OCR
RECOGNISING ACHIEVEMENT

Thursday 13 June 2013 – Afternoon

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G495/01 Field and Particle Pictures

Candidates answer on the Question Paper.

OCR supplied materials:
- Data, Formulae and Relationships Booklet (sent with general stationery)
- Insert (inserted)

Other materials required:
- Electronic calculator
- Ruler (cm/mm)

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **100**.
- You may use an electronic calculator.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means for example, you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that the meaning is clear
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You are advised to show all the steps in any calculations.
- This document consists of **24** pages. Any blank pages are indicated.
- The questions in Section C are based on the material in the Insert.

DC (DTC (CGW)) 00687 1/12 59681/5

Turn over

Answer **all** the questions.

SECTION A

1 Here is a list of units:

$\mathbf{J\,s^{-1}}$ $\mathbf{J\,kg^{-1}}$ $\mathbf{J\,m^{-1}}$ $\mathbf{J\,C^{-1}}$

State the equivalent unit from the list for

(a) Sv, radiation dose equivalent

.... **[1]**

(b) $\mathrm{Wb\,s^{-1}}$, rate of change of flux linkage.

.... **[1]**

2 The charge on a u quark is $+\frac{2}{3}$ e.

The charge on a d quark is $-\frac{1}{3}$ e.

Draw lines from the descriptions given in the left hand boxes to the names of the particles given in the right hand boxes.

particle composed of 2 u and 1 d quark	neutron
negatively charged lepton	electron
neutral lepton	proton
neutral hadron	neutrino

[2]

3 The rest energy of an electron is about 510 keV.

An electron is accelerated through a potential difference of 90 keV.

Choose the value from the list below which gives the best estimate for the relativistic factor γ of the accelerated electron.

0.80 **1.0** **1.2** **1.4**

best estimate = ... **[1]**

4 Fig. 4.1 shows a length of wire carrying a current at right angles to a magnetic field.

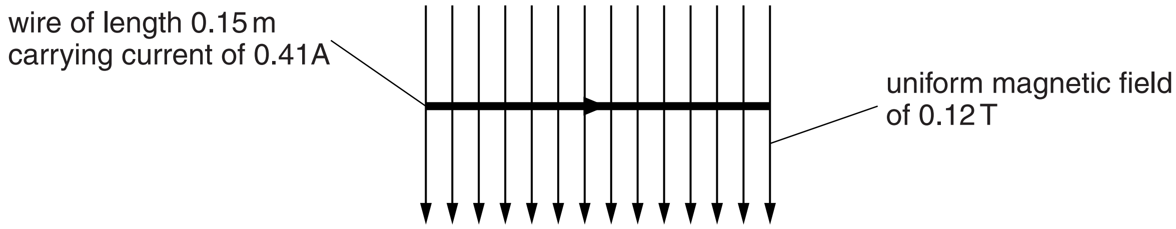

Fig. 4.1

Calculate the force on the wire.

force = ... N **[2]**

5 Fig. 5.1 shows the variation of electric field strength E with distance r from a point charge.

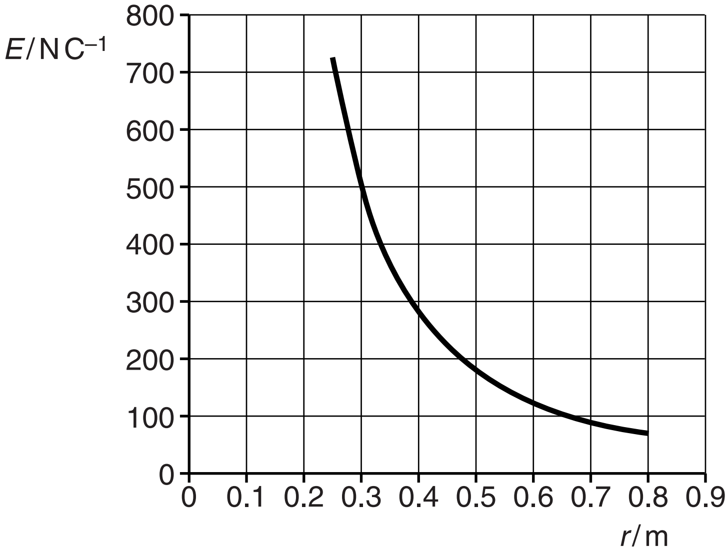

Fig. 5.1

Use the graph to estimate the potential difference between r = 0.3 m and r = 0.7 m. Describe the method you use.

potential difference = ... V **[3]**

6 Fig. 6.1 shows the path of a proton as it is deflected by a nucleus. This is labelled proton **A**.

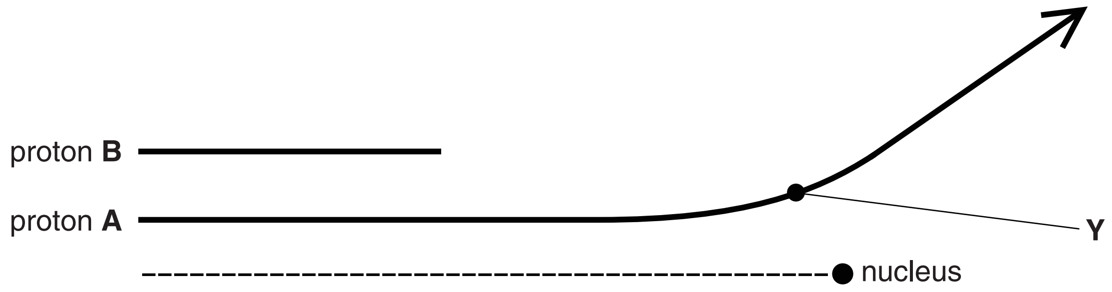

Fig. 6.1

(a) Draw an arrow to show the direction of the force acting on the proton at point **Y**. **[1]**

(b) Proton **B** has the same energy as proton **A**. Complete the line showing the path of proton **B**. **[2]**

7 Here is a list of numbers.

8 **10** **12** **14** **16**

Choose from the list the value that gives the best estimate for

(a) the average emf generated when the magnetic flux through a 400 turn coil changes by 2.5×10^{-4} Wb in 0.012 s

best estimate = ... V **[1]**

(b) the pd across the secondary coil of a transformer when the primary coil is connected to a 230 V, 50 Hz supply.

number of turns on primary coil = 1200

number of turns on secondary coil = 60

best estimate = ... V **[1]**

8 A simple model of an atom represents an electron as a standing wave in a box. The wave for the lowest energy level of the electron (n = 1) is shown in Fig. 8.1.

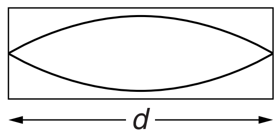

Fig. 8.1

The wavelength λ of the electron is given by

$$\lambda = \frac{h}{p}$$

where p is the momentum of the electron.

Momentum is related to kinetic energy E by the equation

$$E = \frac{p^2}{2m}.$$

(a) Show that $E = \frac{h^2}{2m\lambda^2}$.

[1]

(b) The wave for the second energy level of the electron (n = 2) is shown in Fig. 8.2.

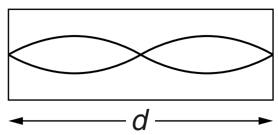

Fig. 8.2

Choose the value from the list below which gives the ratio $\frac{\text{energy for n = 2}}{\text{energy for n = 1}}$ using this model.

0.25 **0.5** **1.0** **2.0** **4.0**

ratio = ... **[1]**

9 Fig. 9.1 shows some equipotential lines in a region of electric field.

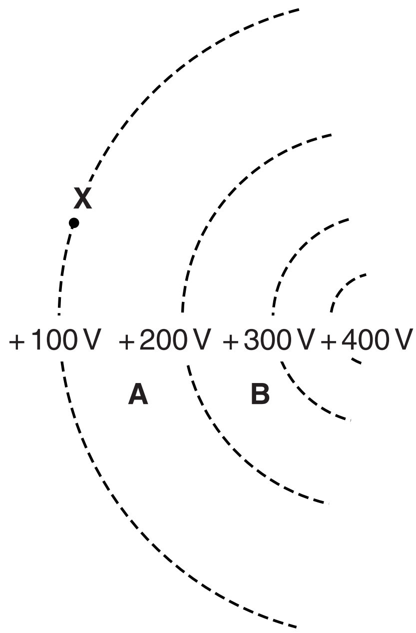

Fig. 9.1

(a) Explain how the diagram shows that the electric field is weaker at **A** than at **B**.

[2]

(b) Draw an arrow through point **X** to show the direction of the field at that point. **[1]**

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SECTION B

10 This question is about an electric motor which uses a rotating magnetic field.

Fig. 10.1 shows the magnetic flux in the motor in which a permanent magnet is the rotor. The flux is shown at one particular instant.

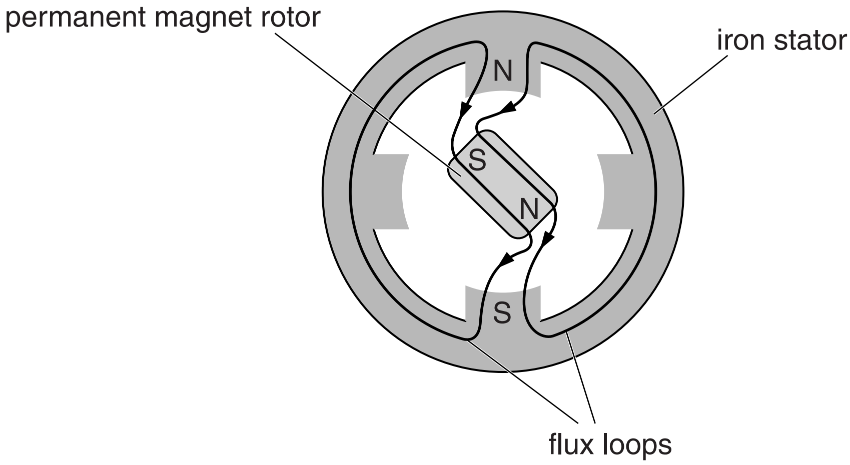

Fig. 10.1

(a) **(i)** State how the position of the poles shown in Fig. 10.1 indicate that the permanent magnet will turn clockwise.

[1]

(ii) State how the shape of the flux lines shown in Fig. 10.1 **also** indicates that the permanent magnet will turn clockwise.

[1]

(b) The force on the permanent magnet can be increased by increasing the permeance of the system. Suggest **two** ways in which the permeance of the system can be increased.

[2]

(c) The flux in the stator is produced by 25 Hz alternating currents in the two pairs of coils **X** and **Y**. Fig. 10.2 shows the flux in the stator at times t = 0.0 s and t = 10 ms.

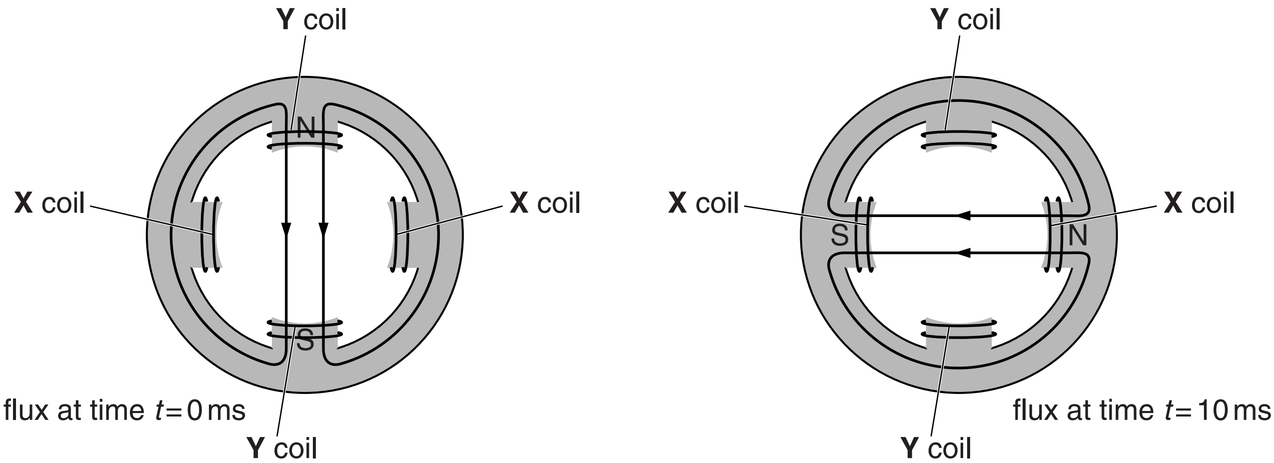

Fig. 10.2

Fig. 10.3 shows how the alternating current in the **X** and **Y** coils varies with time.

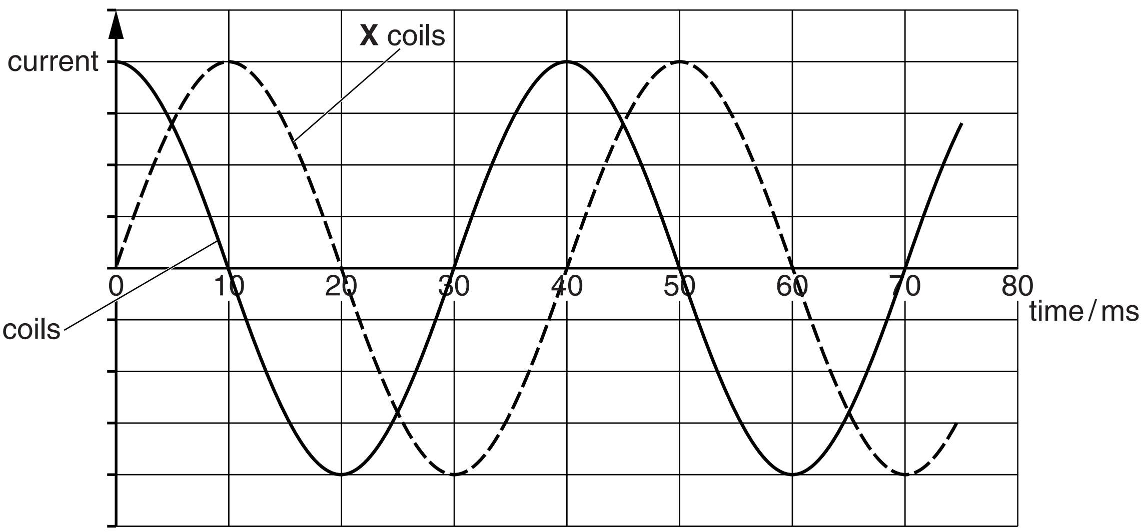

Fig. 10.3

(i) Use Fig. 10.3 to explain the flux change shown in Fig. 10.2.

[2]

(ii) Explain how, as the alternating currents vary over one complete cycle, the flux rotates by one turn.

[2]

(d) When the permanent magnet is replaced with a non-magnetic copper rotor the motor still spins as the flux rotates.

By considering the changing magnetic field in the rotor, explain why the copper rotor spins.

[3]

[Total: 11]

11 This question is about a nuclear fusion reaction that may be able to provide a future energy source. The symbol equation for the first stage of the reaction is given below:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

The word equation for the reaction is:

deuterium nucleus + tritium nucleus ⟶ helium nucleus + neutron.

(a) **(i)** Here are some data for the reaction:

mass of deuterium nucleus = 2.0135 u
mass of tritium nucleus = 3.0155 u
mass of helium nucleus = 4.0015 u
mass of neutron = 1.0087 u

Show that the total mass of the particles decreases by about 3×10^{-29} kg in each fusion reaction.

$1\,u = 1.66 \times 10^{-27}$ kg

[2]

(ii) Calculate the energy released in one reaction.

$c = 3.0 \times 10^{8}\,m\,s^{-1}$

energy released = ... J **[2]**

(b) The separation of the deuterium and tritium nuclei must be about 10^{-14} m for fusion to occur.

Show that the work done in bringing the two nuclei to within 10^{-14} m is about 2×10^{-14} J.

electric force constant $\frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9\,\mathrm{N\,m^2\,C^{-2}}$

$e = 1.6 \times 10^{-19}\,\mathrm{C}$

[2]

(c) In a working fusion reactor, a tritium-deuterium plasma is kept at high temperatures to give the nuclei the energy required for fusion to occur.

(i) Use $E \approx kT$ to estimate the temperature required of the tritium and deuterium plasma for fusion to occur.

minimum energy of nuclei required for fusion = 1×10^{-14} J
Boltzmann constant $k = 1.4 \times 10^{-23}\,\mathrm{J\,K^{-1}}$

temperature = ... K **[1]**

(ii) Explain why this fusion reaction may occur when the plasma is at a lower temperature.

[2]

[Total: 9]

12 This question is about technetium-99m, an isotope that is used in about 20 million medical investigations each year. The isotope is represented as $^{99m}_{43}Tc$. The nucleus falls to a lower energy state with the release of a gamma photon:

$$^{99m}_{43}Tc \rightarrow ^{99}_{43}Tc + \gamma$$

The half life of this process is 6 hours.

(a) Show that λ, the decay constant for the process, is about $3 \times 10^{-5}\,s^{-1}$.

[2]

(b) In a medical investigation a patient is injected with a compound containing technetium-99m. The original activity of the injected compound is 9.3×10^{8} Bq. Each gamma photon released in the decay process has an energy of 140 keV.

Calculate the initial number of technetium-99m nuclei present in the dose and use this value to show that the total energy emitted by the technetium-99m is less than one joule.

$1\,eV = 1.6 \times 10^{-19}\,J$

original number of technetium-99m nuclei = ...

total energy of dose = ... J
[4]

(c) About 99% of the gamma photons produced pass out through the body of the patient. This can yield information of medical value. However, the patient still receives a significant dose.

Use your answer to **(b)** to calculate an estimate for the whole-body dose equivalent in Sv received by a patient undergoing a technetium-99m investigation.

mass of patient = 77 kg
quality factor of γ radiation = 1

dose equivalent = ... Sv **[3]**

(d) The risk of developing cancer from radiation exposure is approximately 5% per sievert. Use your answer from **(c)** to consider the risk implications of this procedure for an individual patient and the global effect of the 20 million procedures each year which use technetium-99m.

Make each step in your calculation and explanation clear.

[4]

[Total: 13]

13 This question is about the principles behind a mass spectrometer, an instrument which can identify isotopes from very small samples of their ions. Fig. 13.1 shows the basic components of the instrument.

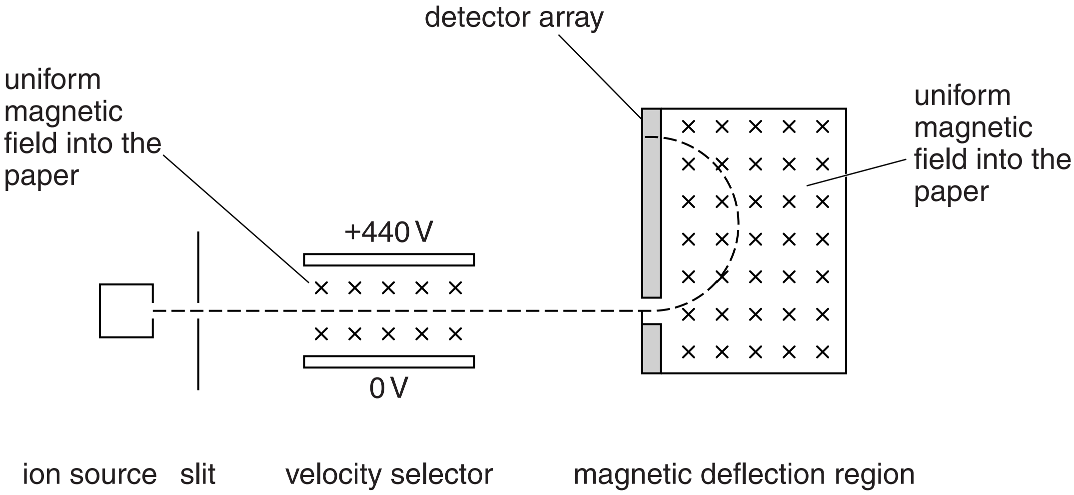

Fig. 13.1

(a) The velocity selector contains two plates separated by 0.022 m. There is a potential difference of 440 V between the plates, producing a uniform electric field.

(i) Show that a singly-charged positive ion will experience a force of 3.2×10^{-15} N due to the electric field between the plates.

charge on ion = 1.6×10^{-19} C

[1]

(ii) A uniform magnetic field of 0.11 T also acts between the plates as shown in the diagram.

The force *F* on a charge *q* moving at speed *v* in a magnetic field of strength *B* is given by $F = qvB$. With the aid of a suitable calculation, explain why the path of a singly-charged positive ion moving at about 1.8×10^{5} m s^{-1} can be a straight line through the velocity selector.

[3]

(b) Singly-charged tin ($^{118}Sn^{+}$) ions enter the magnetic deflection region as shown in Fig. 13.2.

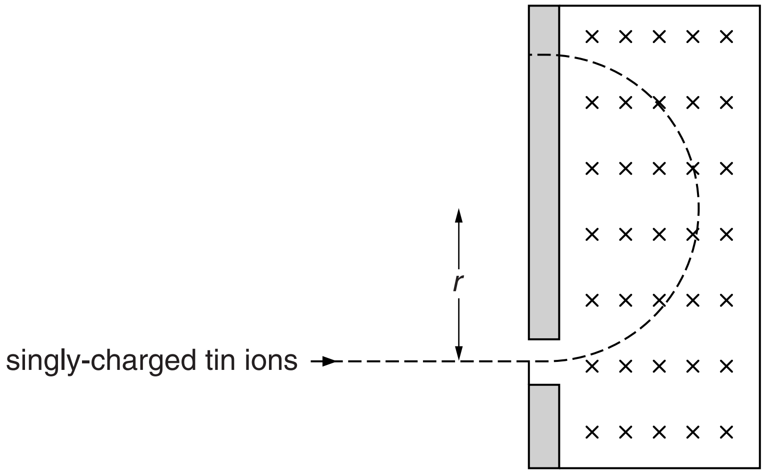

Fig. 13.2

(i) The magnetic force on the ions acts centripetally.

Show that the radius of the path of an ion of charge q and mass m moving at velocity v in a magnetic field of strength B is given by $r = \frac{mv}{Bq}$.

[1]

(ii) Calculate the radius of the path followed by a singly-charged $^{118}Sn^{+}$ ion of mass 2.0×10^{-25} kg with a speed of $1.8 \times 10^{5}\ m\,s^{-1}$. The magnetic field in the deflection region is 0.70T.

radius = ... m **[2]**

(iii) The sample of tin also includes more massive singly-charged $^{120}Sn^{+}$ ions which also pass though the velocity selector at a speed of $1.8 \times 10^{5}\ m\,s^{-1}$. Describe and explain how their path through the magnetic deflection region differs from the path of $^{118}Sn^{+}$ ions.

[2]

[Total: 9]

SECTION C

These questions are based on the Insert.

14 Fig. 14.1 shows the fundamental standing wave pattern of a length of steel violin string.

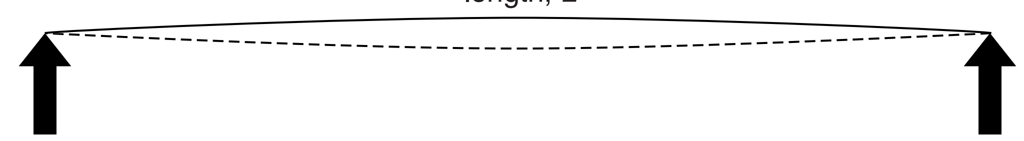

Fig. 14.1

(a) The length, L, of the string is 0.32 m. State the wavelength of the fundamental standing wave shown.

wavelength = ... m **[1]**

(b) The frequency of the fundamental note produced is 440 Hz. Calculate the speed of the wave along the string.

speed = ... $m\,s^{-1}$ **[2]**

(c) The speed v of a transverse wave along a stretched string like this is given by the equation

$$v = \sqrt{\frac{T}{\mu}}$$

where T is the tension and μ the mass per unit length of the string.

Show that the units of $\sqrt{\frac{T}{\mu}}$ are $m\,s^{-1}$.

[2]

(d) **(i)** Show that the frequency of the fundamental mode of oscillation is given by

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

where L is the length of the string.

[1]

(ii) Show that if the tension T were increased by 10% (a factor of 1.1) then the frequency of the fundamental note would be about 460 Hz. Assume that both μ and L remain constant.

[2]

(iii) In practice, the value of μ will change as the tension is increased. Explain why.

[2]

(iv) Suggest and explain how the change in μ affects the value of the frequency you have calculated in part **(ii)**.

[2]

[Total: 12]

15 In line 30 in the article it is stated that the air inside the instrument can resonate.

(a) Using a suitable example, explain the meaning of *resonance*.

[2]

(b) The vibrations lead to standing waves in the body of the instrument (Chladni patterns, line 36 in the article).

Explain how the sand displays these standing wave patterns.

[2]

(c) The material from which a traditional (acoustic) violin is made significantly affects the sound it makes. Explain how making the violin body from stiffer wood would affect the resonant behaviour of the instrument.

[2]

[Total: 6]

16 A diagram of a magnetic pickup for a violin string is shown in Fig. 16.1.

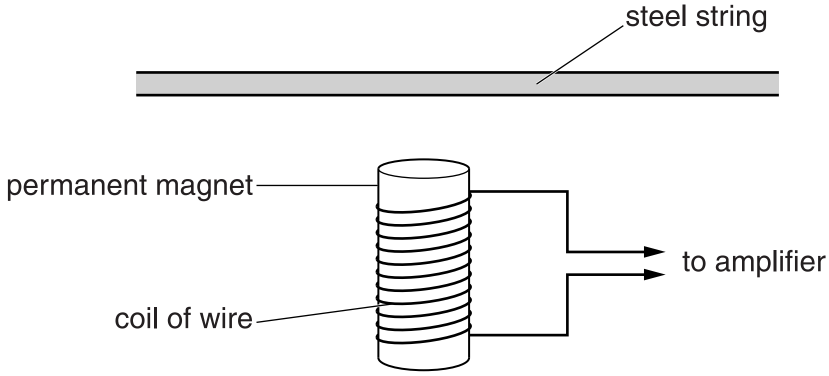

Fig. 16.1

(a) Add **two** lines of flux to the figure to indicate the magnetic circuit created by the pickup. **[2]**

(b) The permanent magnet used is 6.0 mm in diameter.

Show that if the field strength at the poles of the magnet is 0.10 T, the magnetic flux in those regions is about 3×10^{-6} Wb.

[2]

(c) The coil of wire consists of 8 200 turns. Show that this requires about 150 m of wire.

[2]

(d) The wire has a resistance of 50 Ω per metre. An emf of 0.12 V is induced across the coil. Calculate the current in the coil when the ends of the wire are joined together.

current = ... A **[2]**

(e) Explain how a steel wire vibrating near the pole of the magnet causes an emf to be induced in the coil.

Your explanation should be clear and follow a logical order.

[4]

[Total: 12]

17 **(a)** Explain how a piezoelectric pickup detects the vibrations of the strings and explain why the strings do not have to be steel when such a pickup is used.

[4]

(b) Suggest an advantage of using a piezoelectric pickup rather than a magnetic pickup for a violin.

[1]

[Total: 5]

Question 18 begins on page 24

18 Fig. 18.1 shows the waveform of a pure note. Fig. 18.2 shows a more complex note.

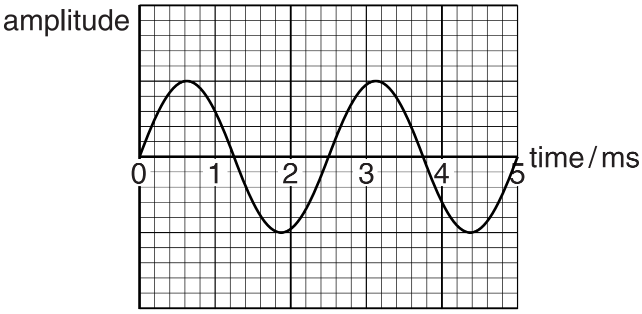

Fig. 18.1

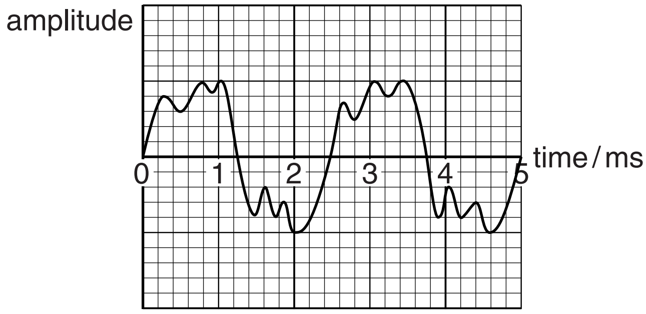

Fig. 18.2

(a) Use Fig. 18.1 to calculate the frequency of the pure note.

frequency = ... Hz **[1]**

(b) Explain why both notes have the same pitch yet sound different.

[2]

[Total: 3]

END OF QUESTION PAPER

RECOGNISING ACHIEVEMENT

Thursday 13 June 2013 – Afternoon

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G495/01 Field and Particle Pictures

INSERT

G412100613

Duration: 2 hours

INSTRUCTIONS TO CANDIDATES

- This Insert contains the article required to answer the questions in Section C.

INFORMATION FOR CANDIDATES

- This document consists of **8** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

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Fiddles of the Future

Although electric violins have a very modern sound, they have been around in one form or another for nearly 100 years. The first type was created by adapting the pickup devices from electric guitars and fitting them to normal violins and although other types now exist, many are still designed in this way. Apart from producing a sound that is in keeping with other electric instruments of the modern era, an electric violin has the benefit of producing notes that can be electronically amplified, especially useful for live performances at big concert venues. The understanding and development of both the acoustic and electric versions of the instrument have relied heavily on the discoveries of many physicists throughout the centuries.

The basic 4-stringed acoustic violin can be traced back to ancient Central Asia but emerged in its current form in Italy in the 16th century. Fig. 1 shows the basic structure and the names of some of the important features.

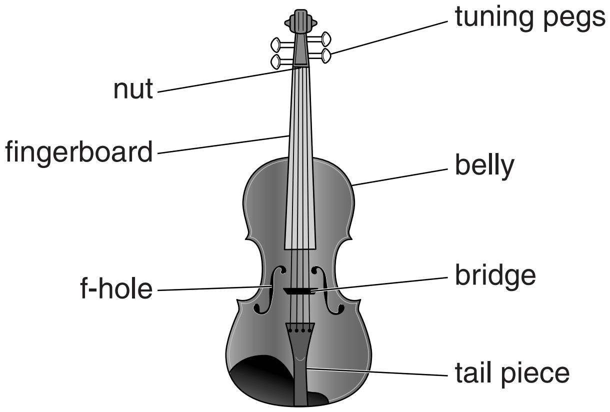

Fig. 1: the basic parts of an acoustic violin

The strings can produce a sound when plucked but the usual way to produce a note is to draw a bow across a string to cause it to vibrate. The note produced depends upon a large number of factors, the most important relating to the nature of the string itself. How the frequency of the note depends upon the length of a string is probably most famously associated with Pythagoras (500 BC). The density and tension of the violin string also affect the pitch of the note it produces since the speed of the wave along the string depends upon these values.

Standing wave theory can be applied to a violin string to account for the range of frequencies that can be produced by a single string. Consider a string that is plucked. The distance between the bridge and the position of the player's finger (or, if an 'open string', to the 'nut' at the end of the fingerboard) defines the length of the vibrating string – see Fig. 2. The pitch of the main note produced is then determined by the fundamental standing wave for that length.

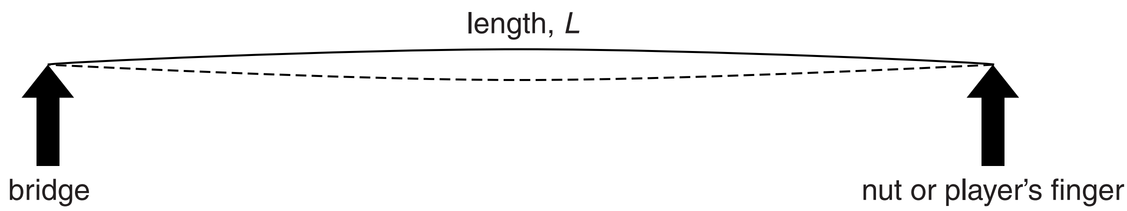

Fig. 2: fundamental standing wave on bowed string

Other factors affecting the tone quality (timbre) include the shape of the violin frame itself, the type of wood from which it is made and, some experts claim, even the varnish with which the violin has been coated.

Sound production

The vibrating strings themselves disturb the air surrounding them only very little, producing hardly any sound. In an acoustic violin, the vibrations of the strings are transferred to the body of the violin via the bridge and sound post (Fig. 3) and a louder sound is produced. The vibrating violin body can also cause the air inside to resonate. This effect is similar to that of producing notes by blowing across the top of a bottle, first studied in detail by Helmholtz in 1885. In the violin, strong resonances at particular frequencies can produce extra, unwanted notes, so-called ‘wolf notes’.

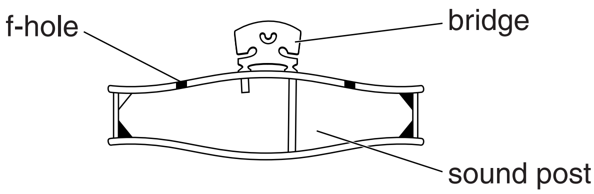

Fig. 3: cross-section of the violin body showing the sound post supporting the bridge

Further resonances are set up in the wooden body of the instrument. As with the strings themselves, standing waves can be set up in the materials of which the violin is made, the wave shapes produced being examples of the two-dimensional standing wave patterns known as Chladni Patterns. The mechanical properties of the material will determine the sorts of patterns produced and these in turn will depend upon many contributing factors. Fig. 4 shows one type of pattern set up in a rectangular wooden plate and a similar pattern produced in the back plate of a violin.

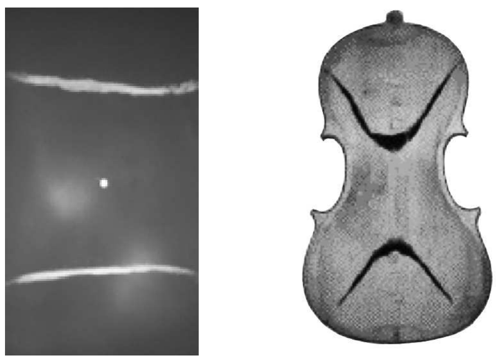

Fig. 4: Chladni pattern for a simple rectangular plate and a violin back plate

The patterns in these pictures have been made visible with sand scattered onto the surface. A more sophisticated modern technique employing lasers and holography can be used to show the nodal lines for the more complicated wave patterns (see Fig. 5).

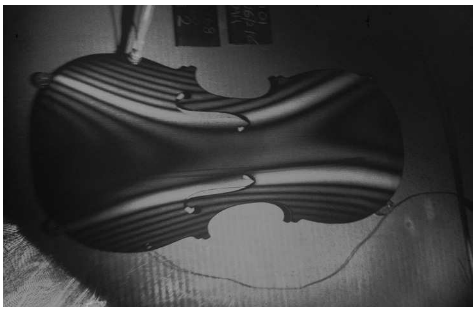

Fig. 5: Chladni standing wave pattern on a vibrating violin plate imaged using holographic techniques

Amplifying the sound

In an electric violin, the vibrations of the strings are detected and converted into electrical signals which can then be electronically amplified and used to produce sound waves in loudspeaker systems. The detection device is called a "pickup" and there are two main types used in electric violins.

1. Magnetic pickup

Magnetic pickups require the violin to have steel strings. The pickup (Fig. 6) consists of a coil of wire wrapped around a permanent magnet, which is placed on the body of the violin underneath each steel string.

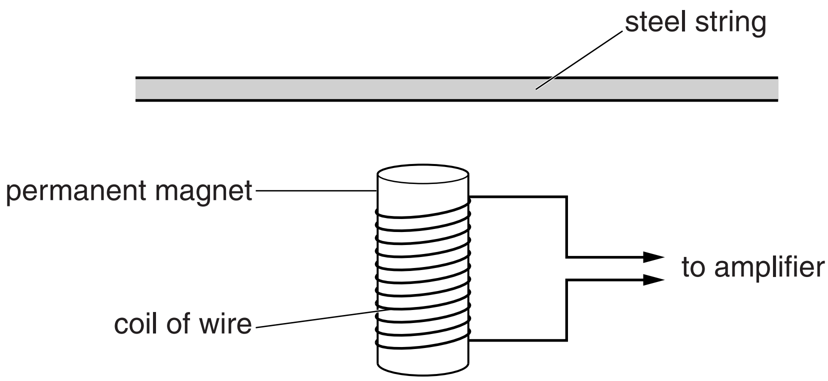

Fig. 6: magnetic (induction) pickup for one steel string

The permanent magnet produces a flux linkage in the coil which depends mainly upon the permeance of the material within the coil, ie the permanent magnet. However, the steel string near the coil contributes to the permeance too, slightly changing the strength of the magnet. If the steel string vibrates and moves relative to the pickup, the total permeance of the magnetic circuit changes. This produces an emf across the coil. This emf produces a current, the frequency components of which will be the same as those of the string. Hence the vibration of the string is detected electrically and can be amplified and broadcast through a sound system.

2. Piezoelectric pickup

The piezoelectric effect was first demonstrated in the late 19th century by the brothers Pierre and Jacques Curie. They showed that voltages can be generated across some materials when they are squeezed. Today this effect has many applications including producing sparks in gas lighters. This effect is especially useful for sensing subtle changes in force and is used in a wide range of sensors from strain gauges to accelerometers used in mobile phones – and, of course, violin pickups.

In this type of pickup, the piezoelectric sensor is placed onto the body of the violin usually on or near the bridge. The sensor then detects the vibrations produced in the instrument body when the strings are bowed or plucked (Fig. 7).

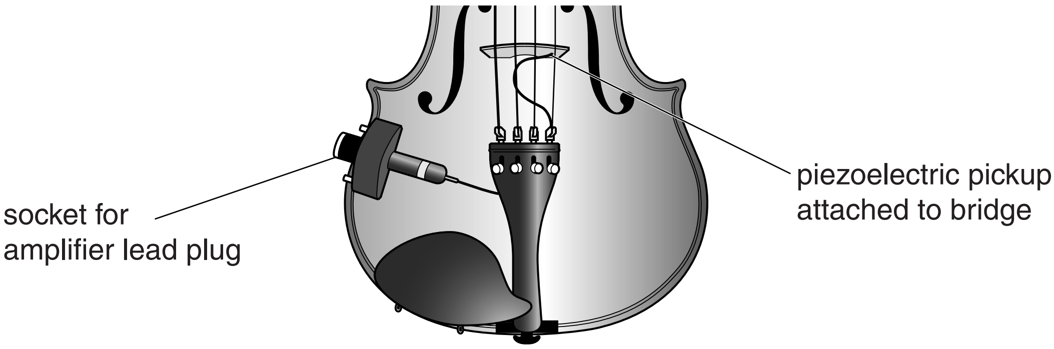

Fig. 7: piezoelectric pickup attached to an acoustic violin

Although the vibrations of the strings and of the instrument body will have the same dominant frequencies, the amplified sound of the notes produced in each case will be very different as the vibrations are being produced in different media in each case. The quality of the sound heard, described as the timbre of the sound, depends on the presence of higher frequencies above the dominant frequency. This is why, for example, a flute sounds different from a violin when they play the same note; the dominant frequency is the same but the mix of higher frequencies is specific to the instrument.

END OF ARTICLE