Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
January 2010

Physics

Assessment Unit A2 2

assessing

Module 5: Electromagnetism and Nuclear Physics

[A2Y21]

A2Y21

THURSDAY 28 JANUARY, AFTERNOON

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all six** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in questions **2 and 6**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.
Question **6** contributes to the synoptic assessment requirement of the Specification.
You are advised to spend about 45 minutes in answering questions **1–5**, and about 45 minutes in answering question **6**.

For Examiner's use only	
Question Number	**Marks**
1	
2	
3	
4	
5	
6	
Total Marks	

Examiner Only	
Marks	Remark

If you need the values of physical constants to answer any questions in this paper, they may be found on the Data and Formulae Sheet.

Answer **all six** questions

1 (a) A capacitor of capacitance C is connected to a supply voltage which is gradually increased from zero to a value V_{max}.

(i) (1) At a particular instant, the potential difference across the capacitor is V_1.
Write down an expression, in terms of C and V_1, for the energy E_1 stored in the capacitor at that instant.

E_1 = ______________________________ [1]

(2) On **Fig. 1.1**, sketch a graph to show how the energy E stored in the capacitor depends on the supply voltage V. [1]

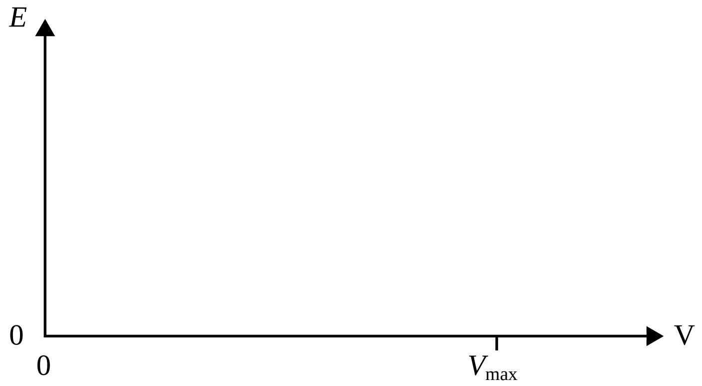

Fig. 1.1

(ii) The capacitance of the capacitor is 10.0 μF. Over a period of time, as a result of changing the supply voltage, the charge on the capacitor is increased from 30.0 μC to 90.0 μC. Calculate the range of supply voltage that produces this change in charge.

Voltage range: from ___________ V to ___________ V [3]

(b) (i) A capacitor has capacitance C and carries a charge Q. Write down an expression, in terms of C and Q, for the energy E stored in the capacitor.

E = ______________________________ [1]

(ii) **Fig. 1.2** shows three capacitors, of capacitance 3 μF, 6 μF and 9 μF, connected in series to a battery.

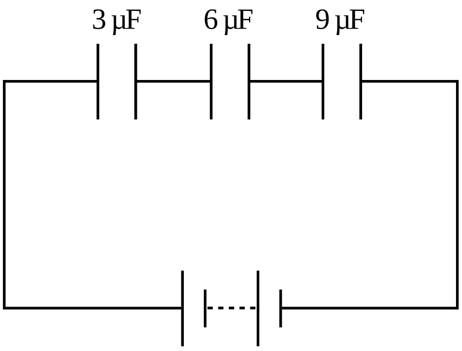

Fig. 1.2

Which of the capacitors has the **least** energy stored in it? Indicate your answer by placing a tick in the appropriate box. Explain your reasoning.

The capacitor with the **least** energy is the

3 μF capacitor ☐

6 μF capacitor ☐

9 μF capacitor ☐

Explanation:

____

____

____ [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

2 In part (c) of this question you should answer in continuous prose. You will be assessed on the quality of your written communication.

(a) The unit of magnetic flux density is the tesla. Define the tesla.

____

____

____ [3]

(b) The flux density at a point on the axis near the centre of a solenoid carrying a current of 8.0 A, is 1.0×10^{-2} T. Calculate the number of turns per unit length of the solenoid.

Number of turns per unit length = ________________________ [2]

(c) Describe an experiment to investigate how the magnetic flux density at the centre of a long straight solenoid depends on the current through the solenoid.

Your answer should include a description or labelled diagram of the apparatus used and a brief experimental procedure.

(i) Apparatus

[3]

(ii) Procedure

____

____

____

____

____ [3]

Quality of written communication [1]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

3 **(a)** Your Data and Formulae Sheet includes the entry

elementary charge $e = 1.60 \times 10^{-19}$ C

(i) Name **two** particles that have a charge of this magnitude.

1. ____

2. ____ [1]

(ii) The elementary charge is important in connection with the quantisation of charge. What is meant by the quantisation of charge?

____

____ [1]

(b) In an experiment to determine the elementary charge, a very small, positively-charged, polystyrene sphere S is held stationary in the vertical electric field between two horizontal conducting plates **A** and **B**, shown in side view in **Fig. 3.1**.

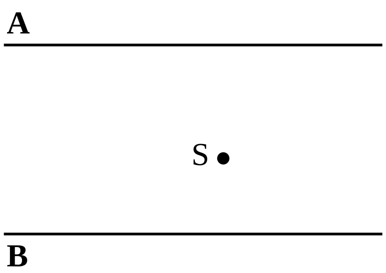

Fig. 3.1

(i) On **Fig. 3.1**, draw a suitable circuit to provide an electric field in the appropriate direction. Your circuit design should allow the field strength to be adjusted. [2]

Examiner Only	
Marks	Remark

(ii) State the quantities which must be measured in order to determine the magnitude of the electric field strength. Write down an expression for the electric field strength E in terms of these measurements.

Quantities to be measured: ______________________________

____

Expression: ____ [2]

(iii) In this experiment, the sphere has mass of 7.82×10^{-14} kg. When it carries a certain positive charge, it is held stationary by a vertical electric field of magnitude 6.66×10^{4} V m^{-1}. Calculate the number n of elementary charges carried by the sphere.

n = ____________________ [3]

Examiner Only	
Marks	Remark

4 The scattering of X-rays (X-ray diffraction) may be used in the study of crystalline solids and large molecules.

(a) What is the characteristic feature of the arrangement of the atoms of a crystalline solid?

____

____ [1]

(b) State **two** features of a crystalline solid about which information can be gained using X-ray diffraction.

1. ____

2. ____ [2]

(c) In order to process data from X-ray diffraction experiments, it is necessary to know the wavelength of the X-rays.

Suggest an appropriate value for an X-ray wavelength that might be used.

X-ray wavelength = ______________________________ [1]

(d) Electron diffraction may also be used in the study of crystalline solids and large molecules. What advantages would this method have over X-ray diffraction?

____

____

____ [2]

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(Questions continue overleaf)

Examiner Only	
Marks	Remark

5 **(a)** Your Data and Formulae Sheet gives the following equations for radioactive decay:

$$A = \lambda N$$

$$A = A_0 e^{-\lambda t}$$

Name the quantities represented by the following symbols in these equations:

A ____

A_0 ____

N ____

λ ____ [2]

(b) The rubidium isotope $^{87}_{37}Rb$ decays by a single-stage radioactive emission to the strontium isotope $^{87}_{38}Sr$.

(i) Deduce the particle which is emitted in this decay.

Particle: ____________________________ [1]

Examiner Only	
Marks	Remark

(ii) The rubidium–strontium decay is used in dating rocks containing fossil animals. At the time the rock was laid down and the fossil was formed it is assumed that the rock contained no $^{87}_{38}Sr$. As time passes, the $^{87}_{37}Rb$ in the rock decays to $^{87}_{38}Sr$, so that the ratio of the $^{87}_{38}Sr$ to $^{87}_{37}Rb$ increases continuously from zero. Determination of this ratio allows the rock to be dated.

When a rock containing a certain fossil is sampled it is found that the $^{87}_{37}Rb$ content had dropped from 100% to 88%. Calculate the age of the fossil. The half-life of $^{87}_{37}Rb$ is 4.75×10^{10} years.

Fossil age = ____________________ years [4]

(c) Nuclei of atoms can exist in excited states. When an excited nucleus returns to its state of lowest energy (the ground state), a gamma-ray photon may be emitted. The mass of a ^{60}Co atom when the nucleus is in its ground state is 59.9308 u and when the nucleus is in the excited state it is 59.9322 u. Calculate the energy of the gamma-ray photon emitted when this nucleus returns from its excited state to the ground state. Give your answer in MeV.

Energy = ________________ MeV [3]

6 Comprehension question

In your answer, you will be expected to bring together and apply principles and contexts from different areas of physics, and use the skills of physics, in the particular situation described.

You are advised to spend about 45 minutes in answering this question.

Read the passage carefully and answer all the questions which follow.

In parts (b), (f)(ii), (g)(ii) and (h)(i) of this question you should answer in continuous prose. Marking will reflect the quality of language used in your answers to these parts of the questions.

The Physics of Waves

The physics of waves is present in many branches of science. The application of waves in devices like mobile phones and CD players makes this topic in physics a common part of everyday life.

In research laboratories and in space, electromagnetic waves are used to determine the order of magnitude of very small and very large distances. These waves can be used to show that, in crystalline solids, the separation distance of atoms is a few tenths of a nanometre, whereas the distance from the Earth to stars in our galaxy is in the order of several parsecs.

The theory of progressive and stationary waves employs many terms also used in simple harmonic motion, such as frequency, period and amplitude. New terms also arise, including wavelength, waveform, phase and wave number. The wave number k is defined as $k = \frac{2\pi}{\lambda}$, where λ is the wavelength of the wave.

The origin of the sound produced by many musical instruments is a stationary wave on a string. The string may be stimulated by bowing, as in a violin, by striking, as in a piano, or by plucking, as in a guitar. The technique of each of these actions influences the harmonics produced along with the fundamental frequency. Harmonics are integral multiples of the fundamental frequency. The fundamental frequency f_o of a stretched string is given by **Equation 6.1**:

$$f_o = \frac{1}{2L}\sqrt{\frac{T}{M}}$$ **Equation 6.1**

where L is the length of the string, T is the tension in it, and M is the mass per unit length of the string.

The simplest sound wave has a waveform identical to that of a pure tone obtained from a tuning fork. However, the sound wave generated by a violin sounding a constant note has a complex waveform. This is caused by the simultaneous vibration and resonance of different parts of the instrument due to its construction and the materials used. The vibrations are combined with the vibrations of the string. Thus, all violins do not sound the same. A Stradivarius violin is considered to produce a sound of much better quality than that from a cheaper instrument. The Stradivarius is said to have superb timbre, which means that it produces a certain distinctive recipe of harmonics.

The phenomenon of beats is an example of the superposition of sound waves. Two pure tones of slightly different frequency played together produce a combined sound wave, the loudness of which rises and falls at a frequency called the beat frequency. The beat frequency is the difference in frequency of the two pure tones. Beat frequency of up to about 7 Hz are readily perceived by the human ear. When the frequencies of the pure tones are equal, they are in unison and a single note only is heard. Beats may be used to aid the tuning of musical instruments.

Gravitational waves are thought to exist, but have not yet been detected. It is thought that a rotating pair of stars could be a source of such waves. To detect them, very sensitive detectors are required to extract a faint signal from a jumble of background noise. One such detector is a laser interferometer, kept in a vacuum in an underground chamber. When a gravity wave passes through this instrument, the length of one of the detector arms is expected to change by a minute amount. This change in length should then be detectable by a change in the interference pattern produced by the interferometer.

Examiner Only	
Marks	Remark

(a) Write a few words, or a short sentence, to show the meaning of the following words or phrases, as they are used in the passage.

(i) waves (*line 1*)

____

____ [1]

(ii) order of magnitude (*line 5*)

____

____ [1]

(iii) progressive (*line 9*)

____

____

____ [1]

(iv) frequency (*line 10*)

____

____ [1]

(v) complex waveform (*line 24*)

____

____

____ [2]

(vi) superposition (*line 30*)

____

____

____ [2]

Examiner Only

Marks	Remark

(vii) tuning (*line 36*)

____

____[1]

(viii) noise (*line 40*)

____

____[1]

(ix) vacuum (*line 40*)

____

____[1]

(b) State **one** application of waves commonly encountered in everyday life. Name the type of wave involved and whether it is transverse or longitudinal, the function of the wave, and the approximate frequency of the wave associated with the application. (Note: do **not** describe a laboratory experiment.)

____

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____

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____

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____

____

____[5]

Examiner Only	
Marks	Remark

(c) A parsec (*line 8*) is equal to the distance travelled by light in 3.26 years. Calculate the ratio R.

Where $R = \dfrac{1 \text{ parsec}}{1 \text{ nanometre}}$.

Give your answer to two significant figures.

R = ________________________ [4]

(d) The fundamental frequency of a note played on a flute is 440 Hz.

(i) The speed of sound in air is $330\,\text{m}\,\text{s}^{-1}$. Calculate the wave number (*line 11*) corresponding to the fundamental frequency. Give the unit of wave number.

Wave number = ________________________

Unit: ________________________________ [4]

(ii) State the frequency of the fourth harmonic of the fundamental frequency.

Frequency = ________________________ Hz [1]

(iii) What is the name of the mathematical function representing the shape of the waveform of the fundamental frequency?

____ [1]

Examiner Only

Marks | Remark

(e) **Equation 6.1** (*line 19*) expresses how the fundamental frequency of a stretched string depends on the length L of the string, the tension T in it and its mass per unit length M.

On **Figs 6.1, 6.2 and 6.3**, draw three linear graphs showing how the fundamental frequency f_o depends, separately, on each of these variables. In each case, label the horizontal axis with the appropriate function of L, T or M and sketch the graph obtained.

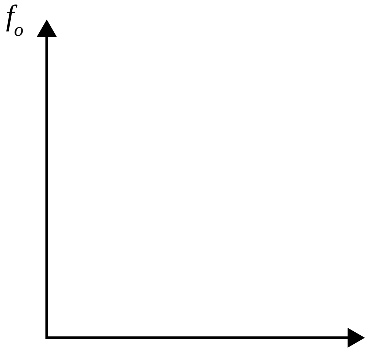

Fig. 6.1

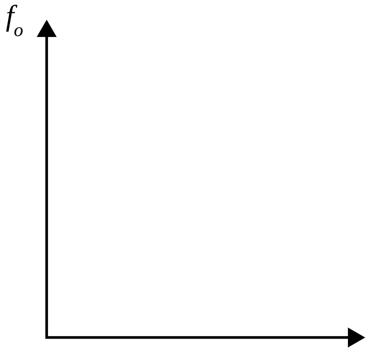

Fig. 6.2

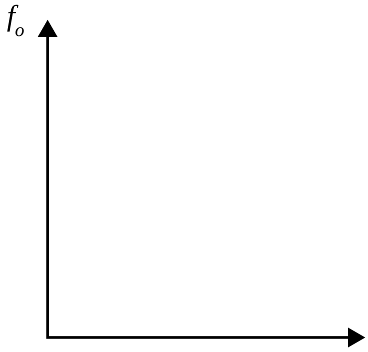

Fig. 6.3

[3]

(f) **(i)** A violin string produces a note of fundamental frequency 660 Hz. The tension in the string is 68.0 N, and the mass per unit length of the string is 0.38 g m^{-1}. Calculate the length of the string.

Length = ___________ m [2]

(ii) Explain how the type of wave on the violin string generates a wave in air which can be heard by a listener.

____

____

____ [3]

Examiner Only	
Marks	Remark

(g) A note is played on a violin at the same time as a pure tone is emitted from a loudspeaker connected to a signal generator. When the generator frequency is set to 261 Hz, beats (*lines 30–36*) are detected. The beat frequency is 5 Hz.

(i) Find two possible frequencies of the violin note.

Frequencies = ____________ Hz and ____________ Hz [1]

(ii) Explain how, by altering the frequency of the signal generator once only, the actual frequency of the violin note could be determined.

____

____

____

____

____ [3]

(h) A laser interferometer (*lines 40–44*) uses a laser as a light source.

(i) State **two** characteristics of laser lights.

1. ____

2. ____ [2]

Examiner Only	
Marks	Remark

(ii) In the laser interferometer, light is combined after it has travelled two different paths along the arms of the instrument. The length of one of these arms is 220 m, and the light beam traverses this arm twice, so that the total path length of the light is 440 m. The laser light has wavelength 690 nm.

For a change in the length of the interferometer arm to be detectable, the path length must change by at least a quarter of a wavelength of the laser light. Calculate the minimum percentage change in length of the interferometer arm for the passage of a gravitational wave to be confirmed.

Percentage change = ______________________ % [4]

Quality of written communication [1]

THIS IS THE END OF THE QUESTION PAPER