OCR
RECOGNISING ACHIEVEMENT

Monday 18 June 2012 – Morning

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G494 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. 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 **60**.
- 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.
- 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.
- This document consists of **16** pages. Any blank pages are indicated.

DC (NH/CGW) 43907/8

Answer **all** the questions.

Section A

1 Here is a list of units.

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

(a) Which is a correct unit for gravitational potential?

answer .... **[1]**

(b) Which is a correct unit for momentum?

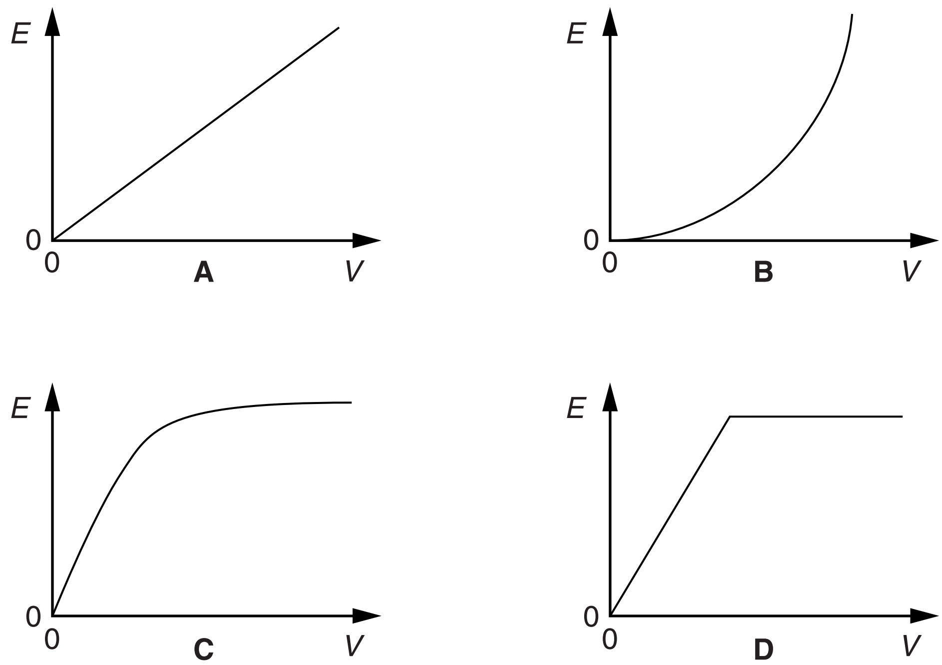
answer .... **[1]**

2 Ultra capacitors using new technology are now available with capacitances of 5000 F and a maximum voltage of 2.7 V.

(a) Calculate the energy stored in an Ultra capacitor when it is charged to its maximum voltage.

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

(b) These graphs show how the stored energy *E* varies with potential difference *V*.



Which one of the graphs **A**, **B**, **C** or **D** is correct for a capacitor?

answer .... **[1]**

3 A type of sub-atomic particle at rest in a laboratory has a known half-life of 10 μs.
A beam of these particles moves through the laboratory at a speed of $2.8 \times 10^8\,\mathrm{m\,s^{-1}}$.
Calculate the half-life of these particles in the beam as measured by observers in the laboratory.

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

half-life = ... μs **[2]**

4 Radioactive decay can be modelled with this equation.

$$\frac{dN}{dt} = -\lambda N$$

(a) Here are some possible definitions of the decay constant λ.
Put a tick (✓) in the box next to the correct definition.

probability of decay of any atom in a sample	☐
probability of decay of a nucleus per unit time	☐
number of nuclei which decay in a sample per unit time	☐
reciprocal of time taken for half the atoms in a sample to decay	☐

[1]

(b) The equation can be used to estimate the half-life $T_{1/2}$ of a radioisotope from its decay constant λ by recasting it as

$$\Delta N = -\lambda N \Delta t$$

where ΔN is the change in the number of undecayed nuclei in the time interval Δt.

A student considers a sample of 100 nuclei of a radioisotope whose decay constant is $2.1 \times 10^{-2}\,s^{-1}$ and uses $\Delta N = -\lambda N \Delta t$ to estimate the value of N at $t = 30\,s$.

Complete the table.

t / s	N	ΔN
0	100	–21
10		
20		
30	49	

[2]

(c) The table suggests that $T_{1/2}$ is slightly less than 30 s. The correct value for $T_{1/2}$ is actually 33 s.
State how the calculation could be altered to give an answer closer to the correct one.

[1]

5 A student uses the apparatus of Fig. 5.1 to launch a brick down an inclined plane covered in sandpaper.

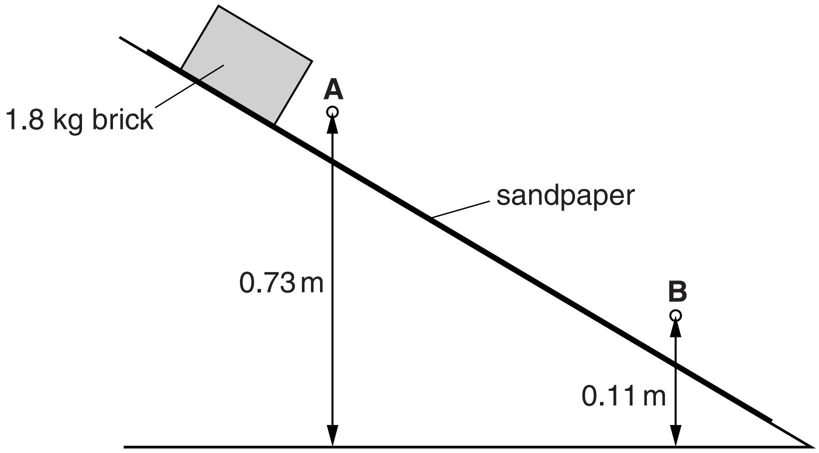


Fig. 5.1

The brick of mass 1.8 kg passes a sensor at **A** with a speed of 0.52 $m\,s^{-1}$ and passes a sensor at **B** with a speed of 2.9 $m\,s^{-1}$.

(a) Show that the change in kinetic energy of the brick between the two sensors at **A** and **B** is about +7 J.

[1]

(b) By calculating the change of gravitational potential energy of the brick, calculate the work done by the sandpaper on the brick as it moves between the sensors at **A** and **B**.

$g = 9.8\,N\,kg^{-1}$

work done = ... J **[2]**

6 Fig. 6.1 shows two rocks in space approaching each other.

Fig. 6.1

One approaches from the left with a mass of 1.2×10^3 kg and velocity of $+2.3\,\mathrm{m\,s^{-1}}$. The other approaches from the right with a mass of 8.3×10^2 kg and a velocity of $-3.7\,\mathrm{m\,s^{-1}}$.
They crash and stick together.
Calculate the velocity of the joined rocks after the collision.

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

7 The Boltzmann factor *f* is given by the expression:

$$f = e^{-\frac{\varepsilon}{kT}}$$

Draw straight lines to link each **term** in the expression with its correct **meaning**.

term	**meaning**
f	extra energy of particles
	average total energy of particles
ε	average thermal energy of particles
	fraction of particles with extra energy
kT	number of particles with extra energy

[1]

8 Fig. 8.1 shows a large massive star in cross-section.

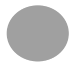


Fig. 8.1

Sketch **three** equipotentials around the star, each separated from the next by the same potential difference. **[1]**

9 Here are some properties of a body which oscillates with undamped simple harmonic motion.

A velocity

B total energy

C acceleration

D kinetic energy

E potential energy

(a) Which property **A** to **E** is constant?

answer .... **[1]**

(b) Which property **A** to **E** is proportional to displacement?

answer .... **[1]**

[Section A Total: 20]

Section B

10 This question is about the Hubble law and the age of the Universe.

(a) The Hubble law can be expressed by the equation

$$v = H_0 r$$

where H_0 is the Hubble constant.

(i) What are the meanings of the terms v and r in the expression for the Hubble law?

[2]

(ii) Show that the unit of the Hubble constant is s^{-1}.

[1]

(b) The graph of Fig. 10.1 gives some data for v and r.

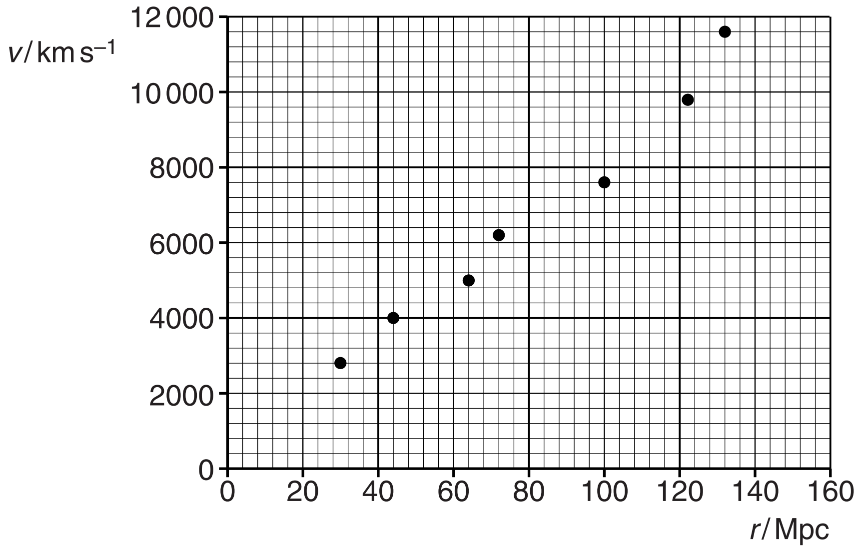


Fig. 10.1

Use the graph to determine a value for the Hubble constant H_0.

1 MPc = 3.1×10^{22} m

H_0 = ... s^{-1} **[4]**

(c) **(i)** Explain how the Hubble law $v = H_0 r$ supports the idea that the Universe started with a Big Bang.

[2]

(ii) If the value of v for a particular galaxy has remained constant, explain why the value of $\frac{1}{H_0}$ gives an estimate of the age of the Universe.

[1]

(iii) Recent data from the Hubble telescope allows the value of H_0 to be determined as $2.40 \times 10^{-18}\,s^{-1}$. Use this value of H_0 to estimate the age of the Universe in years.

1 yr = 3.2×10^{7} s

age = ... yr **[1]**

[Total: 11]

11 This question is about the use of domestic freezers.

(a) A freezer has an interior volume of $0.23\,m^3$.
When the door is opened, air at room temperature, $15\,°C$, and atmospheric pressure, $1.0 \times 10^5\,Pa$, fills the inside of the freezer.

(i) Show that the freezer holds about 6×10^{24} air particles.

$k = 1.4 \times 10^{-23}\,J\,K^{-1}$

[2]

(ii) When the door is shut the air is cooled to $-20\,°C$.
Estimate the total energy removed from the air particles to make this happen.

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

(b) The pressure of the air inside the freezer drops as it cools to $-20\,°C$.

(i) Explain why the pressure drops in terms of the behaviour of the particles.

Your answer should clearly link the change in pressure to the behaviour of the particles.

[3]

(ii) Calculate the final pressure inside the freezer assuming that it is sealed when the door is shut.

pressure = ... Pa **[2]**

(c) The spoiling of food can be modelled as a change in its molecular structure which requires an activation energy ε. This means that the length of time τ that food can be safely stored at absolute temperature T is given approximately by the relationship

$$\tau = C\mathrm{e}^{+\frac{\varepsilon}{kT}}$$

where C is a constant.

If food which spoils after 2 days at 15 °C can be made to last for 500 days in a freezer at –20 °C, do a calculation to estimate a value for ε.

$k = 1.4 \times 10^{-23}\,\mathrm{J\,K^{-1}}$

ε = ... J **[3]**

[Total: 12]

12 Many bicycles incorporate a spring on the front fork to improve the ride over rough ground.

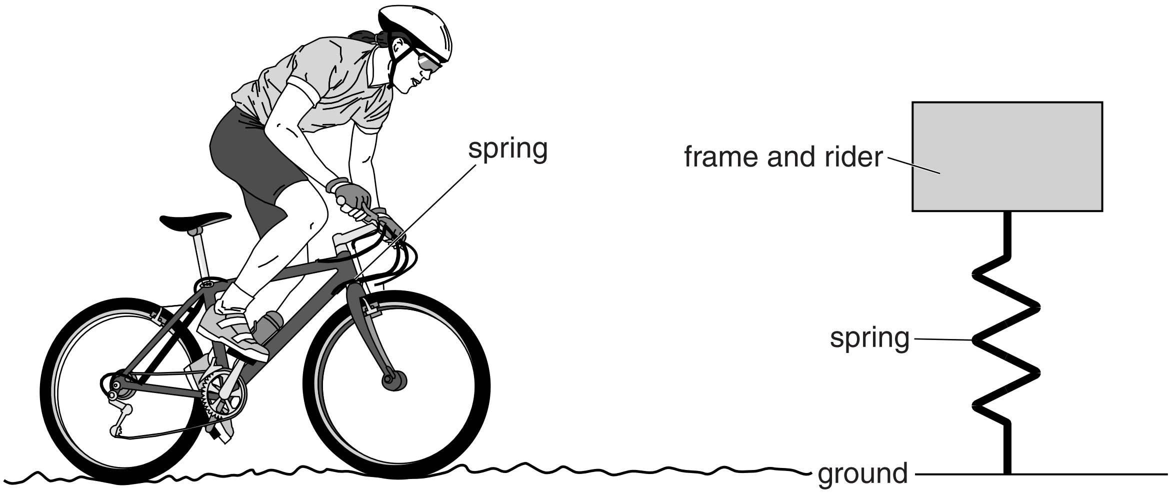


Fig. 12.1

When the bicycle goes over a bump the rider and frame supported by the spring oscillate vertically. For these oscillations, the frame and rider can be modelled as a mass m supported by a spring of force constant k, as shown in Fig. 12.1.

(a) The spring compresses by 1.3×10^{-2} m when the rider mounts the bicycle, increasing the force on the spring by 3.6×10^{2} N.
Show that the force constant of the spring is about 3×10^{4} N m^{-1}.

[1]

(b) Calculate the frequency of free oscillations of the mass supported on the spring.

$m = 62$ kg

frequency = ... Hz **[2]**

(c) Explain why the spring on the bicycle will need to be damped if it is to be safely ridden across bumpy ground.

Your answer should use technical terms correctly.

[3]

(d) The graph of Fig. 12.2 shows the variation of displacement with time for the mass when the bicycle is ridden along a bumpy road.

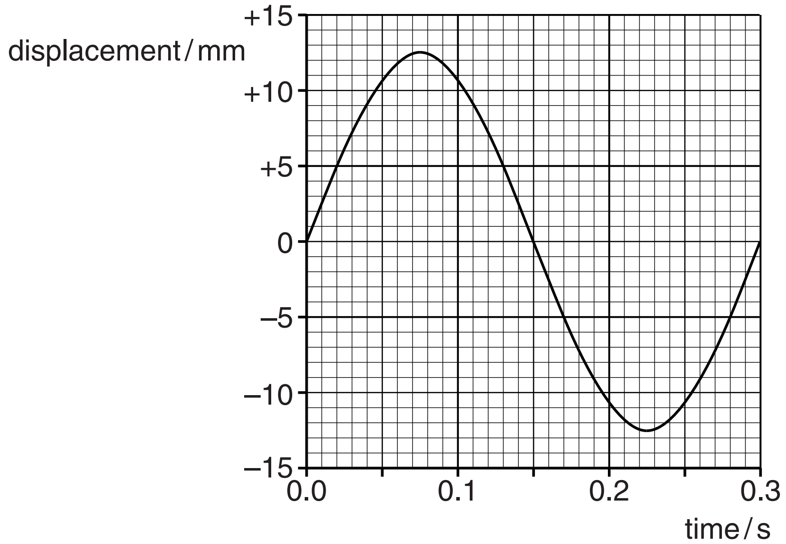


Fig. 12.2

Draw a graph on Fig. 12.3 to show the variation of kinetic energy for the same time period.

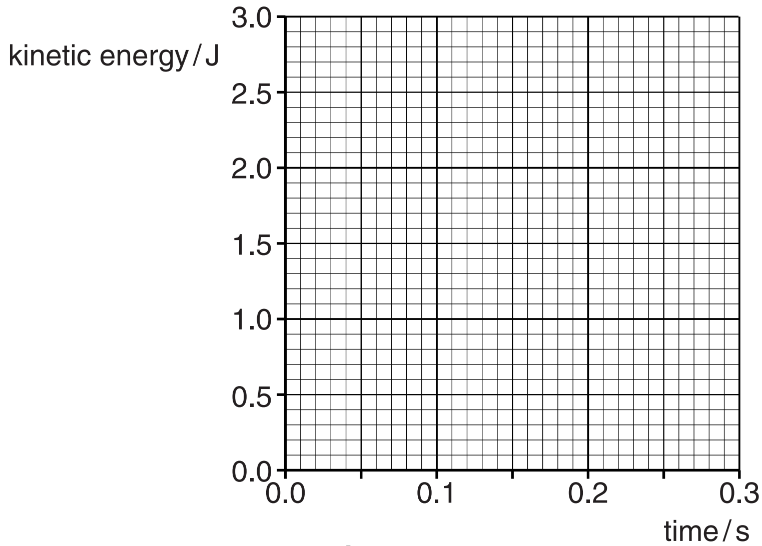


Fig. 12.3

[2]

[Total: 8]

13 This question is about the satellites in low altitude orbit around the Earth which provide the satellite telephone service.

(a) Each satellite follows a circular orbit centred on the Earth. By equating the centripetal force on a satellite of mass *m* to the gravitational force from the Earth of mass *M*, show that the speed of the satellite *v* when the orbit radius is *r* is given by

$$v^2 = \frac{GM}{r}.$$

[2]

(b) Show that the **total** energy $E = E_{kinetic} + E_{gravitational}$ of the satellite is given by

$$E = -\frac{GMm}{2r}.$$

[2]

(c) On the axes of Fig. 13.1, sketch a graph to show how *E* depends on *r* for a satellite in orbit, when *r* is greater than *R*, the radius of the Earth. **[1]**

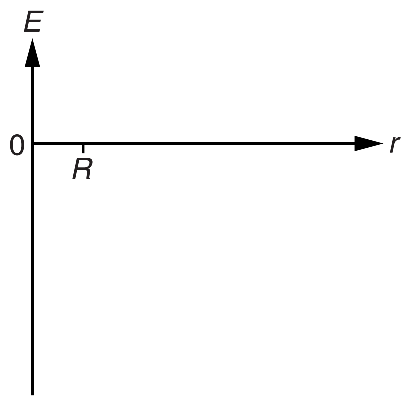
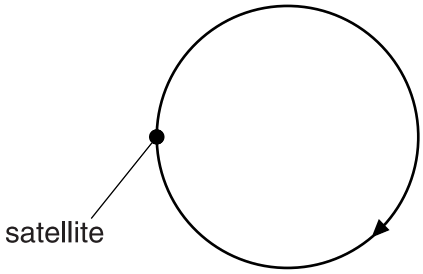


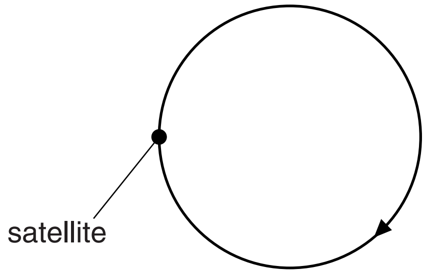
Fig. 13.1

(d) At the end of its lifetime, a rocket engine on the satellite ignites to slow it down and drop it to a lower orbit. Figs. 13.2 and 13.3 show the satellite in its orbit. The arrows show the direction of the satellite's orbit just before the engine ignites.



draw the direction of the force

Fig. 13.2



draw the direction of the gas

Fig. 13.3

(i) Draw an arrow on Fig. 13.2 to show the direction of the force on the spacecraft from the rocket engine when it ignites. **[1]**

(ii) Draw an arrow on Fig. 13.3 to show the direction of the gas from the rocket engine when it ignites. **[1]**

(iii) Calculate the work done by the rocket engines to reduce the orbit radius from 7.2×10^6 m to 6.5×10^6 m.

$G = 6.7 \times 10^{-11}\ \text{N m}^2\,\text{kg}^{-2}$
$M = 6.0 \times 10^{24}$ kg
$m = 6.9 \times 10^2$ kg

work done = ... J **[2]**

[Total: 9]

[Section B Total: 40]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE