OCR
Oxford Cambridge and RSA

Thursday 15 June 2017 – Morning

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G494/01 Rise and Fall of the Clockwork Universe

Candidates answer on the Question Paper.

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

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

Duration: 1 hour 15 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- 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. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

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 **60**.
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- 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.
- This document consists of **16** pages. Any blank pages are indicated.

Answer **all** the questions.

SECTION A

1 Here is a list of units:

$J\,m^{-2}$ $N\,m^{-1}$ $kg\,m\,s^{-2}$ $N\,m^{-2}$

(a) Which one is a correct unit for pressure?

.... **[1]**

(b) Which one is a correct unit for force?

.... **[1]**

2 Study the circuit in Fig. 2.1.

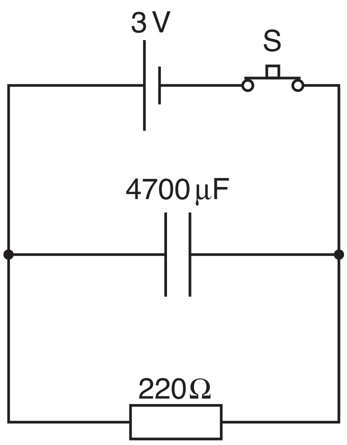

Fig. 2.1

(a) Calculate the time constant τ of the circuit.

τ = ... s **[1]**

(b) Calculate the charge remaining on the capacitor τ seconds after the switch is opened.

charge remaining = ... C **[2]**

3 Fig. 3.1 shows the variation in gravitational field strength with distance from Ceres, the largest known asteroid.

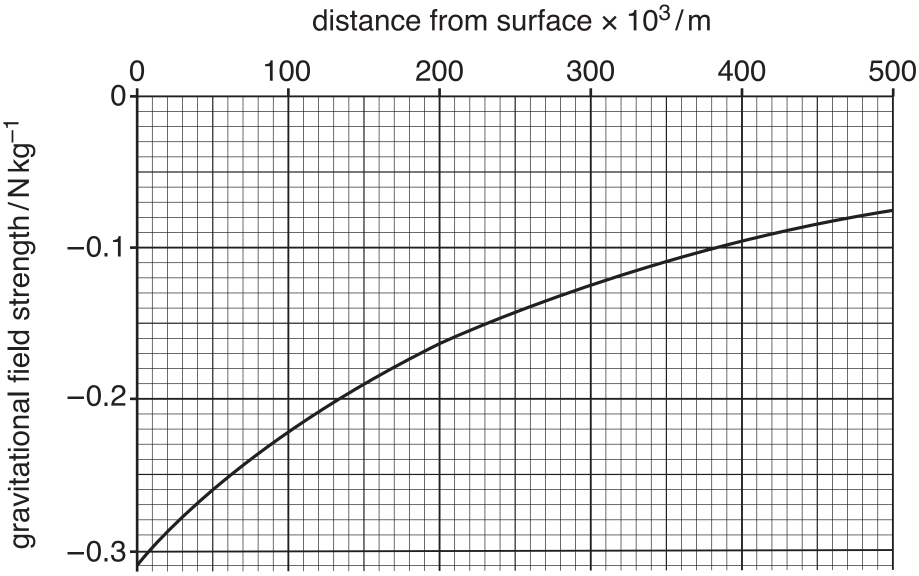

Fig. 3.1

Use the graph to estimate the energy required to move a mass of 2.0 kg from 100 × 10^3 m above the surface to 300 × 10^3 m above the surface.

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

4 Hydrogen atoms can emit ultraviolet light of wavelength 122 nm. A spectrum from a distant astronomical source shows that this light has been stretched to a wavelength of 420 nm.

(a) Calculate the factor by which the Universe has expanded since the light was emitted by the source.

factor = ... **[1]**

(b) Explain why the cosmological redshift observed in light received from a source increases with the distance of the source from Earth.

[2]

5 A central heating system contains 120 kg of water. Energy is transferred to the water at a rate of 10.5 kW.

Calculate the time taken to raise the temperature of all the water in the system from 12 °C to 40 °C. Ignore any energy lost to the surroundings.

specific thermal capacity of water = 4200 $J\,kg^{-1}\,°C^{-1}$

time taken = ... s **[2]**

6 Muons have a half-life of about 1.5 μs at rest. The observed half-life of muons produced from cosmic rays is about 7.5 μs.

(a) Calculate the relativistic factor γ of the muons produced from cosmic rays.

relativistic factor = ... **[1]**

(b) Calculate the speed of the muons produced from cosmic rays.

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

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

7 Fig. 7.1 shows how the acceleration a of a simple harmonic oscillator varies with time.

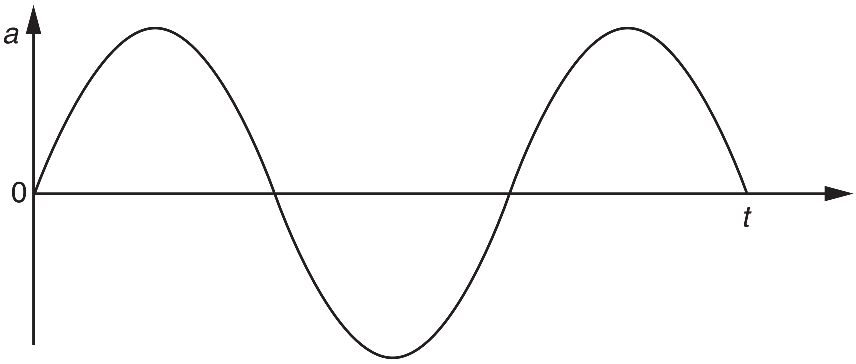

Fig. 7.1

(a) Mark on the graph a point where the velocity of the oscillator is at a maximum. Label this point **V**. **[1]**

(b) Mark on the graph a point where the displacement of the oscillator is at a maximum. Label this point **X**. **[1]**

8 A volume of $2.4 \times 10^{-3}\,\text{m}^3$ of helium gas at a pressure of $1.4 \times 10^{-10}\,\text{Pa}$ contains approximately 1×10^8 atoms. Calculate the root mean square speed of the atoms. Assume that helium behaves as an ideal gas.

mass of helium atom = $6.8 \times 10^{-27}\,\text{kg}$

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

SECTION B

9 This question is about the gravitational field around a small, spherical asteroid. It is assumed that the asteroid is of uniform density.

(a) Fig. 9.1 shows some equipotential lines around the asteroid. Draw the gravitational field line through point **X**. **[2]**

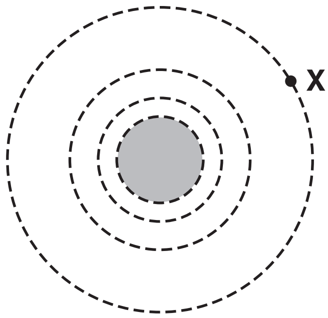

Fig. 9.1

(b) It is suggested that a space vehicle could land on the asteroid. Calculate the gravitational force on a vehicle of mass 2.9×10^2 kg on the surface of the asteroid.

Data: radius of asteroid = 1.45×10^5 m

mass of asteroid = 7.0×10^{19} kg

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

(c) The asteroid is spinning, making one rotation every 320 minutes. The space vehicle is on the equator of the asteroid at a distance 1.45×10^5 m from the centre.

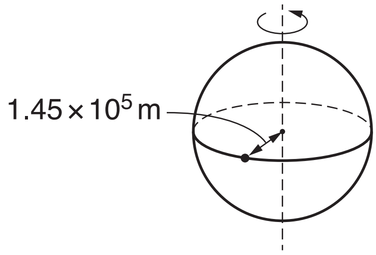

Fig. 9.2

(i) Calculate the force needed to keep the space vehicle on the surface of the spinning asteroid at the equator and explain why the space vehicle remains on the surface despite the rotation of the asteroid.

You should use technical terms correctly in your answer.

[4]

(ii) It is suggested that a less massive space vehicle would be less likely to remain on the surface of the asteroid. Comment on this suggestion.

[2]

10 This question is about using compressed air to accelerate a toy vehicle.

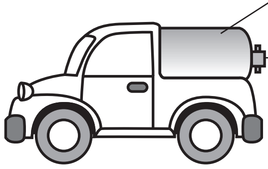

Fig. 10.1

Here are some data about the air in the tank:

pressure = 1.0×10^5 Pa

temperature = 298 K

mass of air = 0.60 g

mass of one mole of air = 29 g

(a) Show that the volume of the tank is about $5 \times 10^{-4}\,m^3$.

Assume the air behaves as an ideal gas.

R, molar gas constant = $8.3\,J\,mol^{-1}\,K^{-1}$

[3]

(b) More air is pumped into the tank and the pressure rises to 6.0×10^5 Pa. The temperature of the air does not change. Explain why adding more air increases the pressure.

[2]

(c) The valve is opened and air is released. In the first two seconds after opening 1.7 g of air leaves the tank at an average velocity of 9 m s^{-1}.

Calculate the initial acceleration of the car.

mass of car and air = 0.07 kg

acceleration = ... m s^{-2} **[2]**

(d) The acceleration of the toy car does not remain constant as the air is expelled. Suggest and explain factors which affect the acceleration of the toy car as the air is expelled.

Your answer should have correct spelling, punctuation and grammar.

[4]

11 This question is about using carbon-14 to estimate how long ago an ancient stone circle was constructed.

(a) Living matter has 4.0×10^{10} atoms of carbon-14 in every gram of carbon.
This gives an activity of about 0.16 Bq. Use this information to show that the half-life of carbon-14 is about 5500 years.

1 year = 3.2×10^{7} s

[3]

(b) **(i)** Draw a graph on Fig. 11.1 to show how the number N of carbon-14 atoms per gram of carbon varies over time. **[2]**

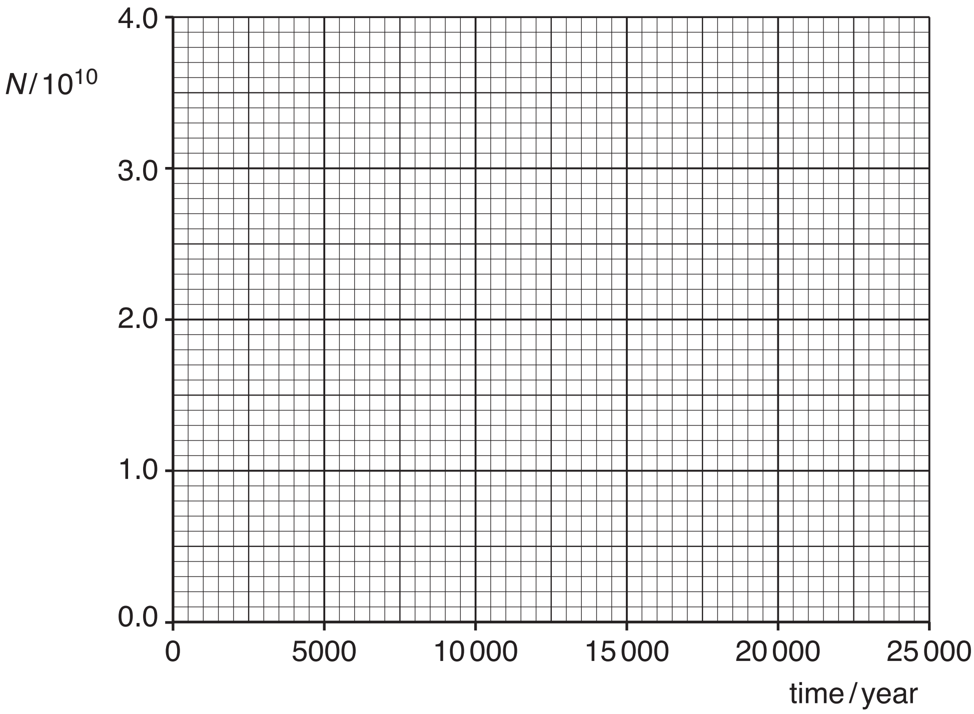

Fig. 11.1

(ii) A fragment of bone was found buried near one of the large stones. It is assumed that the bone was buried when the stone was laid in place and that the bone had 4.0×10^{10} atoms of carbon-14 in every gram of carbon at the time of burial.

The number of carbon-14 atoms per gram of carbon in the samples from the bone varied between 1.9×10^{10} and 2.1×10^{10}.

Use the graph to estimate the age of the sample. State the uncertainty in your estimate.

age = ... uncertainty ± .... years **[2]**

(c) Carbon dating is used to date samples of organic material up to about 50 000 years old.

(i) Calculate the activity of one gram in a sample of organic matter remaining after 50 000 years.
Assume that the original activity per gram was 0.16 Bq and only due to carbon-14.

activity per gram = ... Bq **[2]**

(ii) Suggest why this method of carbon dating is not suitable for determining the age of objects older than about 50 000 years and explain how contamination with modern matter can affect the calculated age of the sample.

[3]

12 This question is about a mass between springs acting as a simple harmonic oscillator.

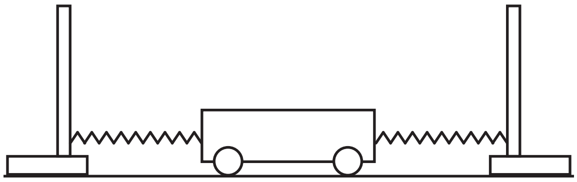

Fig. 12.1

The acceleration a of a simple harmonic oscillator of frequency f is given by the equation

$$a = -4\pi^2 f^2 x$$

where x is the displacement from the equilibrium position.

(a) State what the negative sign in the equation implies about the acceleration of the oscillator.

[1]

(b) The springs remain in tension throughout a complete oscillation of the mass. Frictional forces can be ignored. The acceleration of a mass m between two identical springs is given by the equation

$$a = -\frac{kx}{m}$$

where k is the spring constant of the whole spring system.

Use the equations above to show that k of the system in Fig. 12.1 is about 45 N m^{-1}. Show all your working.

mass of oscillator m = 1.4 kg
frequency of system = 0.90 Hz

[3]

(c) **(i)** The amplitude of the oscillation is 0.18 m.
Calculate the total energy of the oscillating system.

energy = ... J **[1]**

(ii) Use your answer to **c(i)** to calculate the maximum velocity of the system. Make your reasoning clear.

maximum velocity = ... $m\,s^{-1}$ **[3]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).