| Centre Number | Candidate Number | Name |
|---|---|---|
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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

**PHYSICS** **9702/06**

Paper 6 Options

October/November 2006

**45 minutes**

Candidates answer on the Question Paper.
No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** of the questions in any **two** options.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| **A** | |
| **F** | |
| **M** | |
| **P** | |
| **T** | |
| **Total** | |

This document consists of **20** printed pages.

**Data**

| | |
|---|---|
| speed of light in free space, | $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$ |
| permeability of free space, | $\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$ |
| permittivity of free space, | $\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ |
| elementary charge, | $e = 1.60 \times 10^{-19}\ \text{C}$ |
| the Planck constant, | $h = 6.63 \times 10^{-34}\ \text{J s}$ |
| unified atomic mass constant, | $u = 1.66 \times 10^{-27}\ \text{kg}$ |
| rest mass of electron, | $m_e = 9.11 \times 10^{-31}\ \text{kg}$ |
| rest mass of proton, | $m_p = 1.67 \times 10^{-27}\ \text{kg}$ |
| molar gas constant, | $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$ |
| the Avogadro constant, | $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$ |
| the Boltzmann constant, | $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$ |
| gravitational constant, | $G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$ |
| acceleration of free fall, | $g = 9.81\ \text{m s}^{-2}$ |

**Formulae**

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

work done on/by a gas, $W = p\Delta V$

gravitational potential, $\phi = -\frac{Gm}{r}$

simple harmonic motion, $a = -\omega^2 x$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$
$v = \pm \omega \sqrt{(x_0^2 - x^2)}$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\epsilon_0 r}$

capacitors in series, $1/C = 1/C_1 + 1/C_2 + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

energy of charged capacitor, $W = \frac{1}{2}QV$

alternating current/voltage, $x = x_0 \sin \omega t$

hydrostatic pressure, $p = \rho g h$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

critical density of matter in the Universe, $\rho_0 = \frac{3H_0^2}{8\pi G}$

equation of continuity, $Av = \text{constant}$

Bernoulli equation (simplified), $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$

Stokes' law, $F = Ar\eta v$

Reynolds' number, $R_e = \frac{\rho v r}{\eta}$

drag force in turbulent flow, $F = Br^2\rho v^2$



[Turn over

Answer **all** of the questions in any **two** of the Options.

Answer the questions in the spaces provided on the Question Paper.

The Options are as follows.

| | | |
|---|---|---|
| Option A | Astrophysics and Cosmology | questions 1, 2, 3 and 4 |
| Option F | The Physics of Fluids | questions 5, 6 and 7 |
| Option M | Medical Physics | questions 8, 9 and 10 |
| Option P | Environmental Physics | questions 11, 12 and 13 |
| Option T | Telecommunications | questions 14, 15 and 16 |

## Option A

## Astrophysics and Cosmology

**1** In June 2004, the planet Venus could be seen crossing the disc of the Sun.

**(a)** State what is meant by a *planet*.

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..... [2]

**(b)** Suggest why this observation leads to the conclusion that Venus was less than 1 AU from Earth.

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.....

..... [2]

**2** **(a)** Describe what is meant by *redshift*.

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.....

..... [3]

**(b)** Suggest why stars must be moving at relatively high speeds before redshift can be observed.

.....

.....

..... [2]

**3** Hubble's law may be written in the form

$$v = H_0 d,$$

where $H_0$ is the Hubble constant.

**(a)** Explain the meanings of the symbols $v$ and $d$.

$v$ .....

.....

$d$ .....

..... [2]

**(b)** One estimate of $H_0$ is $60\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$. Use this value to estimate the age of the Universe.

age = ..... s [3]

**4** The ultimate fate of the Universe depends on the density of matter in the Universe. This matter consists, in part, of dark matter.

**(a)** Suggest two reasons why dark matter is not visible.

1. .....

.....

2. .....

..... [2]

**(b)** Suggest and explain two reasons why, even if dark matter could be observed, it would **not** be possible to obtain a reliable estimate for the mean density of matter in the Universe.

1. .....

.....

.....

2. .....

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..... [4]

## Option F

## The Physics of Fluids

**5** **(a)** On Fig. 5.1, draw lines to illustrate the streamline flow of a fluid round the object. [3]

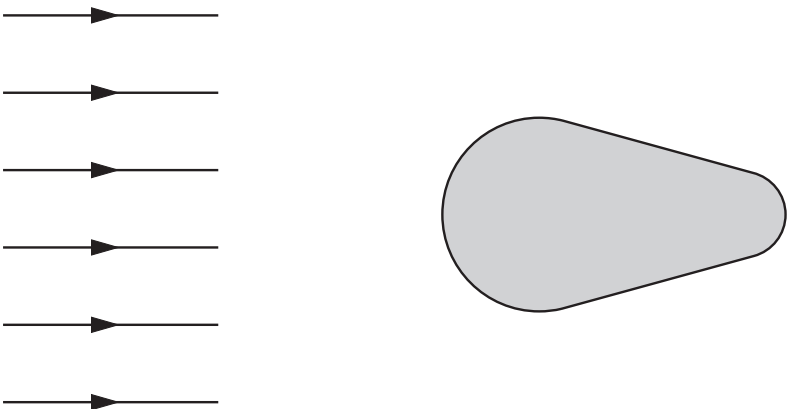

**Fig. 5.1**

**(b)** State what feature on your drawing indicates that the speed of the fluid is **not** constant.

.....

..... [1]

**6** A hollow tube contains some sand. When placed in a liquid, the tube floats upright as illustrated in Fig. 6.1.

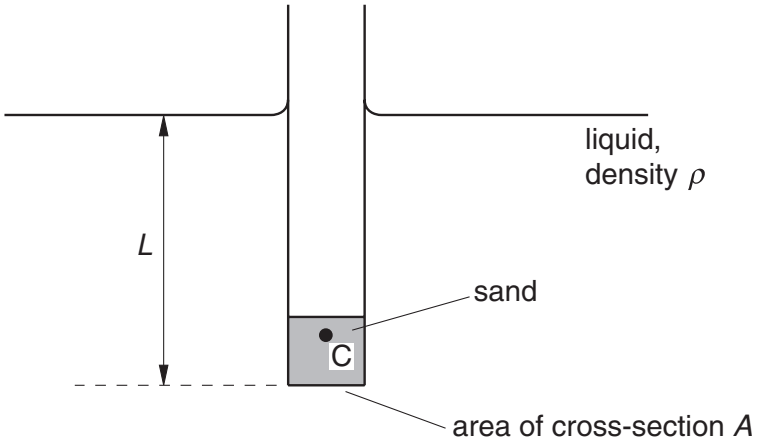


**Fig. 6.1**

The centre of mass of the tube and the sand is at C.

**(a)** Explain why the tube remains upright as it floats in the liquid.

.....

.....

..... [2]

**(b)** The tube and its contents have a total mass $M$. The tube, of uniform cross-section $A$, floats with length $L$ submerged in a liquid of density $\rho$.

Show that the length $L$ is given by the expression

$$L = \frac{M}{A\rho}.$$

[2]

**(c)** When placed in water of density 0.99 g cm$^{-3}$, the length $L$ is 12.1 cm. The tube is then transferred to a liquid of density 1.11 g cm$^{-3}$. Calculate the change in the submerged length.

change in length = ..... cm [3]

**7** A sphere falls from rest in a viscous fluid. The flow of fluid round the sphere remains laminar.

Explain

**(a)** by reference to the forces acting on the sphere, why the sphere reaches a terminal speed,

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.....

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.....

.....

..... [5]

**(b)** why the sphere may **not** fall vertically if it is spinning.

.....

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..... [4]

## Option M

## Medical Physics

**8** **(a)** Outline the use of ultrasound to obtain diagnostic information about internal body structures.

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..... [4]

**(b)** Suggest and explain why, in many medical applications, the ultrasound probe is made up of a number of crystals.

.....

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.....

..... [3]

**9** The eye is capable of adjustment to different environmental conditions.

**(a) (i)** Explain what is meant by *accommodation*.

.....

.....

..... [2]

**(ii)** Describe how accommodation is achieved in the human eye.

.....

.....

..... [2]

**(b)** The eye can adjust to light intensities ranging from bright sunlight to moonlight.

By making reference to the diameter of the pupil of the eye, suggest why the iris cannot be responsible for all of this adjustment.

.....

.....

.....

..... [3]

**10** Fig. 10.1 shows the variation with frequency *f* of the threshold of hearing of a certain person.

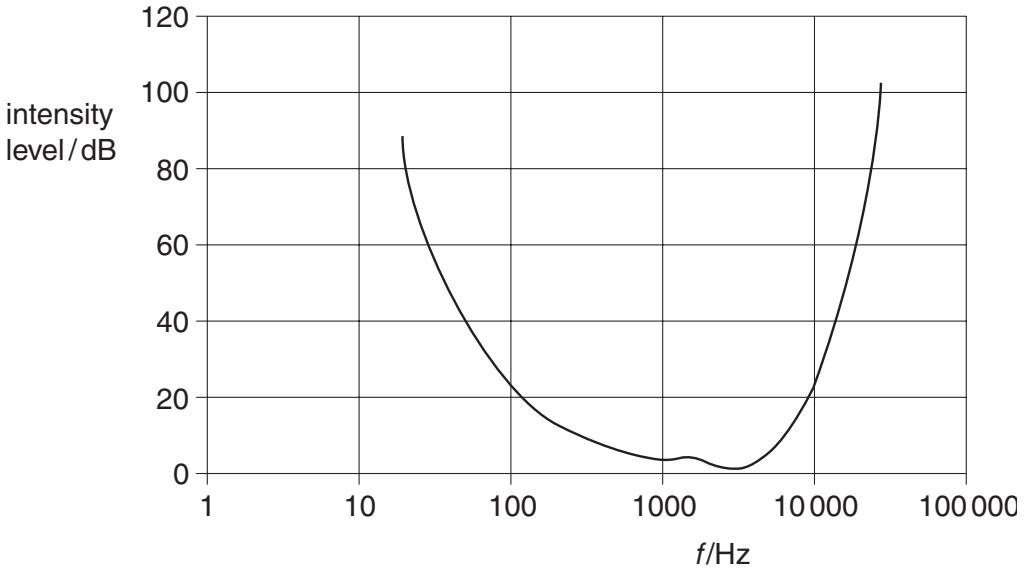


**Fig. 10.1**

**(a)** Use Fig. 10.1 to determine the range of frequencies within which sounds of intensity $1.6 \times 10^{-10}$ W m$^{-2}$ may be heard. The threshold intensity at 3.0 kHz is $1.0 \times 10^{-12}$ W m$^{-2}$.

frequency range from ..... Hz to ..... Hz [4]

**(b)** Fig. 10.1 represents the threshold of hearing for a person with no hearing defect. Suggest two changes to this graph that occur as a result of deafness brought on by old age.

1. .....

.....

2. .....

..... [2]

## Option P

## Environmental Physics

**11** **(a)** Explain the role of the following components in a nuclear reactor.

**(i)** moderator

.....

.....

..... [2]

**(ii)** control rods

.....

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..... [2]

**(iii)** reactor vessel

.....

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..... [2]

**(b)** During the fission of a Uranium-235 nucleus, 198 MeV of energy is released. Outline how some of this energy is converted to thermal energy in the coolant of a nuclear reactor.

.....

.....

.....

..... [3]

**(c)** One disadvantage of the use of nuclear reactors for the generation of electrical energy is the difficulty of storing nuclear waste.

Suggest two advantages of nuclear power when compared to coal-fired or oil-fired power stations.

1. .....

.....

2. .....

..... [2]

**12** A solar cell has a surface area of 2.5 $cm^2$. It produces an e.m.f. of 0.60 V and an output power of 30 mW when sunlight of intensity 960 W $m^{-2}$ is incident normally on its surface.

**(a)** Calculate the efficiency of the solar cell for the conversion of solar power to electrical power.

efficiency = ..... [2]

**(b) (i)** Suggest why a solar cell is **not** used where comparatively large power outputs are required.

.....

..... [1]

**(ii)** Suggest how a number of solar cells may be connected to provide both a large e.m.f. and a large current.

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..... [2]

**13** Fig. 13.1 shows a Sankey diagram for the production of electrical energy and its use by an electric motor.

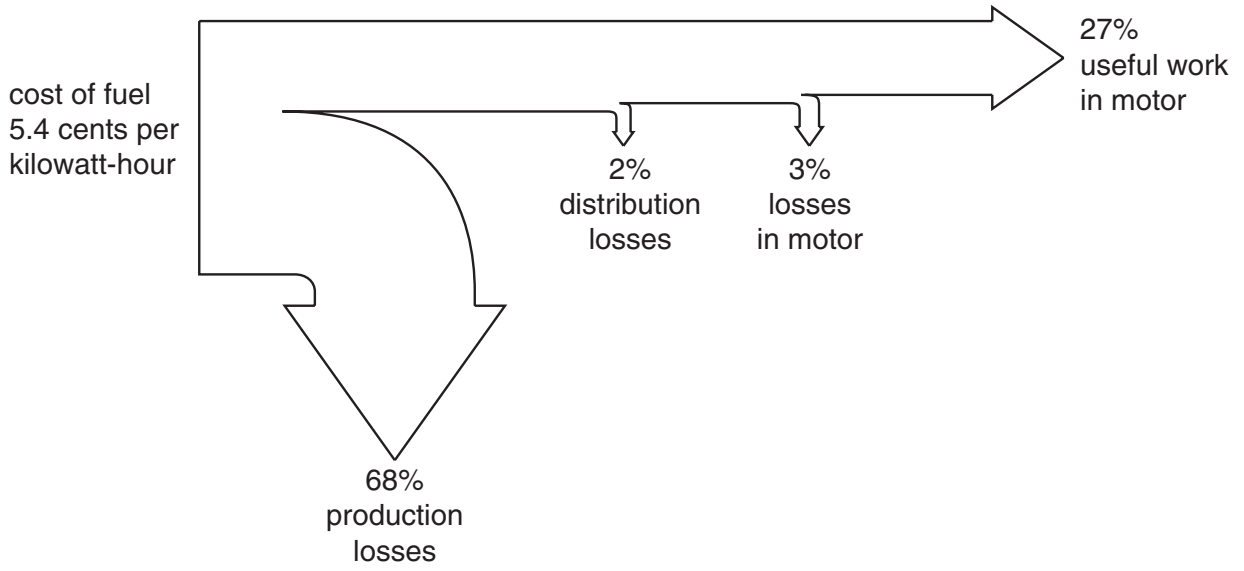


**Fig. 13.1**

**(a)** The cost of the fuel is 5.4 cents per kilowatt-hour of input energy.

Calculate the cost of the fuel in order to supply 5.0 kW h of energy to the motor.

cost = ..... cents [2]

**(b)** With reference to Fig. 13.1, suggest how a desalination plant or a CHP scheme may be developed as an economical proposition.

.....

.....

..... [2]

## Option T

## Telecommunications

**14** A radio station on Earth transmits a signal of power 2.4 kW in the direction of a geostationary satellite.

The power loss between the radio station and the satellite is 170 dB.

**(a)** Explain what is meant by a *geostationary* satellite.

.....

.....

.....

..... [3]

**(b)** Calculate the signal power received by the satellite.

power = ..... W [3]

**(c)** Suggest why the carrier frequency of the signal received by the satellite is changed and the signal is amplified before transmission back to Earth.

.....

.....

.....

..... [2]

**15 (a)** Radio communication may be either frequency modulated or amplitude modulated.

Explain what is meant by *modulation*.

.....

.....

..... [2]

**(b)** An amplitude-modulated radio wave is to be used for the broadcast of music having frequencies between 30 Hz and 4500 Hz. The radio station is broadcasting in the long wave waveband (wavelengths between $1 \times 10^3$ m and $1 \times 10^4$ m).

Determine

**(i)** the bandwidth of the broadcast,

bandwidth = ..... Hz [1]

**(ii)** the maximum number of radio stations that could operate simultaneously in the same area within the long wave waveband.

number = ..... [3]

**(c)** On the axes of Fig. 15.1, sketch a graph of a typical power spectrum for the radio station in **(b)**.

Label the *x*-axis with values of frequency. [3]


**Fig. 15.1**

**16 (a)** Suggest one example of the use, in a communications system, of a wire pair.

.....

..... [1]

**(b)** For many applications, wire pairs have been replaced by co-axial cables or optic fibres.

Suggest two reasons for this change.

1. .....

.....

2. .....

..... [2]