enough then an effect called total internal reflection (TIR) means that the light is completely reflected each time resulting in no light escaping as it travels along the optical fibre. The physicists in charge of designing these things can prove that the minimum value angle ϕ can have for TIR to take place is given by the equation: 3

$$\phi = \sin^{-1}\left(\frac{n_3}{n_2}\right)$$

Paragraph

This angle is around 80° for the optical fibre shown. The minimum angle for ϕ means that there is a maximum angle for θ_1. This gives an acceptance cone where the input light gets propagated without loss. A quick bit of geometry shows you that the exit angle is the same as the entry angle so that when light exits it produces an almost perfect cone shaped beam with a circular cross-section as can be seen in Figure 3. 4

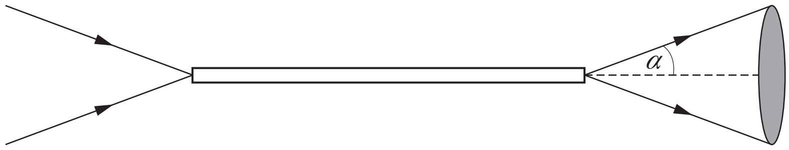

Figure 3

An important term in optical fibre technology is maximum bit rate. Since each pulse represents a bit of data, this is the highest frequency of pulses that can be sent down an optical fibre before the pulses start to overlap and become indistinguishable from each other. A monomode optical fibre cable of length 80 km can comfortably have a maximum bit rate of 10 Gb s^{-1}. This means that 10^{10} pulses can pass along its length every second without overlapping. A typical telephone conversation requires around 10 kb s^{-1} meaning that one monomode optical fibre cable can carry a million telephone conversations simultaneously. High definition TV requires a much higher bit rate and a 10 Gb s^{-1} fibre will only handle around 2 000 high definition TV signals. 5

One of the most important factors that limit data transfer in optical fibres is multimode dispersion. This, put simply, is to do with the entrance cone of light in Figure 3. There is a range of distances that the pulses have to travel because there are a variety of angles at which they can travel along the fibre. The pulses then become spread out and indistinct, ruining the digital signal. Multimode dispersion is eliminated by using monomode optical fibre cables which have very thin cores. As a rule, monomode fibres have a core diameter of around 8 μm. This means that the core is less than 10 wavelengths thick so that the light stops behaving like rays. For monomode fibres there is only one propagation direction – along the axis. 6

Another drawback of sending signals down long lengths of optical fibres is that some of the light is either scattered or absorbed by the glass molecules themselves (an effect known as attenuation). Although no light escapes the fibre due to TIR there are other losses involved and these are usually summarised by using a decibel (dB) scale. This scale is defined by saying that a 10 dB decrease (-10 dB) in power is when the power has dropped to 10% of its input value. A loss of -20 dB then corresponds to a drop to 1% power and -30 dB is a drop to 0.1% power. The following table shows the relationship between dB values and power ratio: 7

dB	Power ratio $\left(\dfrac{P}{P_0}\right)$
-5	0.316
-10	0.100
-15	0.032
-20	0.010

Table 1 8

The losses of optical fibres are usually quoted in the unit dB/km and some modern optical fibres can have values as low as 0.01 dB/km. Hence, each km of cable loses 0.01 dB meaning that you can use 1 000 km before your signal is down to 10% strength. Optical fibres have come a long way since they were born in a fountain of light nearly 200 years ago. They stretch out (literally) to all areas of the world bringing light, sound and broadband wherever they go. Technical advances mean that data can be sent at a rate of 1.05×10^{15} pulses per second over a distance of 50 km with only one monomode optical fibre. Nonetheless, the technology has its limitations of which attenuation and multimode dispersion are but two. 9

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8. Answer the following questions in your own words. Direct quotes from the original article will not be awarded marks.

(a) Explain why the water in Figure 1 flows in a downward curve (paragraph 1). [2]

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(b) Show that the minimum angle (ϕ) for total internal reflection in the optical fibre of Figure 2 is less than 80° (paragraph 3). [2]

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(c) Explain why the light emerging from the optical fibre is in the shape of a cone of light (paragraphs 3 & 4 and Figures 2 & 3). [2]

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(d) Calculate the angle (α) of the cone of light emerging from the optical fibre in Figure 3 (see paragraphs 3 & 4 and Figures 2 & 3). [4]

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(e) Rhys makes the following claim:

"A multimode optical fibre that can transfer data at a maximum bit rate of $500\,\mathrm{Mb\,s^{-1}}$ over a distance of 1 km would be able to transfer data at a maximum rate of $50\,\mathrm{Mb\,s^{-1}}$ over a distance of 10 km."

Discuss whether or not Rhys's claim is valid (paragraph 5 & 6). [3]

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(f) A certain type of optical fibre has an attenuation of 0.8 dB/km. When the signal decreases to 6% of its original intensity it must be amplified or the signal will be lost. An engineer intends to install these optical fibres in lengths of 20 km before each amplifier. Determine whether or not this is an appropriate length of optical fibre to use (see paragraph 7 and Table 1). [3]

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(g) Aled claims that a core diameter of around $13\,\mu\mathrm{m}$ is thin enough for a monomode optical fibre because a wavelength in air of $1.3\,\mu\mathrm{m}$ is usually used in communications. Rhian claims that this is nonsense because the wavelength in the optical fibre is changed due to its refractive index. Justify by including a calculation who is correct (paragraph 6). [4]

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END OF PAPER

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