OXFORD CAMBRIDGE AND RSA EXAMINATIONS

**Advanced GCE**

# PHYSICS B (ADVANCING PHYSICS) 2863/01

Rise and Fall of the Clockwork Universe

Thursday **20 JANUARY 2005** Morning 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator
Ruler

| Candidate Name | Centre Number | Candidate Number |
|---|---|---|
| | | |

**TIME** 1 hour 15 minutes

## INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.

## INFORMATION FOR CANDIDATES

- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The number of marks is given in brackets [ ] at the end of each question or part question.
- There are four marks for the quality of written communication in 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.

| FOR EXAMINER'S USE | | |
|---|---|---|
| **Section** | **Max.** | **Mark** |
| **A** | **20** | |
| **B** | **50** | |
| **TOTAL** | **70** | |

**This question paper consists of 14 printed pages and 2 blank pages.**

SP (NF/AR) S69337/5

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Answer **all** the questions.

## Section A

**1** Fig. 1.1 shows a force-extension graph for an elastic spring.

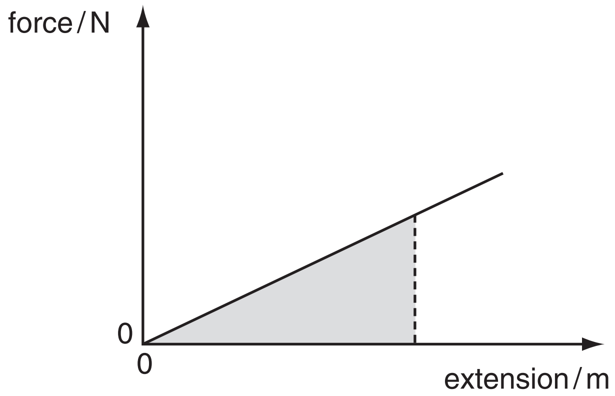


**Fig. 1.1**

State what is represented by

**(a)** the gradient of the line

[1]

**(b)** the shaded area.

[1]

**2** It is observed that the pressure of a gas increases with rise in temperature when the volume is constant.

Choose which of the three statements below **best** explains this observation.

**A** The particles collide with each other more frequently and at a greater speed.

**B** The particles collide with the walls of the container more frequently and at greater speed.

**C** The particles collide with each other randomly with a greater spread of energies.

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

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**3** Some television sets use heated metal filaments to produce electrons which are fired at the screen. The temperature of the filament is about 1200 K.

**(a)** Show that the average energy of a particle at 1200 K is about $2 \times 10^{-20}$ J.
$k = 1.4 \times 10^{-23}\ \mathrm{J\,K^{-1}}$

[1]

It requires an energy $E$ of $9 \times 10^{-20}$ J to remove an electron from a particular filament.

**(b)** Calculate the ratio $\dfrac{E}{\text{average energy of a particle at 1200 K}}$.

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

**(c)** Calculate the Boltzmann factor $f$ for this process.

Boltzmann factor $f$ = ................................. [2]

**4** A bicycle tyre contains a volume of $8.0 \times 10^{-4}\ \mathrm{m^3}$ of gas. The pressure of the gas in the tyre is $4.5 \times 10^5$ Pa. The gas is at a temperature of 293 K.

Assume ideal gas behaviour throughout this question.

**(a)** Show that the tyre contains about 0.15 mol of gas.
$R = 8.31\ \mathrm{J\,mol^{-1}\,K^{-1}}$

[2]

**(b)** At the end of a race, the pressure of the gas in the tyre has risen to $4.6 \times 10^5$ Pa.

Estimate the temperature of the gas in the tyre at the end of the race.

temperature = ............................. K [2]



**[Turn over**

**5** Fig. 5.1 shows the path of a comet travelling **clockwise** around the Sun.

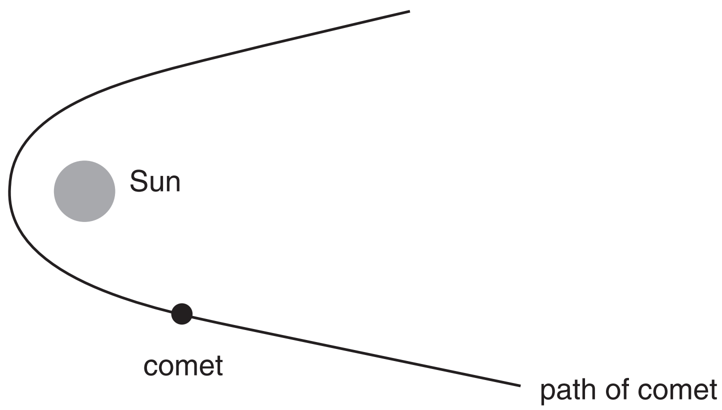


**Fig. 5.1**

**(a)** Draw an arrow on the diagram to show the direction of the velocity of the comet. Label this *V*.

**(b)** Draw an arrow on the diagram to show the direction of the force acting on the comet. Label this *F*.

[2]

**6** Fresh garden peas can be tested for damage by observing how they bounce off a hard surface.

**(a)** An undamaged pea of mass $m$ hits the surface with vertical velocity $v$ and bounces off with equal and opposite velocity.
Explain why the magnitude of momentum change for this pea is $2\,mv$.

[1]

**(b)** When an undamaged pea bounces off the surface, it experiences a change of momentum of $0.0051\,\text{kg m s}^{-1}$.

Show that the rebound velocity of this pea is about $5\,\text{m s}^{-1}$.

mass of pea = $5.0 \times 10^{-4}$ kg.

[1]

(c) Fig. 6.1 shows how the force acting on a damaged pea and on an undamaged pea varies with time during the bounce.

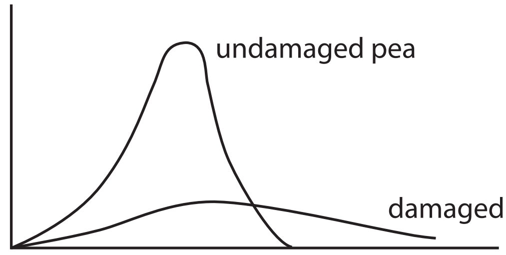


Fig. 6.1

State the feature of the graph in Fig. 6.1 which shows that the change in momentum of the damaged pea is less than that of the undamaged pea.

[1]

7 The image in Fig. 7.1 comes from the COBE satellite. It shows the differences in the mean wavelength of microwave background radiation in different parts of the sky. The differences are very small.

**An image has been removed due to third party copyright restrictions**

Details: An image showing the differences in the mean wavelength of microwave background radiation in different parts of the sky

Fig. 7.1

(a) When the radiation was first emitted 300 000 years after the Big Bang during the so-called era of recombination , it was in the visible region of the spectrum. Explain why the visible radiation emitted during the era of recombination is now observed in the microwave region.

[2]

(b) State and explain what the COBE data tell scientists about the temperature variation of the early Universe.

[2]

[Section A Total: 20]

[Turn over

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## Section B

In this section, four marks are available for the quality of written communication.

8 This question is about keeping the water in an outdoor swimming pool at constant temperature.

A holiday park has an open-air swimming pool of the circular design shown in Fig. 8.1.

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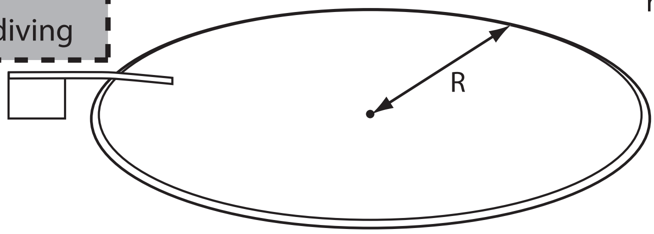
Details: An image of a person diving

radius R = 13 m




not to scale

Fig. 8.1

(a) Show that the mass of water in the pool is about $8.5 \times 10^5$ kg.

average depth of water = 1.6 m

density of water = 1000 kg m$^{-3}$

[2]

(b) The water in the pool is heated to 30 °C. In February, the temperature of the water taken from the supply is 9 °C.

Calculate the energy needed to raise the temperature of all the water in the pool from 9 °C to 30 °C assuming there are no energy losses.

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

energy required = .......................... J [2]

(c) On a particular day in February, a heater running at 90 kW is needed to keep the water temperature constant at 30 °C. The heater is turned off for safety checks.

Show that the initial rate of fall of temperature of the water in the pool is about 0.1 °C per hour when the heater is turned off.

[2]

**(d)** The rate of fall of temperature, $\Delta\theta/\Delta t$, of the water in the pool can be described using the following equation

$$\frac{\Delta\theta}{\Delta t} = -k(\theta_w - \theta_s)$$

where $\theta_w$ is the temperature of the water and $\theta_s$ is the temperature of the surroundings. Different pools will have different values of the constant $k$.

Use your answer to **(c)** to calculate the value of $k$ in this case.

Assume $\theta_w = 30\,°C$ and $\theta_s = 11\,°C$ when the heater was turned off.

value of $k$ = ............................ hour$^{-1}$ [2]

**(e)** A student makes a simple mathematical model of the situation. The model is represented in the flow diagram in Fig. 8.2.

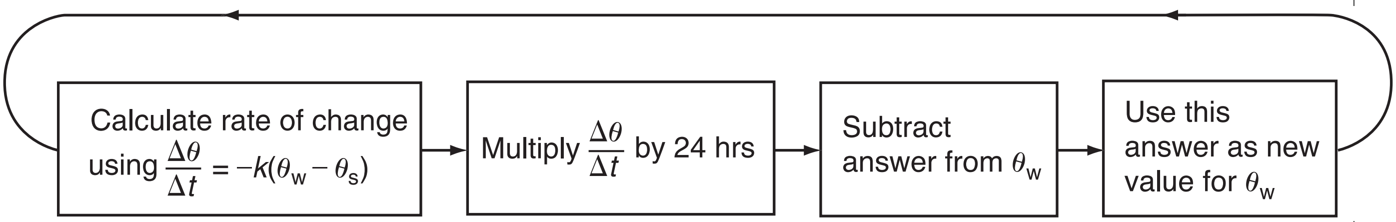



**Fig. 8.2**

The model assumes that the rate of cooling is constant for each 24 hour period.

Explain why this model will **overestimate** the rate of cooling of the pool even if the surroundings remain at a constant temperature of 11 °C.

[1]

**(f)** Suggest **two** changes in the conditions of the surroundings that would increase the cooling rate of the water in the pool.

[2]

[Total: 11]

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**9** This question is about capacitor discharge.

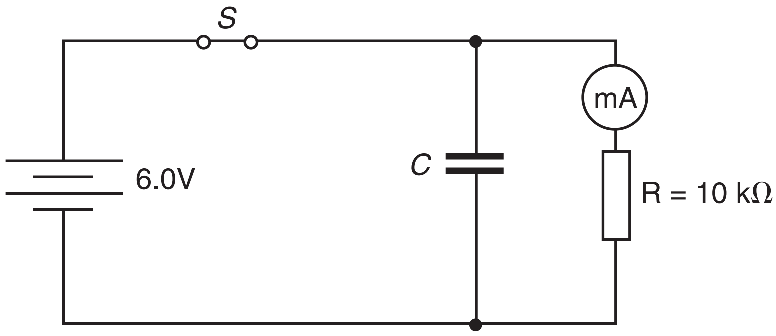



**Fig. 9.1**

The circuit is set up as shown in Fig. 9.1. Switch *S* is then opened and the capacitor discharges through the resistor. The variation of discharge current $I$ with time $t$ is shown in Fig. 9.2.

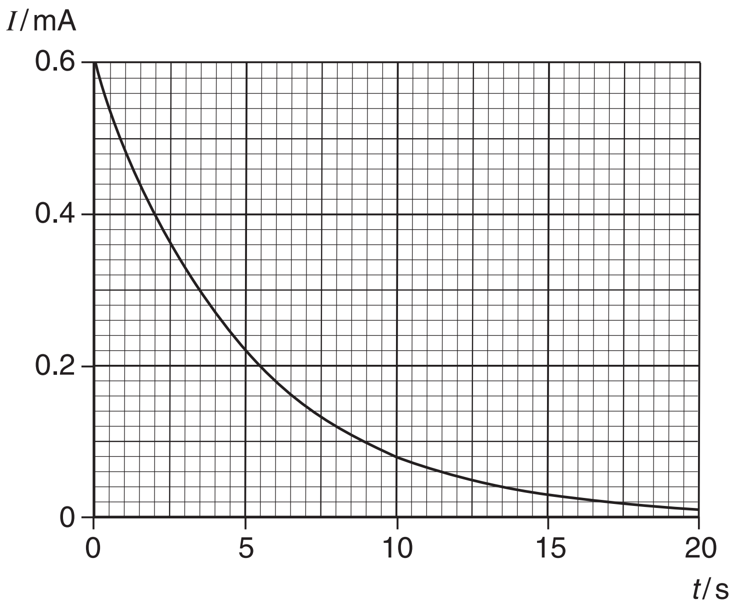



**Fig. 9.2**

**(a)** **(i)** Explain why the area under the curve represents the initial charge on the capacitor.

[1]

**(ii)** Show that the initial charge on the capacitor is about 3 mC.

[2]

**(iii)** Calculate the value of the capacitance used in the experiment.

value of capacitance = .......................... unit ...................... [3]

**(b)** Calculate the energy stored on the capacitor when the switch is closed.

energy stored = ............................J [2]

**(c)** The experiment is repeated. The 10 kΩ resistor is removed and replaced with a 20 kΩ resistor. No other changes are made to the circuit.

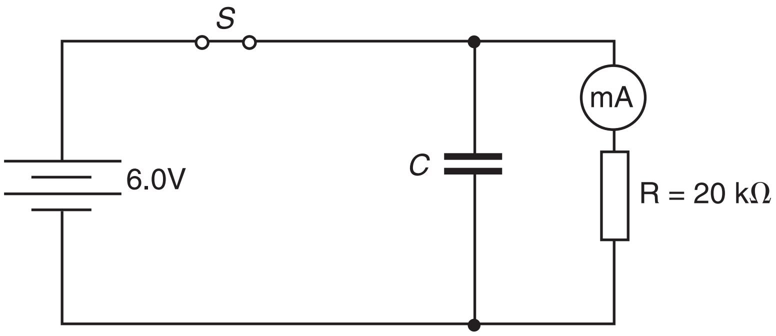
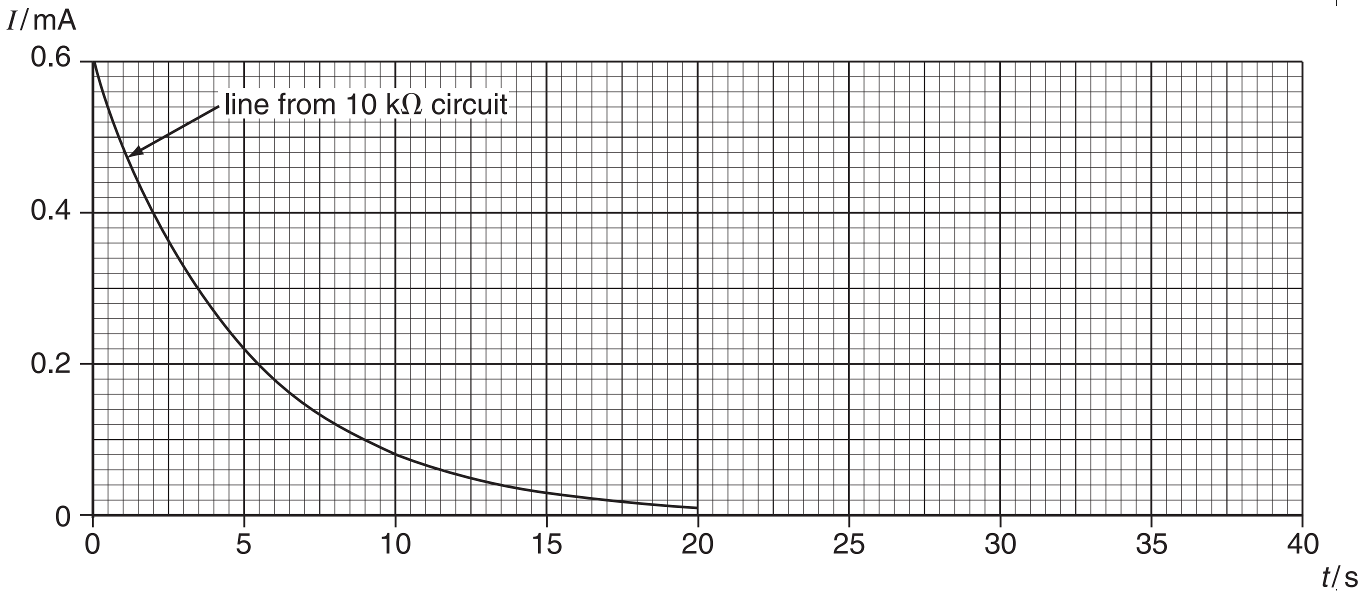



**Fig. 9.3**

Use the axes on Fig. 9.4 to sketch the graph of current against time for the new circuit.




[3]

**Fig. 9.4**

[Total: 11]

**10** This question is about the orbit and return to Earth of a spacecraft such as the space shuttle.

A space shuttle is orbiting at a height of $4.0 \times 10^5$ m above the surface of the Earth.

(**a**) Calculate the radius of the orbit of the space shuttle.

radius of Earth, $R = 6.4 \times 10^6$ m

radius of orbit = ............................m [1]

**(b)** **(i)** Show that the gravitational potential energy of the space shuttle in this orbit is about $-6 \times 10^{12}$ J.

mass of space shuttle = $9.5 \times 10^4$ kg
mass of Earth, $M = 6.0 \times 10^{24}$ kg
$G = 6.7 \times 10^{-11}$ N m$^2$ kg$^{-2}$

[2]

**(ii)** Calculate the kinetic energy of the space shuttle in this orbit.

speed of shuttle in orbit = $7.7 \times 10^3$ ms$^{-1}$

kinetic energy = ...................... J [2]

**(iii)** Calculate the **total** energy of the space shuttle in this orbit.

total energy = ........................ J [1]

(c) Explain why the kinetic energy of the space shuttle increases when it drops to a lower height above the Earth's surface.

[2]

(d) When the space shuttle re-enters the atmosphere, the vehicle is angled so that particles of the atmosphere collide with a heat shield on the lower side of the shuttle. See Fig. 10.1.

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Details: An image of a space shuttle

Fig. 10.1

(i) By considering collisions between the molecules of the atmosphere and the heat shield of the shuttle, explain

- how the atmosphere slows the shuttle down

- why the temperature of the heat shield increases.

[3]

(ii) The heat shield at the underside of the space shuttle glows white hot during descent through the atmosphere. This suggests that the photons radiating from the surface of the heat shield have energies of the order of $1 \times 10^{-19}$ J.
Estimate the temperature of the surface of the heat shield during descent.
$k = 1.4 \times 10^{-23}\ \mathrm{J\,K^{-1}}$

temperature = .................................................K [2]

[Total: 13]

11 This question is about some of the physics of the human ear.

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Details: An image of the human ear

Fig. 11.1

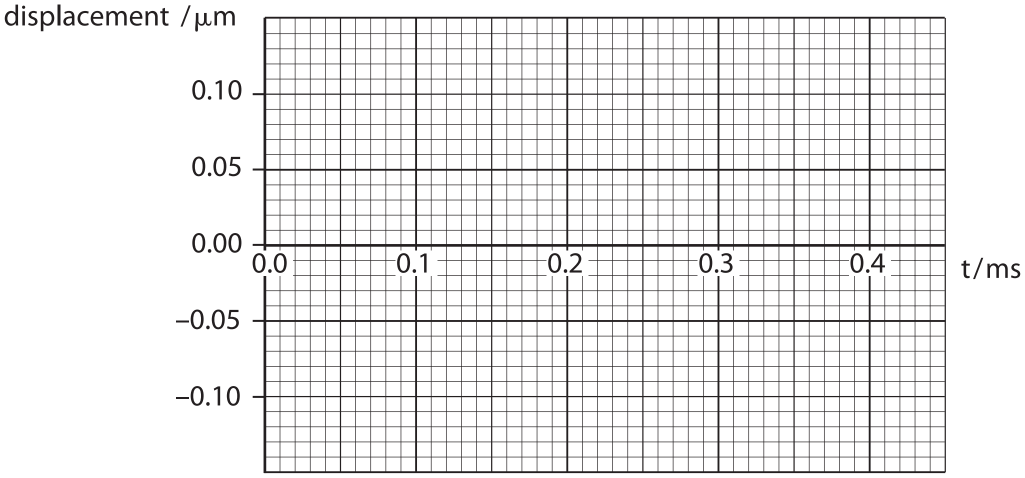
A given sound wave striking the ear drum sets it oscillating in simple harmonic motion.

The ear drum oscillates at a frequency of 2500 Hz with an amplitude of 1.0 $\times 10^{-7}$ m.

(a) (i) Calculate the period of the oscillation.

period = ......................................s [1]

(ii) On the axes of Fig. 11.2, draw a graph to show how the displacement of the eardrum varies with time for one oscillation. Assume that the displacement is zero at t = 0.




[3]

Fig. 11.2

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**(iii)** Calculate the maximum acceleration of the ear drum.

acceleration = ................ $m\,s^{-2}$ [2]

**(b)** At a frequency of 3000 Hz, the ear can detect pressure changes as small as $4.0 \times 10^{-5}\,N\,m^{-2}$.
Calculate the change of force such a pressure change would give on an ear drum of area $20\,mm^2$.

change of force = ............... N [2]

**(c)** The human ear is most sensitive to frequencies around 3000 Hz. This is because air in the auditory canal resonates at this frequency.

**(i)** Explain what is meant by *resonance*.

[1]

**(ii)** Describe how resonance allows the ear to respond to quieter sounds at around 3000 Hz than at other frequencies.

[2]

[Total: 11]

Quality of Written Communication [4]

[Section B Total: 50]

**END OF QUESTION PAPER**

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*Copyright Acknowledgements:*

Fig. 7.1 From http://lambda.gsfc.nasa.gov. We acknowledge the use of the Legacy Archive for Microwave Background Data Analysis (LAMBDA). Support for LAMBDA is provided by the NASA Office of Space Science.