Section C: Waves in communication

Answer ALL questions. Write your answers in the spaces provided.

1 Wi-Fi and Bluetooth® are used to transmit data between instruments and computers, e.g. in a hospital ward or operating theatre. By using different protocols they can successfully share the same frequency range.

(a) In which of these regions of the electromagnetic spectrum do Wi-Fi and Bluetooth® data communications operate? 1 mark

- ☐ **A** 1 MHz
- ☐ **B** 2.5 GHz
- ☐ **C** 30 GHz
- ☐ **D** 1 THz

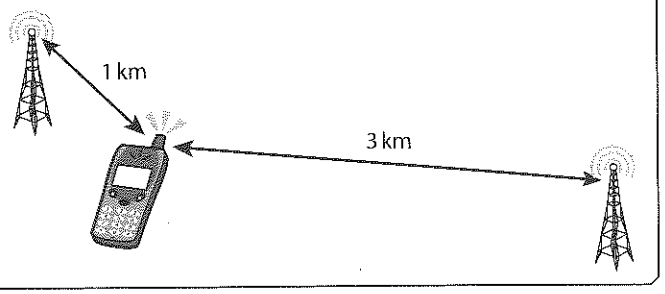
(b) A TV remote control operates on a wavelength of 940 nm. Select the region of the electromagnetic spectrum in which this wavelength falls. 1 mark

- ☐ **A** microwave
- ☐ **B** visible light
- ☐ **C** infrared
- ☐ **D** ultraviolet

Links See page 40 of the Revision Guide for reminders of the regions and the frequency bands of the electromagnetic spectrum.

Guided

A mobile phone handset is 1 km from the nearest cellular mast and 3 km from the mast in an adjacent cell.



(c) Explain how different frequency bands are used by mobile phone networks to achieve interference-free communications. 3 marks

Each mobile phone operator is allocated a separate set of frequency bands by the .....

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For three marks you need to make three separate points.

The upload signal from a mobile handset is broadcast on a slightly different frequency from the

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The cell masts in adjacent cells .....

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Guided

(d) The upload signal broadcast from the phone handset is detected at both the masts shown in th diagram.

Calculate how many times stronger the detected signal will be at the nearest mast, compared with that at the mast in the next-door cell.

2 mark

The broadcast is in all directions, so its intensity obeys the inverse square law: $I = k/r^2$

So $I_1 / I_2 = (r_2 / r_1)^2 = (\ldots\ldots\ldots\ldots\ldots\ldots$km / 1 km$)^2$

$= \ldots\ldots\ldots\ldots\ldots\ldots$ times stronger.

Quote the law or formul you are using, and show your calculation working. There is a mark for each

Total for Question 1 = 7 mark

2 A clarinet has a mouthpiece with a single reed. That end of the clarinet behaves like a closed-ended pipe. The other end of the instrument is open to the air.

When air is blown over the reed in the clarinet mouthpiece, a stationary wave is set up in the instrument and a sound is produced.

(a) A sound wave is produced by compressions and rarefactions of the material through which it travels. Name this type of wave. 1 mark

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The diagram shows how the amplitude of air vibrations varies down the length of such a pipe

(b) Label **one** node and **one** antinode on the diagram. 2 marks

Node means a point of no vibration.

Guided

(c) The pipe is 0.75 m long. Calculate the wavelength for the next higher harmonic above the fundamental mode. 2 marks

The next harmonic has two nodes and still has an antinode at the open end.

So it fits ¾ of a wavelength into the pipe. So, ¾ λ = ...

Therefore λ = ...

Links You can revise musical instruments on page 36 of the Revision Guide.

Total for Question 2 = 5 marks

Guided

3 All four strings on a violin are the same length, but they have different mass per unit length values and can be separately tensioned to tune them. In the head of a violin, each string is wound round a peg, which can be turned to adjust the tension in that string.

Guided

(a) (i) Calculate how many times larger the tension force must be to double the frequency of the note.

2 marks

Look on the formula sheet (page 163) to find equations: 'wave speed' and 'speed of a transverse wave on a string'.

$f = v/\lambda$

$v = (T/\mu)^{1/2}$

It is the same string throughout, so μ has a constant value,

Therefore, $v \propto T^{1/2}$

So, if f_1 is the original frequency, and f_2 is the frequency of the note one octave higher:

$f_2/f_1 = 2 = v_2/v_1 = (T_2/T_1)^{1/2}$

Because the length of the string does not change, λ is constant, so can be disregarded in this equation.

So, $(T_2/T_1) = 2^2 =$ ..... times larger.

(ii) Give **two** differences between the types of wave produced in the string when the violin bow is drawn across it and the sound waves that radiate out from it through the air.

2 marks

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Waves can be progressive or stationary. They can also be either transverse or longitudinal.

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(iii) Interference patterns occur when waves are coherent. State what is meant when two waves are coherent.

1 mark

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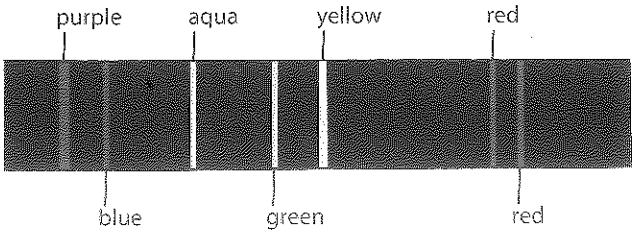
The diagram shows a spectrum made when light, produced by passing an electric discharge through a mercury vapour sample, is passed through a diffraction grating. This spectrum is a series of separate lines of specific colours.



Guided

(b) Describe how emission spectra such as the one shown above can be used to identify elements in samples of unknown composition.

2 marks

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Links You can revise interference and diffraction gratings on pages 33–34 of the Revision Guide.

Total for Question 3 = 7 marks

Guided

4 A table decoration can be created using optical fibres made from Perspex®. A light source in the base of the decoration feeds light into the cut ends of a bunch of fibres. The fibres are allowed to spread out at their other cut ends, where bright dots of light appear. The fibres appear to be unlit along their length apart from those bright spots.

(a) Perspex® has a refractive index of 1.48.

Calculate the critical angle for Perspex®.

2 marks

Refractive index, $n = 1/\sin C$. So $\sin C = 1/n =$ .....

Therefore the critical angle, $C = \sin^{-1}$ .....

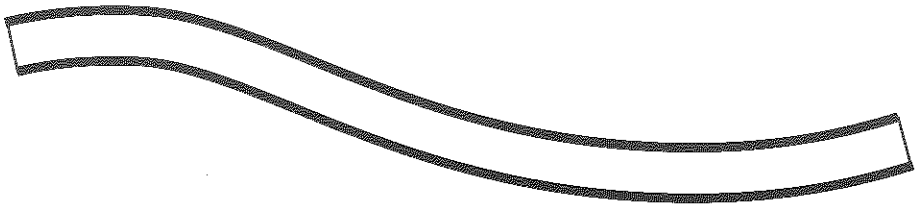
= .....

Find the formula connecting critical angle with refractive index on the formula sheet and rearrange.

(b) Perspex® is a transparent material, but light emerges only from the ends of the fibres.

Draw the path taken by one of the light rays passing through a fibre on the diagram.

2 marks



(c) Explain why no light is seen coming out from the sides of the fibres.

1 mark

Most of the light that enters the fibre will strike the outside surface at an angle ..... than the critical angle and so will undergo .....

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Optical fibres make important contributions to improved healthcare.

One use of them is in endoscopy. This technique, widely used in hospitals, allows many types of medical investigation and operation to be performed with only minimal cutting of body tissue.

To transmit and receive patient data, hospitals, GPs and other health professionals also increasingly rely on broadband internet connections that use fibre optics.

(d) Compare the uses made of optical fibres in endoscopy and in broadband internet connections.

In your answer you should refer to frequencies, analogue and digital data types, the types of fibre used and the quality of the data communicated. 6 marks

In a medical endoscope, the optical fibres can carry light with a full range of visible frequencies.

One bundle of fibres carries .....

Another bundle of fibres .....

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By contrast, fibres in a broadband network .....

That means .....

To demonstrate your understanding of the topic, it helps to explain the term 'digital' by describing how numbers are encoded by flashes of light.

Each separate frequency band of IR radiation can carry another separate set of digital information. The fibres used in an endoscope do not need to carry the signal more than about a metre and just need to deliver a lot of light efficiently. But in broadband optical fibre cables .....

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Links You can revise fibre optics and types of signal on pages 37–39 of the Revision Guide.

Total for Question 4 = 11 marks

END OF PAPER

TOTAL FOR SECTION C = 30 MARKS
TOTAL FOR PAPER = 90 MARKS