Teacher Resource Bank

GCE Physics B: Physics in Context:

Additional Sample Questions and Mark Schemes:

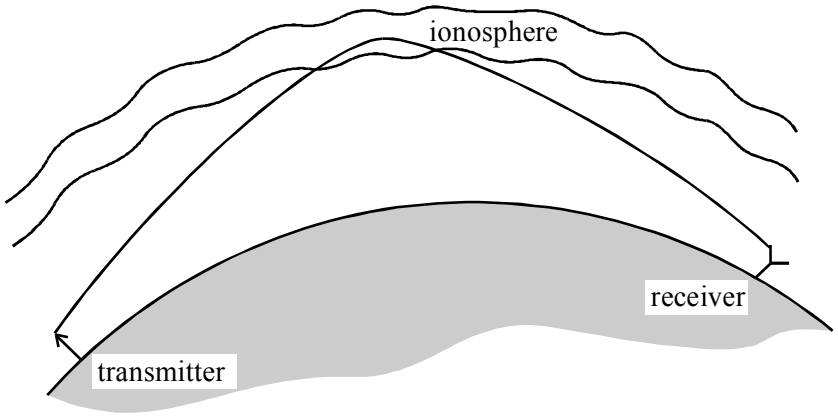
- PHYB1 - Harmony and Structure in the Universe

ADDITIONAL SAMPLE QUESTIONS

This document provides a directory of past questions from the current AQA GCE Physics (Specification B), these questions may prove relevant/useful to both the teaching of the new AQA GCE Physics B: Physics in Context specification and the preparation of candidates for examined units. It is advisable when using these questions that teachers consider how these questions could relate to the new specification. Teachers should be aware of the different treatment of the Quality of Written Communication between the specifications.
For specific examples of the style and flavour of the questions which may appear in the operational exams, teachers should also refer to the Specimen Assessment Materials which accompany the specification.

A mark scheme has been produced which accompanies this document.

1 The diagram below shows one way of transmitting information from a transmitter to a receiver that is not directly in its line of sight.



(a) State the property of waves that enables the signals to be transmitted back to Earth by the ionosphere.

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(1)

(b) (i) Describe briefly **one** other method of transmitting signals to a receiver that is not in the line of sight of a transmitter.

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(2)

(ii) State **one** advantage or disadvantage of the method you have described when compared with that in the diagram above.

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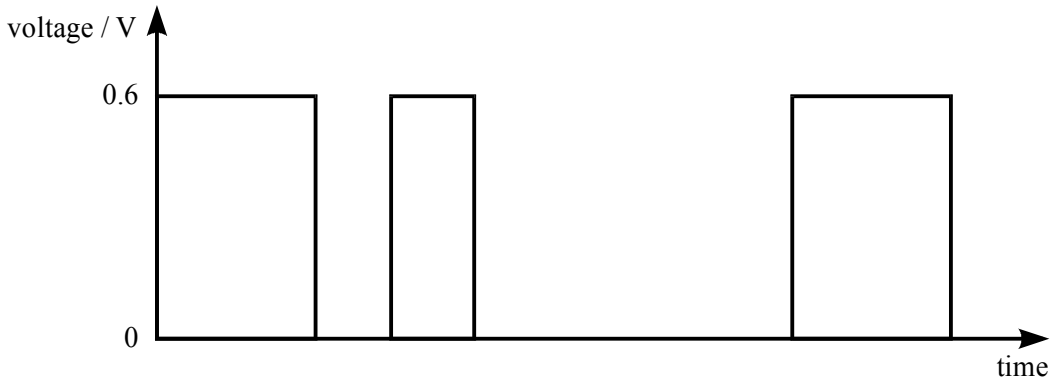
(1)

(Total 4 marks)

2 **Figure 1** shows a digital signal input to a long copper cable.

Figure 1



(a) (i) Explain what aspect of **Figure 1** indicates that the signal is digital.

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(1)

(ii) State and explain **two** advantages of digital data transmission compared with analogue data transmission.

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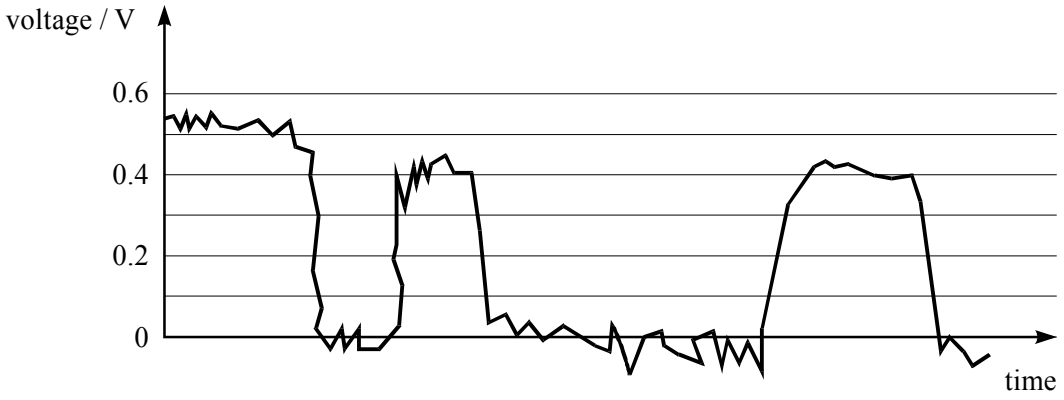
(4)

(b) **Figure 2** shows the output signal at the end of the long copper cable.

Figure 2



(i) State and explain **two** reasons why the output signal differs from the input signal.

Two of the 6 marks in this question are available for the quality of your written communication.

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(6)

(ii) Suggest the name of a transmission medium which overcomes these problems.

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(1)

(iii) Despite the differences between the input and output signals there may be no error in reading the output signal provided the sensitivity of the coding is appropriate. Choose appropriate voltage ranges to represent 0 and 1 in order to allow the output signal to be correctly read.

range of voltage to represent 0.....

range of voltage to represent 1.....

(2)

(Total 14 Marks)

3 (a) State:

(i) the typical frequency range of human hearing;

.....

(ii) the base bandwidth required for the transmission of music with the frequency range you have quoted in part (a)(i);

.....

(iii) the minimum sampling rate required for the digital transmission of a signal with a base bandwidth of 6 kHz.

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(3)

(b) Digital Audio Broadcasting (DAB) is a technique in which radio stations transmit programme material using digital rather than analogue signals. State **two** advantages that DAB has over analogue transmission.

Advantage 1 .....

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Advantage 2 .....

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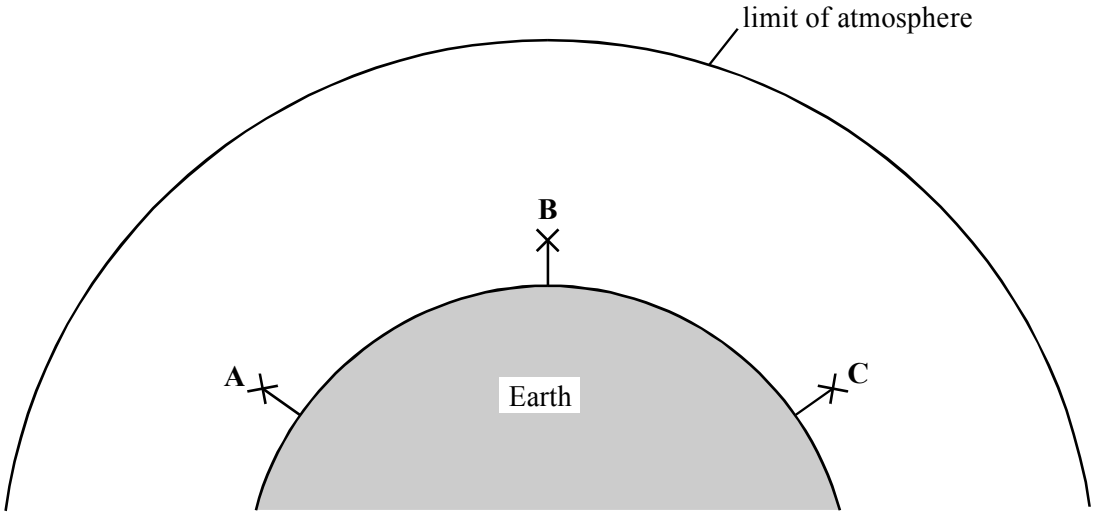
(2)

(c) The diagram below shows three radio stations **A**, **B** and **C** at three points on the Earth's surface.



Station **A** transmits radio signals to **B** and **C**. Describe the various paths that can be taken by the radio waves in order to travel between stations. For each path, state whether it is suitable for long or short wavelengths, or for any wavelengths. You can sketch paths onto the diagram above if you wish in order to illustrate your answer.

Two of the 7 marks in this question are for the quality of your written communication.

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(7)

(Total 12 marks)

4 A satellite orbiting the Earth receives electromagnetic signals and then re-transmits them back to Earth at a frequency of 2.3 GHz.

(a) Calculate the wavelength of the re-transmitted signal.

Speed of electromagnetic waves in a vacuum, $c = 3.0 \times 10^8\ \text{m s}^{-1}$

Wavelength .....

(2)

(b) State the region of the electromagnetic spectrum to which these waves belong.

.....

(1)

(c) The satellite's signal is radiated by an antenna that resembles the satellite dishes used to receive television signals on Earth. The antenna dish is 0.60 m in diameter. Show that the angle at which the signal intensity falls to a minimum is about 12°.

(3)

(d) The satellite is positioned 35 000 km from the Earth. The power received by the dish antenna on the Earth is 16 nW.

Calculate the power that would be received at the dish if the satellite were to be re-positioned at a distance of 17 500 km from Earth. Give your reasoning.

Power received .....

(2)

(e) The orbit of the satellite is not perfectly circular. At one moment it has a velocity component of 2.5 $m\,s^{-1}$ towards the receiving antenna. Calculate the frequency shift that will be detected in the receiver on Earth.

Frequency shift .....

(2)

(f) State whether the received frequency will be higher or lower than the transmitted frequency.

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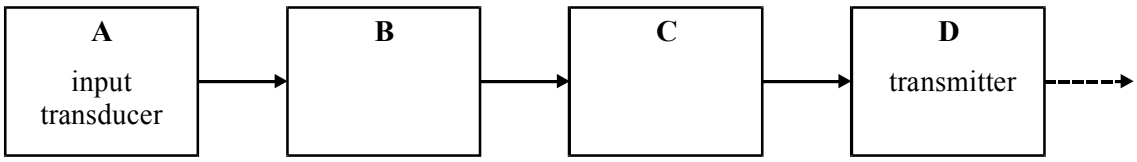
(1)

(Total 11 marks)

5 The diagram below shows the components of the transmitting stage of a simple audio-communication system prior to the signal being transmitted. The signal path is from left to right.



(a) (i) State a suitable transducer for stage **A**.

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(ii) State the name given to stage **B**.

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(iii) State the name given to stage **C**.

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(3)

(b) Describe and explain the purpose of modulation in a communication system.

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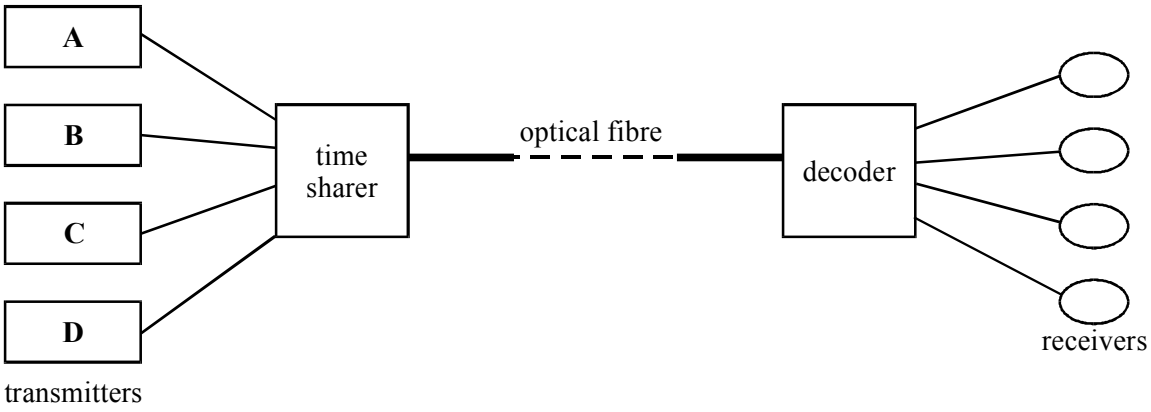
(4)

(Total 7 marks)

6 The diagram below shows four radio stations **A**, **B**, **C** and **D** that are producing analogue signals with frequencies up to a maximum of 20 kHz. After sampling, the signals are being transmitted as digital signals down a single optical fibre.



(a) Calculate the minimum frequency at which the signal from each station must be sampled for high quality transmission of data from the transmitters.

(1)

(b) Explain why the use of a sampling frequency that is lower than the minimum sampling frequency could reduce the quality of the data received.

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(1)

(c) A single optical fibre can transmit 1.5×10^8 bits per second. Calculate the number of radio stations transmitting signals up to 20 kHz that could be transmitted using the single fibre. Each time a signal is sampled 8 bits have to be sent down the fibre.

Number of radio stations .....

(2)

(d) Explain how the digital signals from stations **A**, **B**, **C** and **D** are simultaneously transmitted down the optical fibre and why an optical fibre is preferred to a coaxial cable made from copper wire. You may draw a diagram to support your explanation if you wish.

Two of the 6 marks for this question are available for the quality of your written communication.

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(6)

(Total 10 marks)

7 By the end of this year it is expected that 85% of the population of the United Kingdom will be able to receive Digital Audio Broadcasts (DAB).

(a) The base bandwidth of these broadcasts depends on the frequency response of the human ear.

(i) State the normal frequency range for human hearing.

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(1)

(ii) State the highest frequency that has to be transmitted for high-fidelity broadcasting of an orchestral concert.

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(1)

(b) Before it can be broadcast in digital form the output from a microphone has to be *sampled*.

(i) Explain the term *sampling* and sketch a graph to show the conversion of the microphone output voltage into digital form.

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(2)

(ii) What would be the minimum sampling frequency for the broadcast referred to in part (a)(ii)?

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(1)

(c) State **two** advantages of DAB compared with FM and AM audio broadcasting.

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(2)

(Total 7 marks)

8 (a) State the difference between *transverse* and *longitudinal* waves.

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(2)

(b) State what is meant by *polarisation*.

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(2)

(c) Explain why polarisation can be used to distinguish between transverse and longitudinal waves.

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(2)

(Total 6 marks)

9 (a) A musical note has a frequency of 512 Hz. Calculate the wavelength of the note.

the speed of sound = 330 m s^{-1}

Wavelength = ...

(2)

(b) (i) Suggest why a doorway might cause such a note to diffract significantly.

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(1)

(ii) A normal room doorway of width 0.81 m acts as an aperture for diffraction of sound. Calculate the angle to the straight through direction at which the note in part (a) would give the first minimum.

Angle = ...

(3)

(Total 6 marks)

10 Short pulses of sound are reflected from the wall of a building 18 m away from the sound source. The reflected pulses return to the source after 0.11 s.

(a) Calculate the speed of sound.

Speed of sound .....

(3)

(b) The sound source now emits a continuous tone at a constant frequency. An observer, walking at a constant speed from the source to the wall, hears a regular rise and fall in the intensity of the sound. Explain how the **minima** of intensity occur.

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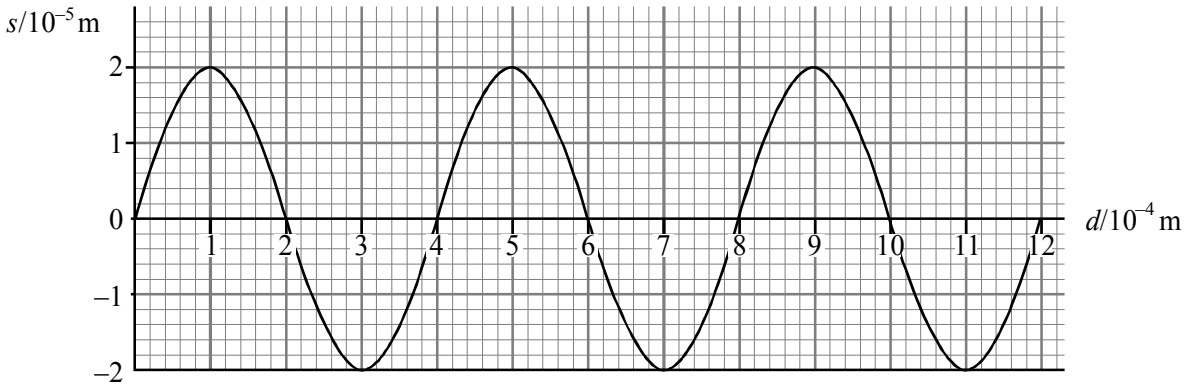
(3)

(Total 6 marks)

11 (a) **Figure 1** shows how the displacement *s* of the particles in a medium carrying a pulse of ultrasound varies with distance *d* along the medium at one instant.

Figure 1



(i) State the amplitude of the wave.

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(1)

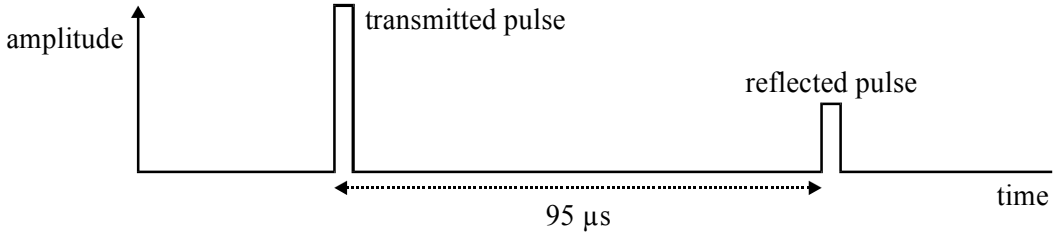
(ii) The speed of the wave is 1200 m s^{-1}. Calculate the frequency of oscillation of the particles of the medium when the ultrasound wave is travelling through it.

Frequency of oscillation .....

(3)

(b) An ultrasound transmitter is placed directly on the skin of a patient. **Figure 2** shows the amplitudes of the transmitted pulse and the pulse received after reflection by an organ in the body.

Figure 2



(i) Give **two** possible reasons why the amplitude of the received pulse is lower than that which is transmitted.

Reason 1 .....

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Reason 2 .....

.....

(2)

(ii) The speed of ultrasound in body tissue is 1200 m s^{-1}. Calculate the depth of the reflecting surface below the skin.

Depth of reflecting surface .....

(2)

(Total 8 marks)

12 The fundamental frequency of a stretched string is given by:

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

(a) (i) State the quantity represented by μ.

.....

(1)

(ii) Draw a sketch of the apparatus you would use to test the relationship between f and μ.

(2)

(iii) State the quantities that are kept constant in the experiment.

(2)

(iv) Describe how you would obtain data using the apparatus you have sketched, and how you would use this data to test the relationship.
You can gain up to 2 marks in this question for good written communication.

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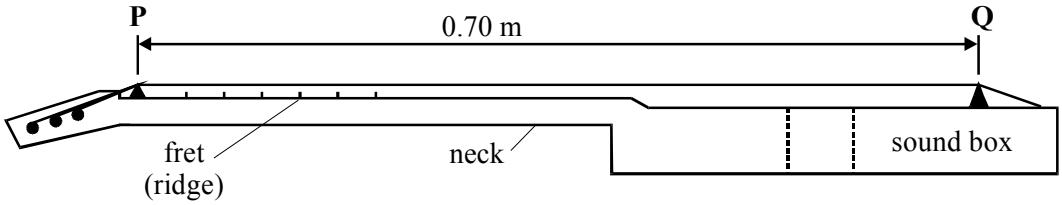
(7)

(b) **Figure 1** shows a guitar. The length of the string **PQ** free to vibrate is 0.70 m. The string is tuned so that when its full length is plucked it vibrates at a frequency of 384 Hz, corresponding to G on the musical scale.

Figure 1



(i) Show in the space below how the string vibrates when emitting its fundamental frequency.

P **Q**

• •

(1)

(ii) Show in the space below how this string would vibrate when emitting a frequency **three times** its fundamental frequency.

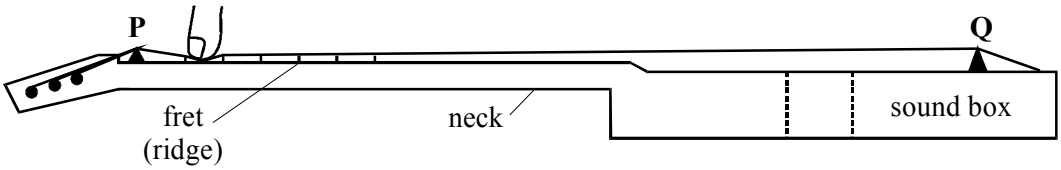
P **Q**

• •

(1)

(iii) To play a higher note, the string is pressed so that the length free to vibrate is shorter. A fret (ridge) on the neck of the guitar ensures that the correct length is produced when the string is pressed as shown in **Figure 2**.

Figure 2

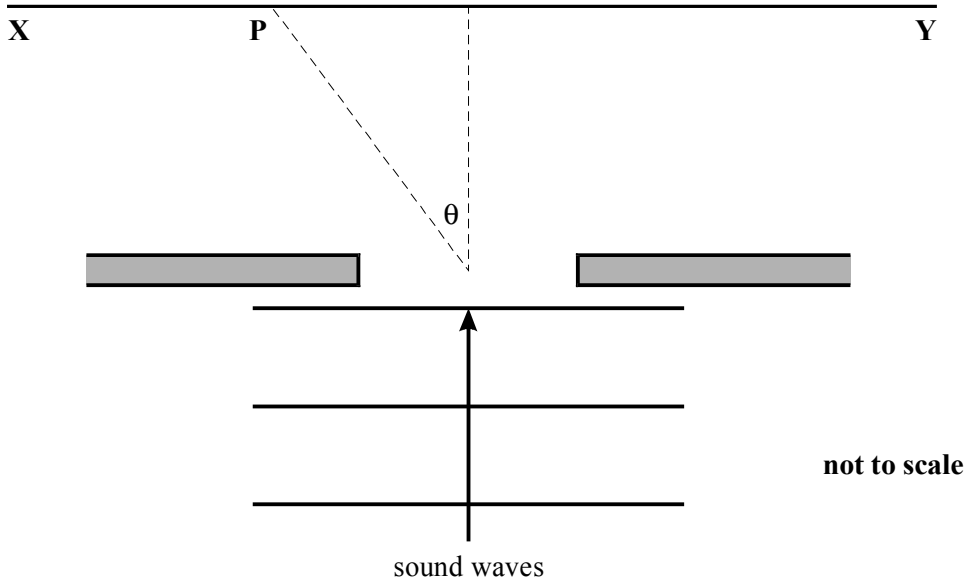


The second ridge from **P** has to be positioned so that when this ridge is used the frequency of vibration is 427 Hz, corresponding to A on the musical scale. Calculate the distance of the second ridge on the guitar from the point **Q**.

(2)

(Total 16 marks)

13 (a) The diagram shows a doorway with sound waves of wavelength 0.37 m incident upon it. The doorway is 0.80 m wide. An observer walks past the doorway along the line **XY.**



(i) At the point **P,** the observer notices a minimum in the volume of the sound. Calculate the angle θ.

(2)

(ii) The sound is changed for one of lower frequency but of the same amplitude. State

and explain how this will affect the variation of the loudness of the sound as heard by the observer walking along the line **XY.**

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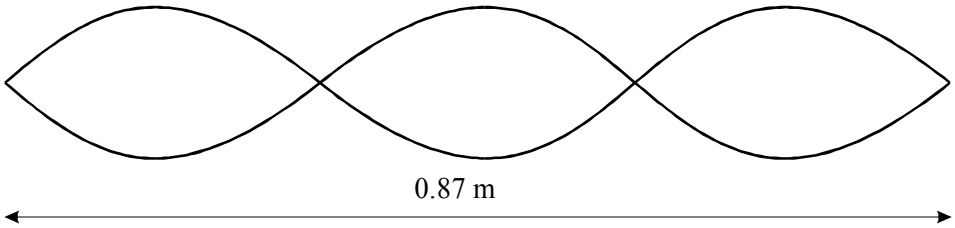
(3)

(b) Monochromatic light is incident normally on a diffraction grating which has 3.0×10^5 lines per metre. A second order maximum is observed at an angle of 18° from the normal. Calculate the wavelength of the light.

(3)

(Total 8 marks)

14 The drawing below shows a standing wave set up on a wire of length 0.87 m. The wire is vibrated at a frequency of 120 Hz.



(a) Calculate the speed of transverse waves along the wire.

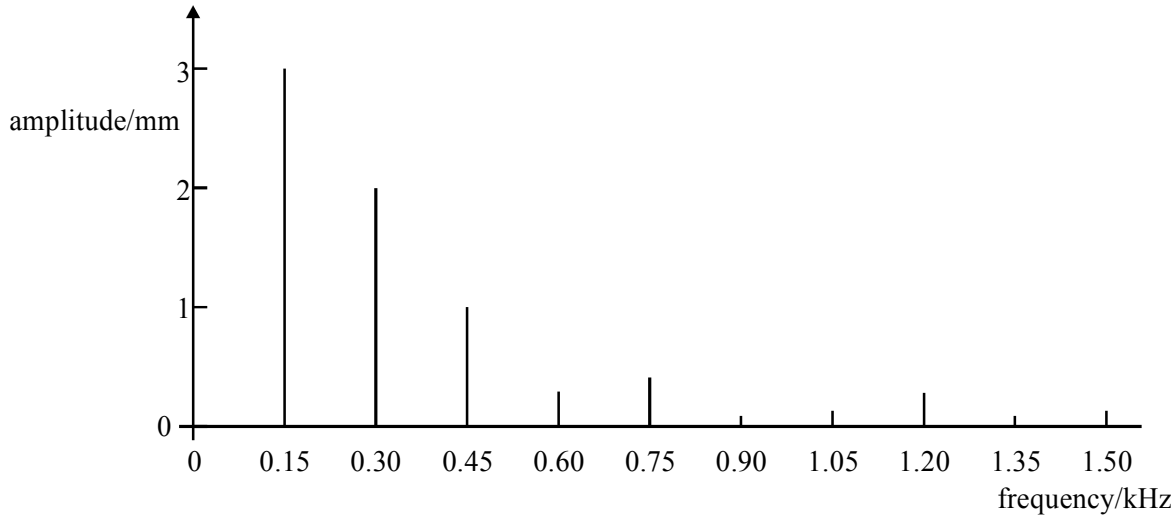
(3)

(b) Show that the fundamental frequency of the wire is 40 Hz.

(2)

(Total 5 marks)

15 The range of frequencies in the note emitted when a guitar string is plucked is shown in the sound frequency spectrum in the diagram below.



The lengths of the vertical lines represent the relative amplitudes of the frequencies present. The frequency with the highest amplitude is the fundamental frequency of the string.

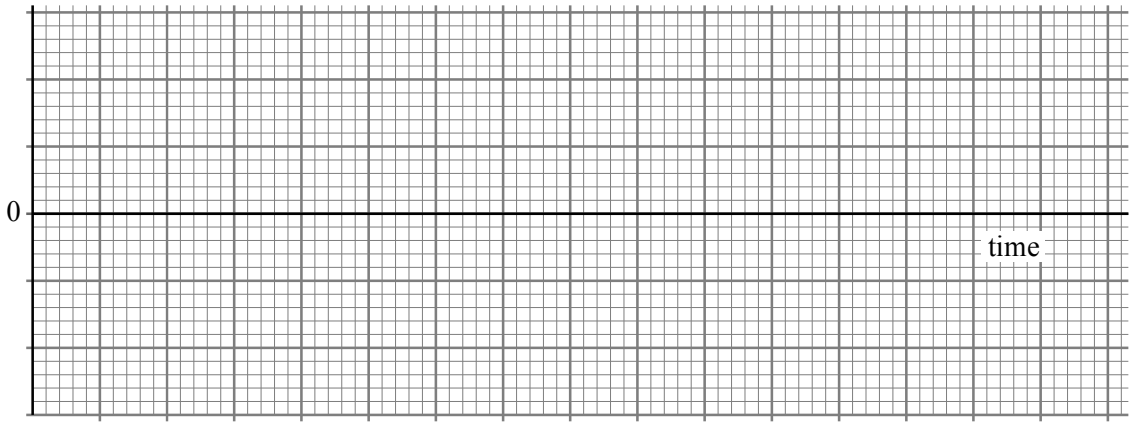
(a) (i) Calculate the period of the fundamental frequency.

Period .....

(1)

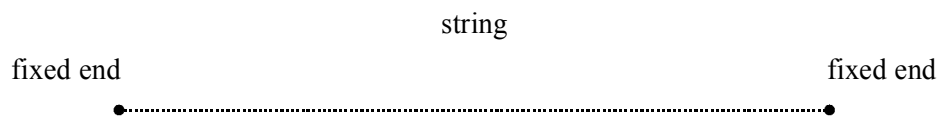
(ii) Show, on the axes below, how the displacement of the centre of the string would vary with time if the string were emitting only the fundamental frequency. Give appropriate scales for the axes.

displacement



(2)

(b) Draw below the mode of vibration of the string if it were emitting only the third harmonic (second overtone) with the amplitude shown in the frequency spectrum.
Use a suitable scale that shows the magnitude of the amplitude clearly.



(2)

(c) The length of the string affects the frequency of the emitted note. State **two** other factors that determine the frequency of the emitted note and, in each case, explain its effect.

Factor 1 .....

Effect .....

Factor 2 .....

Effect .....

(2)

(d) State **one** effect of transmitting this note using a base bandwidth of 100 Hz to 1000 Hz.

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(1)

(Total 8 marks)

16 A white-light source illuminates a diffraction grating that has 6.30 × 105 lines per metre. The light is incident normally on the grating.

(a) Show that adjacent lines in the grating are separated by a distance of about 0.0016 mm.

(1)

(b) **Table 1** shows the diffracting angles measured from the normal for the visible spectral orders using this grating. The angles are given for the red and blue ends of each spectrum.

Table 1

	First order	Second order	Third order
red	25.4°	59.0°	not possible
blue	15.0°	31.1°	50.0°

(i) Use the value for the first order diffracting angle to calculate the wavelength of the red light.

Wavelength of the red light .....

(3)

(ii) Describe carefully the appearance of the complete diffraction pattern on the screen. You may draw a sketch of the pattern to help your explanation if you choose.

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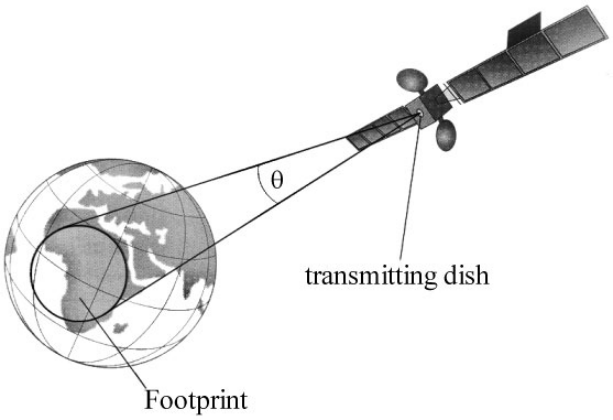
(4)

(Total 8 marks)

17 **Figure 5** shows the Afristar satellite. Afristar orbits the Earth and is used to broadcast high quality digital signals to parts of Africa. The area over which signals can be received is called the .footprint. of the satellite.

Figure 5



(a) (i) The satellite broadcasts at a frequency of 1.5 GHz. Calculate the wavelength of the transmitted signal.

speed of electromagnetic radiation, $c = 3.0 \times 10^8\ ms^{-1}$

Signal wavelength.....

(2)

(ii) The satellite is 36 000 km above the Earth's surface. The footprint of the satellite has an area of radius 3500 km. Calculate the angle, θ, indicated on **Figure 5** over which signals can be detected.

Angle .....

(2)

(iii) Use your answers to part (i) and part (ii) to calculate the maximum diameter of the transmitting dish that is required on the satellite. Assume that the edge of the footprint corresponds to the diffraction minimum.

Diameter of satellite transmitting dish .....

(2)

(iv) The radio signals are transmitted to the satellite from a ground station that also has a satellite dish. The station is 36 000 km from the satellite. Explain why this dish has a larger diameter than the dish on the satellite.

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(1)

(b) The satellite uses time division multiplexing to transmit its multi-channel digital audio services. Explain what is meant by time division multiplexing and go on to suggest why the satellite uses this technique.

Two of the 7 marks in this question are available for the quality of your written communication.

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(7)

(Total 14 marks)

18 (a) State the conditions necessary for a stationary wave to be produced.

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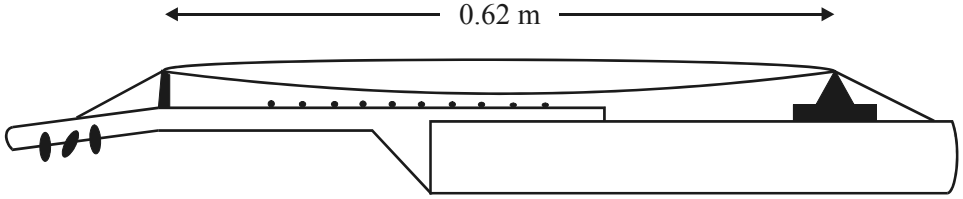
(3)

(b) The diagram shows a stationary wave on a stretched guitar string of length 0.62 m.



Not to scale

The speed of transverse waves along the string is 320 m s^{-1}. Calculate the frequency of the note being played.

Frequency…….

(3)

(Total 6 marks)

19 Light from a characteristic part of the hydrogen spectrum, and coming from a stationary source, has a wavelength of 6.56255×10^{-7} m. Light from the same part of the hydrogen spectrum, and coming from a distant star, has a wavelength of 6.56285×10^{-7} m.

(a) (i) Calculate the difference in frequencies of the light from the two sources.
speed of electromagnetic radiation, $c = 3.00 \times 10^{8}$ m s^{-1}

(3)

(ii) Calculate the speed of the distant star, relative to the Earth.

(2)

(b) Describe how the light from the star could be collected and analysed in order to find its wavelength. You need not describe the apparatus used but you should specify the measurements to be made and how the wavelength is calculated. You can gain up to 2 marks in this question for good written communication.

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(6)

(c) Describe the importance of Hubble's Law in understanding the likely future of the universe.

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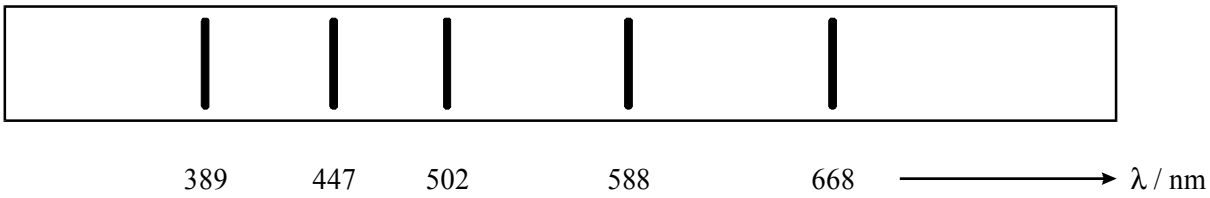
(2)

(Total 13 marks)

20 The drawing below shows some of the principal lines in the visible *emission line spectrum* of helium.



(a) Explain what is meant by the term *emission line spectrum*.

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(3)

(b) Light emitted by a sample of excited helium atoms is passed through a slit and analysed using a diffraction grating with 1.00×10^6 lines m^{-1}. Calculate the angle between the first order images of the 447 nm and 588 nm lines.

(4)

(c) (i) Calculate the frequency of the 588 nm line. The speed of light is 3.00×10^8 m s^{-1}.

(1)

(ii) Write down the colour and the order of magnitude of the photon energy of the 588 nm radiation.

colour..... .*order of magnitude of the photon energy* ..... J

(2)

(d) In observing the helium emission spectrum of a star, the "588 nm" line is measured to be 589 nm. The star is at a distance of 11 Mpc from Earth. (The Mpc is a unit of distance used in astronomy). The speed of light is 3.00×10^8 m s^{-1}.

(i) Assuming that each measurement of wavelength is accurate, explain how the discrepancy between the observations arises.

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(3)

(ii) Show that the shift in wavelength from 588 nm to 589 nm corresponds to a frequency shift (Δf) of approximately 8.7×10^{11} Hz.

(2)

(iii) Calculate the speed with which the star is moving (as measured from Earth).

(2)

(iv) Using the value calculated in (iii) calculate a value for the Hubble constant in m s^{-1} Mpc^{-1}.

(2)

(Total 19 Marks)

21 (a) Light arriving at the Earth from a distant galaxy is observed to be *red shifted*.

(i) Explain, in terms of spectral lines, what the term *red shift* means.

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(1)

(ii) Explain how the red shift is consistent with the movement of distant astronomical objects away from us.

Two of the 6 marks in this question are for the quality of your written communication.

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(6)

(b) The wavelength of a given line in the spectrum is 5.40×10^{-7} m when measured using a light source in a laboratory on Earth. When the light from the distant galaxy is used for the measurement, the wavelength is found to be 5.61×10^{-7} m.

(i) Show that this wavelength change corresponds to a frequency shift of about 2.1×10^{13} Hz.

speed of light in a vacuum, $c = 3.0 \times 10^{8}$ m s^{-1}

Frequency shift .....

(3)

(ii) Calculate the speed of the galaxy relative to Earth.

Galactic speed .....

(3)

(iii) Estimate the distance, in m, between the galaxy and the Earth.

Hubble constant = 65 km s^{-1} Mpc^{-1}
1 pc (parsec) = 3×10^{16} m

Galactic distance .....

(3)

(Total 16 marks)

22 One spectral line emitted by a helium-filled discharge tube has a wavelength of 590 nm when measured using a source in a laboratory on Earth. The same spectral line measured using light from a distant galaxy has a wavelength 650 nm.

the speed of electromagnetic radiation in free space = 3.0×10^8 m s^{-1}

(a) (i) State the name of the effect that gives rise to this change in wavelength.

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(1)

(ii) What do these measurements of wavelength suggest about the nature of the universe?

.....

(1)

(b) Calculate the velocity of the galaxy relative to Earth. (hint: $\frac{\Delta\lambda}{\lambda} = \frac{\Delta f}{f}$)

Velocity of galaxy .....

(2)

(c) The spectral lines are analysed using a diffraction grating with 4.5×10^5 lines per m.

(i) Calculate the angle at which the spectral line of wavelength 590 nm produces a maximum in the second order spectrum.

Angle .....

(3)

(ii) Explain how the diffraction grating produces the bright spectral lines for a particular wavelength.

You may wish to draw a diagram to help you explain.

Two of the 7 marks for this question are available for the quality of your written communication.

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(7)

(Total 14 marks)

23 (a) (i) State the difference between the appearance of a continuous emission spectrum and that of a line emission spectrum.

.....

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(1)

(ii) State **one** laboratory source of a continuous spectrum.

.....

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(1)

(b) The spectrum of the Sun consists of a continuous spectrum crossed by dark lines. State the name for this type of spectrum and explain how the dark lines arise.

Spectrum name .....

Explanation .....

.....

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(3)

(Total 5 marks)

24 A galaxy is 4.5×10^{24} m from the Earth.

(a) Show that this galaxy is likely to be moving at a speed of about 1×10^{7} m s^{-1} relative to the Earth.

Hubble constant, H = 65 $kms^{-1}Mpc^{-1}$

1 parsec (pc) = 3.1×10^{16} m

(3)

(b) The galaxy emits light of wavelength 580.0 nm as it moves away from the Earth. This light is observed on the Earth.

(i) Calculate the change in wavelength of this light due to the movement of the galaxy.

[Hint: $\Delta\lambda/\lambda = \Delta f/f$]

Speed of light in a vacuum, $c = 3.0 \times 10^8$ ms^{-1}

Change in wavelength .....

(3)

(ii) Calculate the wavelength of the light from the galaxy when observed on the Earth.

Observed wavelength .....

(2)

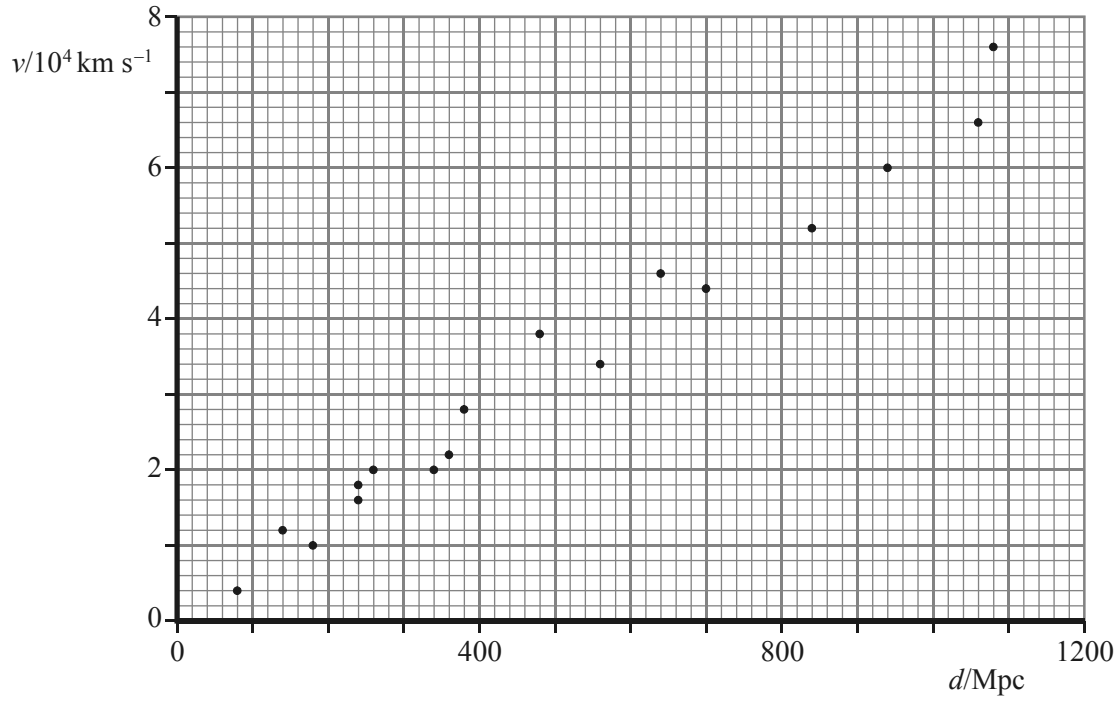
(Total 8 marks)

25 Fill in the blanks in the following table which shows some of the characteristics of several types of electromagnetic radiation.

Radiation type	**Typical wavelength in air/ m**	**Radiation source**
Radio waves	1.5×10^3	High frequency alternating current
	5.0×10^{-4}	Hot bodies
Visible light		Excited atoms
	5.0×10^{-13}	

(Total 3 marks)

26 It is believed that the Universe is expanding with the galaxies receding from each other. The diagram below shows some of the experimental data which support Hubble's Law. Each point on the scatter diagram represents a galaxy: v is the recession speed of a galaxy and d is its distance from Earth.



(a) Use the data on the graph above to show that the Hubble constant H is about 65 km s^{-1} Mpc^{-1}.

(3)

(b) A galaxy which can be seen in the constellation of Ursa Major has a recession speed of 17 000 km s^{-1}. Calculate its distance from Earth in Mpc.

Distance from Earth ..... Mpc

(2)

(c) An estimate for the age of the Universe can be found by assuming that recession speeds have been constant since the Big Bang. The age, T, of the Universe is given by the time it has taken for a given galaxy, travelling at speed v, to recede a distance d from ours. Hence

$$T = \frac{d}{v} = \frac{1}{H}$$

Use the above equation to estimate the age of the Universe in years.

1 light-year = 9.5×10^{15} m
1 pc = 3.3 light-years
1 year = 3.2×10^{7} s

Age of the universe …….. years

(3)

(d) The recession speed of a galaxy can be measured by comparing its emission spectral lines with those from an equivalent light source on Earth. Explain why this comparison enables the recession speed to be calculated and describe how the measurements are used to find the recession speed.

Two of the 6 marks in this question are for the quality of your written communication.

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(6)

(Total 14 marks)

27 (a) Up quarks have a charge of $+\frac{2}{3}e$ and down quarks have a charge of $-\frac{1}{3}e$.

(i) State the number of each type of quark in a neutron.

.....

(2)

(ii) Explain in terms of charge why a neutron has this composition.

.....

(1)

(b) (i) A neutron decays by β emission. Complete the following decay equation, naming all the particles produced in the decay.

neutron → β (electron) + ...

(2)

(ii) State and explain the change of quarks which occurs when this decay happens.

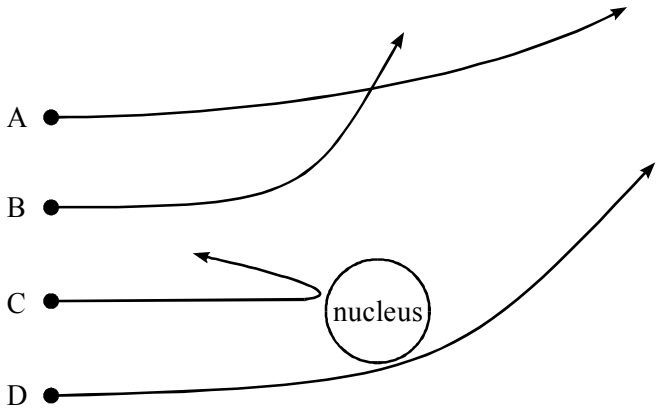
.....

.....

(2)

(Total 7 marks)

28 A beam of α particles irradiates a metal foil. The paths of four α particles near the nucleus of a metal atom are shown in the diagram. Which one of the paths must be i**ncorrect**?



(1)

(Total 1 mark)

29 (a) State the combination of quarks that makes up a neutron.

.....

(1)

(b) When a neutron decays, a down quark changes into an up quark as shown by the following reaction.

$$d \rightarrow u + \bar{e} + \bar{\nu}_e$$

(i) Show, in terms of the conservation of charge, baryon number and lepton number, that this transformation is permitted.

(3)

(ii) State the products arising from the decay of an anti-down quark, $\bar{d}$.

.....

.....

(1)

(Total 5 marks)

30 Leptons, mesons and baryons are three classes of sub-atomic particles.

(a) Some classes of particles are fundamental; others are not. Circle the correct category for each of these three classes.

leptons fundamental/not fundamental

mesons fundamental/not fundamental

baryons fundamental/not fundamental

(1)

(b) Name the class of particles of which the proton is a member.

.....

(1)

(c) By referring to the charges on up and down quarks explain how the proton has a charge of +1*e*.

.....

.....

.....

(2)

(Total 4 marks)

31 A negative pion (π^-) is a meson with a charge of –1e.

State and explain the structure of the π^- in terms of up and down quarks.

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(Total 3 marks)

32 A physicist, who is attempting to analyse a nuclear event, suggests that a π^- particle and a proton collided and were annihilated with the creation of a neutron, a π^+ particle, and a K^- particle.

π and K particles are mesons. The baryon and lepton numbers of both these mesons are zero.

(a) Write down the equation that represents this interaction.

.....

(1)

(b) Show, in terms of the conservation of charge, baryon number and lepton number, that this transformation is permitted.

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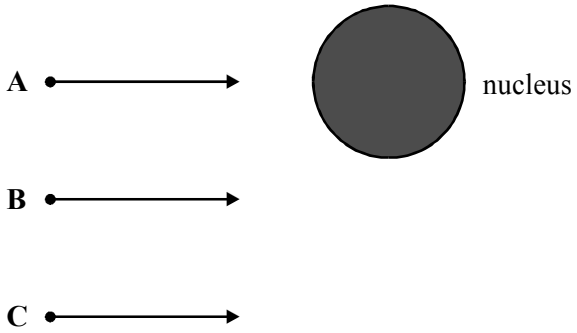
(4)

(Total 5 marks)

33 The diagram below shows a single atomic nucleus that is part of a thin foil. **A**, **B** and **C** are the paths of three α-particles directed at the foil as shown. All three paths are approaching close to the nucleus.

(a) Complete the diagram carefully showing the subsequent paths of the α-particles.



(3)

(b) Suggest **two** pieces of scientific information that can be gained by bombarding matter with particles in this way.

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(2)

(Total 5 marks)

34 The list of sub-atomic particles below contains particles that are either hadrons or leptons:

electron muon neutrino neutron pi-meson proton

(a) Complete the table below by adding the names of the particles to the correct box.

Hadrons	
Leptons	

(4)

(b) Underline the names of the particles that are baryons.

(2)

(Total 6 marks)

35 (a) A particle is made up from an anti-up quark and a down quark.

(i) Name the classification of particles that has this type of structure.

.....

(1)

(ii) Find the charge on the particle.

(1)

(iii) State the baryon number of the particle.

(1)

(b) A suggested decay for the positive muon (μ^+) is

$$\mu^+ \rightarrow e^+ + \nu_e$$

Showing your reasoning clearly, deduce whether this decay satisfies the conservation rules that relate to baryon number, lepton number and charge.

Baryon number .....

Lepton number .....

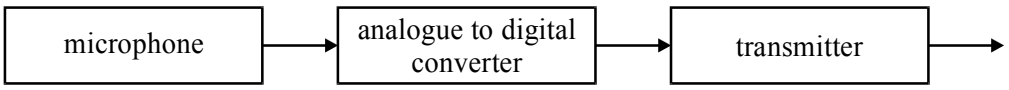
Charge .....

(3)

(Total 6 marks)

36 **Figure 1** is a block diagram showing part of a telephone system.

Figure 1



(a) The output of the microphone is an *analogue* signal of *bandwidth* 3.4 kHz.

(i) Explain the meaning of the following words:

analogue .....

.....

bandwidth .....

.....

(3)

(ii) Compare the bandwidth of the output of the microphone with the typical range of human hearing. Comment on any differences in these values.

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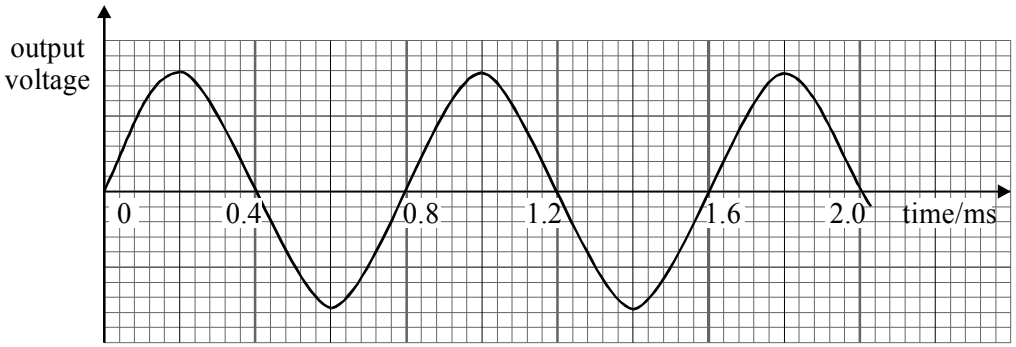
(3)

(b) **Figure 2** shows the signal from the microphone.

Figure 2



(i) Calculate the frequency of this signal.

Frequency = ...

(2)

(ii) State the minimum sampling rate needed to allow effective transmission of this signal.

.....

(1)

(iii) Explain how time division mutiplexing may be used to send many audio signals 'simultaneously' along a transmission medium. You may draw a labelled diagram to help your explanation.

Two of the 6 marks in this question are available for the quality of your written communication.

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(6)

(Total 15 marks)

MARK SCHEMES

The following document has been produced to support the Teacher Resource Bank item *GCE Physics B: Physics in Context – Harmony and Structure in the Universe / Directory of Relevant Questions / Version 1.0*.

Teachers and students should be aware that the treatment of Quality of Written Communication (QWC) in the new AQA GCE Physics B: Physics in Context specification may differ from that used in some of the questions in this document. Please refer to the latest version of the Specimen Assessment Materials which accompany the new GCE Physics B: Physics in Context specification for the treatment of QWC.

Question 1			
(a)	refraction **or** total internal reflection	**B1**	**1**
(b) (i)	use of a land line such as fibre optic cable **or** copper cable radio waves beamed up to a satellite and then back down to the receiver	**B1** **B1**	**2**
(ii)	signals using **Figure 1** depend on conditions in ionosphere **or** signal may fluctuate **or** signals using land line **or** satellite more reliable **or** signals using fibre optics more secure	**B1**	**1**
		Total	**4**

Question 2			
(a) (i)	digital has two possible values/no intermediate values shown	**B1**	**1**
(ii)	signal quality unaffected by noise/(e-m) interference zeros and ones still discernible/can be regenerated multiplexing possible/efficient use of transmitting medium/more data transferred (in same time) many signals can be sent 'simultaneously' (with fast sampling rate)/use of compression techniques condone 'digital data secure' more difficult to 'tap' digitally/decode	**M1** **A1** **M1** **A1** **M1** **A1**	**4**
(b) (i)	noise/(e-m) interference superposes with/degrades (original) signal attenuation/voltage drops/energy loss/fading/energy absorbed energy dissipated in the transmitting medium/wire defects/ resistance	**M1** **A1** **M1** **A1**	**4**
	the use of Physics terms is accurate; the answer is fluent/well argued with few errors in spelling, punctuation and grammar and candidate has obtained at least 3 for Physics the use of Physics terms is accurate but the answer lacks coherence or the spelling, punctuation and grammar are poor and candidate has obtained at least 2 for Physics the use of Physics terms is inaccurate; the answer is disjointed with significant errors in spelling, punctuation and grammar	**2** **1** **0**	**max 2**

	(ii)	optical fibre	**B1**	**1**
	(iii)	0.05 ≤ max value for zero ≤ 0.2 any sensible minimum including negative values 0.25 ≤ min value for one ≤ 0.35 any sensible maximum allow two marks if their range gives no spurious values of 1 or 0/values must be exclusive to one range allow 0.5 ± 0.2 etc	**B1** **B1**	**2**
			Total	**14**

Question 3				
(a)	(i)	range within 15 – 20 000 Hz (high *f* must equal or exceed	**B1**	**1**
	(ii)	10 kHz; (low *f* must be equal to or below 50 Hz)	**B1**	**1**
	(iii)	same as candidate range in (a)(i) (difference or range acceptable) 12 kHz [allow samples per second/per minute as unit]	**B1**	**1**
(b)		two advantages e.g. easy *elimination* of noise [**not** no noise] narrower bandwidth, more channels in available spectrum, opportunity to multiplex, etc) [not fibre optic argument, not distance argument]	**B1** **B1**	**2**
(c)		**three marks max** for three correct routes + **2 max** for two correct wavelengths for these routes - stop marking physics after third route response station A → B: line of sight — long and short* through earth — **very** long cable — long etc station A → C: diffraction — long reflection — long satellites — short refraction — long and short* sporadic E/ducting etc — short do not allow any route twice etc (*) candidate can write 'long and /or short' or 'any wavelength' etc. but sense must be 'all wavelengths'	**B1** **B1** **B1**	**max 5**

	the use of Physics terms is accurate, the answer is fluent/well argued with few errors in spelling, punctuation and grammar **award for 4+ only** the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor **award for 2 or 3 only** the use of Physics terms is inaccurate, and the answer is disjointed with significant errors in spelling, punctuation and grammar **award for 0 or 1**	**B2** **B1** **B0**	**max 2**
		Total	**12**

Question 4			
(a)	recognises GHz as 10^9 $\lambda = 3 \times 10^8/2.3 \times 10^9 = 0.13$ [0] m	**B1** **B1**	**2**
(b)	microwaves [e.c.f. from (a)]	**B1**	**1**
(c)	use of $\sin\theta = \lambda / b$ $= 0.13/0.6 = 0.217$ [e.c.f. from (a)] $\theta = 12.5°$	**M1** **C1** **A1**	**3**
(d)	mention of/evidence of use of inverse-square law 64 nW	**B1** **A1**	**2**
(e)	$\Delta f = fv/c = 2.3 \times 10^9 \times 2.5/3 \times 10^8$ = 19.2 Hz	**M1** **A1**	**2**
(f)	higher	**B1**	**1**
		Total	**11**

Question 5				
(a)	(i)	microphone/telephone mouthpiece	**B1**	**3**
	(ii)	modulator [or analogue- digital converter *if digital answer*]	**B1**	
	(iii)	amplifier/booster [or modulator *if digital answer*]	**B1**	
(b)		mention of carrier *(as wave / frequency or bald)*	**B1**	**4**
		mention of frequency or amplitude modulation	**B1**	
		by signal to be transmitted	**B1**	
		modulation enables more information to be transmitted *or good Physics* *alternative - may include diagram e.g. of modulated signal*	**B1**	
			Total	**7**

Question 6			
(a)	40 kHz	**B1**	**1**
(b)	higher frequencies will not be recognised/transmitted/lost **or** some peaks/troughs /variations will be missed	**B1**	**1**
(c)	number of bits required per second for each station = 40 000 × 8 (e.c.f. from (a))	**C1**	**2**
	total channels = 1.5×10^8/bits per second required for each station (answer 468 gets both marks **n.b.** not 469 (e.c.f. from(a) 1.875×10^7/their (a), rounded down)	**A1**	
	allow B1 only for use of 20 kHz and arriving at 937 stations		
(d)	**any 2**		**2**
	each signal is sampled in turn	**B1**	
	use time division multiplexing	**B1**	
	diagram to aid explanation	**B1**	
	signals sent in sequence ABCDABCD	**B1**	
	signals only use fibre for part of the time	**B1**	
	any 2		**2**
	fibre-cable energy losses are less or transmit further without repeater/boosters/amplifiers or less frequent repeaters/boosting	**B1**	
	less noise/interference (condone no noise but not that it reduces noise)	**B1**	
	higher information handling capacity or greater number of stations can use a single fibre	**B1**	
	signal more secure/cannot be tapped	**B1**	
	at least 3 marks for Physics + use of Physics is accurate,	**2**	**max 2**

	the answer is fluent/well argued with few errors in spelling, punctuation and grammar **at least 1 mark for Physics + some incorrect work** the use of Physics is accurate, but the answer lacks coherence or spelling, punctuation and grammar are poor the use of Physics is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar	**1** **0**	
		Total	**10**

Question 7				
(a)	(i)	15 to 20 000 Hz *allow min 10 ..50 Hz and max 15 ..25 kHz*	**B1**	**1**
	(ii)	15 000 Hz/upper limit from (a)(i)	**B1**	**1**
(b)	(i)	*diagram showing a continuous signal (plotted against time) with sampling ordinates* signal sampled at regular **time** intervals (*clearly on graph or in words)*	**B1** **B1**	**2**
	(ii)	30 000 Hz / 2 × answer in (a)(ii)	**B1**	**1**
(c)		**less** powerful transmitters (needed for DAB)/signal travels further smaller aerials needed to receive signals better quality/clearer sound (heard by listener) easier reduction of interference (*accept less background noise*) more stations available (in a given bandwidth)/more data transferred **in the same time** *any 2 from 5 points*	**B1** **B1** **B1** **B1**	**2**
			Total	**7**

Question 8			
(a)	transverse: vibration/displacement/disturbance not movement is perpendicular to direction of travel longitudinal: vibration/displacement/disturbance not movement is parallel to (same) direction of travel C1 for idea of transverse and longitudinal being perpendicular	**B1** **B1**	**2**
(b)	restriction of vibration/idea of how polarisation occurs single plane/same orientation – diagram may help	**B1** **B1**	**2**
(c)	only transverse can be polarised/longitudinal cannot idea of being able to restrict vibration to single plane **or** longitudinal not being perpendicular to motion **or** longitudinal vibrating in direction of travel	**B1** **B1**	**2**
		Total	**6**

Question 9				
(a)		$v = f\lambda$ or 330/512 0.64(5) m	**C1** **A1**	**2**
(b)	(i)	very approximately size of doorway is same as λ of note	**B1**	**1**
	(ii)	sin $\theta = \lambda/b$ seen $\theta = \sin^{-1}$ (answer to (a)/ 0.81) or sin θ = ans to (a)/0.81 52.7°/52.8°/52.2°/53°	**C1** **C1** **A1**	**3**
			Total	**6**

Question 10			
(a)	distance travelled = 2 × 18 m speed = 36/0.11 = 327 m/s [164 m/s scores 2]	**C1** **M1** **A1**	**3**
(b)	mention of standing waves **or** superposition **or** interference mention of two waves, opposite directions because they are permanently out of phase, permanently destructively interfere, permanently in antiphase	**B1** **B1** **B1**	**3**
		Total	**6**

Question 11				
(a)	(i)	$2(.0) \times 10^{-5}$ m (i.e. allow 1 s.f.)	**B1**	**1**
	(ii)	$\lambda = 4(.0) \times 10^{-4}$ (m) $v = f\lambda$ (condone $c = f\lambda$) 3.0 MHz s.f. penalty applies allow e.c.f. for omitting 10^{-4} (300 Hz) but s.f. penalty applies for e.g. 0.3 kHz)	**B1** **C1** **A1**	**3**
(b)	(i)	ultrasound/wave/pulse/energy **spreads out** from the transmitter (beam not uni-directional) **energy is absorbed** by(or lost to) the transmitting medium/tissue/body incident ultrasound/wave/pulse/energy is **not all reflected** (by the reflecting object) **or** some is transmitted /absorbed by the organ **or** is reflected at different angles (so does not return to detector) some ultrasound/wave/pulse/energy reflected by the skin **since gel was not used**	**B1** **B1** **B1** **B1**	**max 2**
	(ii)	distance travelled 1200 × 95 or 114 000 or 0.114 m (i.e. mark for **use of** velocity × time ignoring powers of 10) 0.057 m (allow answers in range 0.055 to 0.057)	**C1** **A1**	**2**
			Total	**8**

Question 12				
(a)	(i)	mass per unit length	**B1**	**1**
	(ii)	means of supporting and tensioning string means of measuring frequency	**B1** **B1**	**2**
	(iii)	length tension	**B1** **B1**	**2**
	(iv)	statement of how vibrations are created statement of how f is determined statement of how mass per unit length is determined repeat for other values of mass per unit length plot appropriate linear graph straight line through the origin method of measuring length of tension	**B1** **B1** **B1** **B1** **B1** **B1** **B1**	**max 5**

		the use of Physics terms is accurate, the answer is fluent / well argued with few errors in spelling, punctuation and grammar the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor the use of Physics terms is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar	**2** **1** **0**	**max 2**
(b)	(i)	one loop	**B1**	**1**
	(ii)	three loops	**B1**	**1**
	(iii)	correct use of ratios distance from **Q** = 0.63 m	**C1** **A1**	**2**
			Total	**16**

Question 13				
(a)	(i)	$\sin\theta = \lambda/b$ 28°	**C1** **A1**	**2**
	(ii)	lower frequency implies greater wavelength θ is larger / sound diffracted through larger angle reference to equation / diffraction increases with increasing wavelength	**B1** **B1** **B1**	**3**
(b)		$d \sin\theta = n\lambda$ correct substitution including $d = 1/3 \times 10^5$ and $n = 2$ 5.2×10^{-7} m	**C1** **C1** **A1**	**3**
			Total	**8**

Question 14				
(a)		$\lambda = 0.58$(m) **or** $(2/3 \times 0.87)$ $c = f\lambda$ **or** substituted values 69.6 (70) m s^{-1}	**C1** **C1** **A1**	**3**
(b)		$\lambda = 0.87 \times 2$ **or** $\lambda = 1.74$ **or** in formula 69.6/ 1.74 **or** 70/1.74 = 40.2 **or** the drawing shows third harmonic (second overtone) so $120 = 3 \times f_0$ so $f_0 = 40$ Hz do **not** allow just 120/3	**M1** **A1** **M1** **A1**	**2**
			Total	**5**

Question 15				
(a)	(i)	$6.7\ (6.67) \times 10^{-3}$ s	**B1**	**1**
	(ii)	at least one complete cycle shown (may be a poor attempt) **and** period 6.7×10^{-3} s (e.c.f.) (may be a decaying amplitude) or amplitude = 3 mm clear from scale (must be constant amplitude)	**C1**	**2**
		at least two complete cycles shown (must be reasonable attempt at sine wave and show constant half periods and constant amplitude) both period and amplitude shown period 6.7×10^{-3} s (e.c.f.) and amplitude = 3 mm	**A1**	
		condone silly scales up applies		
(b)		third harmonic: three loops shown (condone wave 'snapshot')	**B1**	**2**
		maximum amplitude 1 mm clear from scale	**B1**	
(c)		tension in the string (condone tighter string)	**M0**	**2**
		increased tension increases **frequency** (not leads to faster oscillations) **or** frequency is proportional to $\sqrt{\text{tension}}$ (not $\sqrt{T}$ unless T is defined)	**A1**	
		plus any one from:		
		mass per unit length of the string	**M0**	
		increases mass per unit length reduces **frequency** **or** frequency is inversely proportional to $\sqrt{\text{mass per unit length}}$	**A1**	
		or frequency is proportional to $\dfrac{1}{\sqrt{\text{mass per unit length}}}$ (not $1/\sqrt{\mu}$ unless μ defined)		
		density of the material (for same thickness) condone heavier string/more weight or more mass	**M0**	
		increased density etc. reduces frequency	**A1**	
		allow B1 for stating tension and mass per unit length as factors without correct effects	**B1**	

(d)	higher harmonics/frequencies (above 1000 Hz) are missed/ not transmitted or only frequencies between 100 Hz and 1000 Hz are transmitted **note:** consequence is not essential but saying that the note will sound lower is 'talk out' allow quieter or poorer quality as consequences	**B1**	**1**
		Total	**8**

Question 16				
(a)		separation = 1/630000	**B1**	**1**
(b)	(i)	quote $n\lambda = d \sin\theta$	**C1**	**3**
		$\lambda = 1.59 \times 10^{-6} \times \sin(25.4)$	**C1**	
		$= 6.8 \times 10^{-7}$ m or 6.8×10^{-4} mm	**A1**	
	(ii)	central maximum/zeroth order mentioned	**B1**	**max 4**
		central maximum is white	**B1**	
		describe/draw $1^{st}/2^{nd}$ orders colours in correct order	**B1**	
		third order overlap	**B1**	
		symmetry of pattern	**B1**	
		dispersion change	**B1**	
		fainter away from centre	**B1**	
			Total	**8**

Question 17				
(a)	(i)	$\lambda = 3 \times 10^8/1.5 \times 10^9$	**C1**	**2**
		$\lambda = 0.20$ m	**A1**	
	(ii)	$\theta/2 = \sin^{-1}$ (or $\tan^{-1}$) 3500/36000 **or** $\theta = \sin^{-1}$ 7000/36000	**C1**	**2**
		$= \sin^{-1}$ (0.098) = 5.6° so θ = 11.2°	**A1**	
	(iii)	b = 0.2 /0.098 [e.c.f. (a)(i)/0.5 × sin (a)(ii); condone use of θ **or** $\theta/2$]	**C1**	**2**
		= 2.0(4) m [condone use of 5.6° c.f. from (a)(ii)]	**A1**	
	(iv)	satellite small/need to concentrate energy on it so θ small too/less diffraction with bigger dish	**B1**	**1**

(b)	binary code/01 etc. required many samples transmitted down same channel or at same frequency/in short period of time sampling process required signals transmitted in sequence good description or diagram of process method is secure cheaper/lighter/more efficient than multi-transmitter/more satellites without tdm considers bandwidth or bit rate issue calculates no of channels available from reasonable estimates of bandwidth and frequency range		**max 5**
	use of Physics terms is accurate, the answer is fluent/well argued with few errors in spelling, punctuation and grammar **and gains at least 3 marks for Physics**	**B2**	**2**
	use of Physics terms is accurate but the answer lacks coherence or the spelling, punctuation and grammar are poor **and gains at least 1 mark for Physics**	**B1**	**1**
	use of Physics terms is inaccurate, the answer is disjointed with significant errors in spelling, punctuation and grammar	**B0**	**0**
		Total	**14**

Question 18			
(a)	*superposition* (of progressive waves) incident wave and reflected wave/wave reflected through 180°/waves travelling in opposite directions same frequency/wavelength in same medium *any 3 out of 4 points*	**B1** **B1** **B1** **B1**	**3**
(b)	$f = c/\lambda$ $\lambda = 1.24$ $f = 258$ Hz e.g. $f = 512$ gets 1 mark	**C1** **C1** **A1**	**3**
		Total	**6**

Question 19			
(a) (i)	$f = c/\lambda$	**C1**	
	one frequency correct to appropriate significant figures (4.57140 **or** 4.57118)	**C1**	**3**
	2.1×10^{10} Hz	**A1**	
(ii)	$v = \Delta f/f$	**C1**	**2**
	1.4×10^{4} m s^{-1}	**A1**	
(b)	light collected by telescope	**B1**	
	diffracted by grating	**B1**	**4**
	angle of diffraction measured	**B1**	
	wavelength given by $d \sin \theta/n$	**B1**	
	the use of Physics terms is accurate, the answer is fluent / well argued with few errors in spelling, punctuation and grammar	**2**	
	the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor	**1**	**max 2**
	the use of Physics terms is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar	**0**	
(c)	it identifies the speed of recession	**B1**	
	establishes that more distant galaxies recede faster	**B1**	**max 2**
	allows consideration of permanent expansion or eventual collapse	**B1**	
		Total	**13**

Question 20				
(a)		mention of gas/atoms/electrons being excited	**B1**	**max 3**
		photons emitted	**B1**	
		discrete wavelengths/frequencies/photon energies	**B1**	
		characteristic of element/gas	**B1**	
		electrons change energy levels	**B1**	
		observed with spectrometer/scope or using diffraction grating	**B1**	
(b)		$n\lambda = d\sin\theta$ seen or used	**C1***	**max 3**
		do not allow these marks * if $\sin\theta = \lambda/b$ used		
		$d = l/N$ **or** $\times 10^{-6}$ seen or obviously used	**C1**	
		$\theta_1 = 26.5(5)°$ (allow 0.0256°)	**C1**	
		$\theta_2 = 36.0(2)°$ (allow 0.0337°)	**C1**	
		$\Delta\theta = 9.5°$ or 9.4(7)° or 9.4°	**A1***	**1**
(c)	(i)	$5.1(0) \times 10^{14}$ Hz	**B1**	**1**
	(ii)	yellow-orange	**B1**	**2**
		$10^{-20} – 10^{-18}$	**B1**	
(d)	(i)	Doppler effect	**B1**	**3**
		star receding from Earth/Earth from star/Universe expands	**B1**	
		apparent increase in wavelength/decrease in frequency/ red shift	**B1**	
	(ii)	5.102 …. $\times 10^{14}$ and 5.093 …. $\times 10^{14}$ seen allow $3.0 \times 10^8/588 \times 10^{-9}$ and $3.0 \times 10^8/589 \times 10^{-9}$ process of subtraction shown	**C1**	**2**
		condone candidates not writing down more than 5.10 and 5.09 and subtracting (on calculator) no u.p.	**A1**	
		or $\frac{\Delta f}{f} = \frac{\Delta\lambda}{\lambda}$	**M1**	
		correct substitution for f (5.1×10^{14}) with e.c.f. $\Delta\lambda$ (1.0×10^{-9}) λ (588×10^{-9})	**A1**	

	(iii)	$\frac{\Delta f}{f}=\frac{v}{c}$ **or** $\frac{\Delta \lambda}{\lambda}=\frac{v}{c}$ **or** correct substitutions for Δf [= (d)(ii)] f [= (c)(i)] c [= 3.0×10^8] etc 5.1×10^5 m s^{-1} or 510 km s^{-1}	**C1** **A1**	**2**
	(iv)	$H = v/d$ **or** correct substitution of values 4.64×10^4 or (d)(iii)/11 no u.p.	**C1** **A1**	**2**
			Total	**19**

Question 21				
(a)	(i)	spectral line moved to longer wavelength position (allow 'to red end of spectrum')	**B1**	**1**
	(ii)	mention of Doppler effect expansion of universe/Big Bang wavelength increased (or frequency decreased) successive 'peaks' of wave emitted at increasing distance from Earth [allow 'wave stretched'] wavelength observed on Earth increases **compared** with source stationary	**B1** **B1** **B1** **B1** **B1**	**max 4**
		award for 2+ the use of Physics terms is accurate, the answer is fluent/well argued with few errors in spelling, punctuation and grammar **award for 1** the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor the use of Physics terms is inaccurate, and the answer is disjointed with significant errors in spelling, punctuation and grammar	**2** **1** **0**	**max 2**
(b)	(i)	use of $c = f\lambda$ $\Delta f = 3 \times 10^8/(561 \times 10^{-9}) - 3 \times 10^8/(540 \times 10^{-9})$ $= (5.348 – 5.556) \times 10^{14}$ [= 2.08×10^{13} Hz] [explicit subtraction **or** to 3+ s.f. required for A mark]	**C1** **M1** **A1**	**3**

	(ii)	$\Delta f/f = v/c$ $V = c * \Delta f/f$ [or $\Delta\lambda/\lambda$] = $3 \times 10^8 \times 2.08 \times 10^{13} / 5.556 \times 10^{14}$ [e.c.f. from (b)(i)] = 1.12×10^7 m/s	**C1** **M1** **A1**	**3**
	(iii)	[$d = v/H$] conversion to km/s $d = 11.2 \times 10^3/65$ = [172 Mpc] [e.c.f. from (b)(ii)] = $172 \times 10^6 \times 3 \times 10^{16} = 5.17 \times 10^{24}$ m		**3**
			Total	**16**

Question 22				
(a)	(i)	Doppler effect/shift	**B1**	**1**
	(ii)	the Universe is expanding (**not** the Universe is moving outwards/away) **or** the universe is the result of a 'big bang'	**B1**	**1**
(b)		change in wavelength = 60 nm and use of $\Delta\lambda/\lambda = v/c$ (condone either λ for this mark) 3.0 to 3.1 $\times 10^7$ m s^{-1} **or c**alculates one frequency correctly using $c = f\lambda$ (5.08×10^{14} Hz or 4.62×10^{14} Hz) arrives at 2.7 to 2.8 $\times 10^7$ m s^{-1} (using approximation $\Delta f/f = v/c$) **or** 3.0 to 3.1 $\times 10^7$ m s^{-1} (using $\Delta f/f' = v/c$)	**C1** **A1** **C1** **A1**	**2**
(c)	(i)	$d \sin\theta = n\lambda$ correct substitution for d (2.22×10^{-6} m or $1/(4.5 \times 10^5)$ seen and $n\lambda$ ($2 \times 590 \times 10^{-9}$) (condone incorrect power of 10 for λ) 32(.1)° (or 32(.4) if d is rounded to 2.2×10^{-6} m)	**C1** **C1** **A1**	**3**

(ii)	useful diagram showing more than two slits with path differences shown (not just waves spreading out from slits) **max 4 for answer that refers only to two slits throughout** mention of interference or superposition light from slits is coherent (condone sources are coherent) path difference (from slits) is a multiple of one wavelength waves arrive in phase (condone light arrives in phase) interference is constructive waves add to produce larger amplitude/intensity/bright light (may be awarded for a good diagram that shows this) explanation of different spectral lines for the same wavelength lines are bright because waves from many slits are interfering (owtte)	**B1** **B1** **B1** **B1** **B1** **B1** **B1** **B1** **B1**	**max 5**
	at least 3 marks for Physics + use of Physics is accurate, the answer is fluent/well argued with few errors in spelling, punctuation and grammar **at least 1 mark for Physics + some incorrect work** the use of Physics is accurate, but the answer lacks coherence or spelling, punctuation and grammar are poor the use of Physics is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar	**2** **1** **0**	**max 2**
		Total	**14**

Question 23				
(a)	(i)	continuous range of frequencies not discrete frequency	**B1**	**1**
	(ii)	glowing/incandescent/white hot body /example of same	**B1**	**1**
(b)		absorption *owtte* absence of light at dark line correct reason	**B1** **B1** **B1**	**3**
			Total	**5**

Question 24			
(a)	correct use of parsec conversion	**C1**	
	correct use of $v = Hd$	**C1**	**3**
	$= 9.43 \times 10^6$	**A1**	
(b) (i)	use of $\Delta\lambda/\lambda = v/c$	**C1**	
	$\Delta\lambda = 5.8 \times 10^{-7} \times 9.43 \times 10^6 / 3 \times 10^8$	**C1**	**3**
	$= 18.2 \times 10^{-9}$ m	**A1**	
(ii)	**adds** wavelengths…	**C1**	**2**
	correctly; candidates' answer to (b) + 580.0 [e.c.f.]	**A1**	
		Total	**8**

Question 25			
	infrared	**B1**	
	a value in the range $(4 .. 7) \times 10^{-7}$ (1 or 2 s.f. only)	**B1**	**3**
	gamma rays and the nucleus *accept nuclear/nuclide etc*	**B1**	
		Total	**3**

Question 26			
(a)	H = v/d	**C1**	
	best fit line drawn	**M1**	**3**
	gradient of line shown to be 65 ± 4	**A1**	
(b)	*use of* d = v/H	**B1**	**2**
	answer 260 (*accept 262* or *accurate graph read-off*) (Mpc)	**B1**	
(c)	(a distance) $\times 10^6 \times 3.3$	**C1**	
	(a distance) $\times 9.5 \times 10^{15}$	**C1**	**3**
	answer = 1.5×10^{10} (years)	**A1**	

(d)	mention or description of *Doppler effect* mention of *red shift* measurement of wavelength or frequency giving *longer wavelength/lower frequencies* than on Earth *description* of use of the shift formula ($\Delta f/f = v/c$) mention of the v<<c condition *any 4 points from 6*	**B1** **B1** **B1** **B1** **B1** **B1**	**max 4**
	accurate use of Physics terminology + fluent, well argued explanation + good spelling and grammar + **at least 2 marks for the Physics** accurate use of terminology + comprehensible explanation + **at least 1 mark for Physics** **no marks for the Physics** *and/or* disjointed answer with poor spelling and grammar	**2** **1** **0**	**max 2**
		Total	**14**

Question 27				
(a)	(i)	3 quarks 1 up and 1 down	**C1** **A1**	**2**
	(ii)	sum of the change is zero	**B1**	**1**
(b)	(i)	proton anti neutrino	**B1** **B1**	**2**
	(ii)	one of the down quarks becomes an up quark the sum of the charges becomes +*e*	**B1** **B1**	**2**
			Total	**7**

Question 28			
	D		**1**
		Total	**1**

Question 29				
(a)		d + d + u	**B1**	**1**
(b)	(i)	conservation of charge: –1/3 = +2/3 + (–1) + 0 conservation of baryon number: 1/3 = 1/3 + 0 + 0 conservation of lepton number: 0 = 0 + (+1) + (–1)	**B1** **B1** **B1**	**3**
	(ii)	anti up–quark plus positron plus electron neutrino	**B1**	**1**
			Total	**5**

Question 30			
(a)	lepton fundamental meson, baryon not fundamental allow underline or crossing out wrong options	**B1**	**1**
(b) (i)	baryon/hadron	**B1**	**1**
(ii)	u u d	**B1**	**2**
	$+\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=+1$(e)	**B1**	
		Total	**4**

Question 31			
	2 quarks	**M1**	**3**
	down and anti-up	**A1**	
	–1/3 + (–2/3) = – 1	**A1**	
		Total	**3**

Question 32			
(a)	$\pi^- + p^{(+)} = n + \pi^+ + K^-$	**B1**	**1**
(b)	charge conservation equation correct	**M1**	**4**
	baryon conservation equation correct	**M1**	
	lepton conservation equation correct	**M1**	
	all comments and checks consistent	**A1**	
		Total	**5**

Question 33			
(a)	A - repelled	**B1**	**3**
	B bends away from nucleus	**M1**	
	B & C would cross beyond nucleus	**A1**	
(b)	one piece of information	**B1**	**2**
	second piece	**B1**	
	[*e.g. substructure of atom/size of nucleus/charge on nucleus /density of nuclear material, atoms mostly empty space/massive nucleus evidence for nucleus/alpha particle*]		
		Total	**5**

Question 34			
(a)	all correct (-1 for each misclassification or omission; total not to go below zero) hadrons: proton/neutron/pion leptons: electron/muon/neutrino	**B4**	**4**
(b)	proton neutron (-1 for each misclassification; total not to go below zero)	**B1** **B1**	**2**
		Total	**6**

Question 35				
(a)	(i)	meson (not muon)	**B1**	**1**
	(ii)	-1 or -1.6×10^{-19} C or $-e$	**B1**	**1**
	(iii)	0	**B1**	**1**
(b)		baryon number $0 \rightarrow 0 + 0$ (satisfied or ^{c}s) (allow statement that as these are all leptons baryon number is not relevant *owtte*) lepton number $-1 \rightarrow -1 + 1 \times$ or not satisfied charge $(+)1 \rightarrow (+)1 + 0$ (satisfied or ^{c}s)	**B1** **B1** **B1**	**3**
			Total	**6**

Question 36				
(a)	(i)	continuously (continually) varying (changing) quantity/voltage/amplitude	**B1**	**3**
		mention of frequency	**M1**	
		range of frequencies or highest *f* - lowest *f*	**A1**	
	(ii)	human hearing 20 Hz – 15-20 kHz (or range 15-20 kHz)	**B1**	**3**
		telephone bandwidth much smaller	**B1**	
		full bandwidth not needed for acceptable communication	**B1**	
(b)	(i)	$f = 1/T$	**C1**	**2**
		1250 Hz	**A1**	
	(ii)	2 × (b)(i) answer (e.c.f.) allow 2500 Hz but otherwise s.f.p.	**B1**	**1**
	(iii)	capacity of transmission medium usually much greater than that needed for single signal/**spare capacity**	**B1**	**max 4**
		digital or sampled signals used	**B1**	
		each signal broken into a fixed **chunks (of data)**	**B1**	
		sent sequentially	**B1**	
		each signal recompiled	**B1**	
		need for synchronisation	**B1**	
		the use of Physics terms is accurate, the answer is fluent/ well argued with few errors in spelling, punctuation and grammar the candidate must have scored at least 3 marks for Physics to access this	**2**	**max 2**
		the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor the candidate must have scored at least 2 marks for the Physics to access this	**1**	
		the use of Physics terms is inaccurate, the answer is disjointed with significant errors in spelling, punctuation and grammar	**0**	
			Total	**6**