OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A 2825/05

Telecommunications

Thursday **22 JUNE 2006** Afternoon 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 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.

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 90.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first five questions concern Telecommunications. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**16**	
2	**16**	
3	**16**	
4	**13**	
5	**9**	
6	**20**	
TOTAL	**90**	

This question paper consists of 16 printed pages.

Data

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

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2} at^2$
	$v^2 = u^2 + 2as$
refractive index,	$n = \frac{1}{\sin C}$
capacitors in series,	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3} \frac{Nm}{V} <c^2>$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \frac{3H_0^2}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\frac{I}{I_0}\right)$

Answer **all** the questions.

1 In the early telephone system, the voice signal was filtered to limit the audio frequencies transmitted to be in the range 300 Hz to 3.4 kHz. This frequency restriction is still in use today.

(a) Suggest **one** reason why the audio input was and still is restricted to frequencies below 3.4 kHz when most people can hear well above this limit.

....

....

....[1]

(b) In a modern digital telephone system, the analogue voice signal is sampled every 125 μs with each sample being converted into an 8-bit number. The duration of each bit is 2.5 ns.

(i) Calculate the sampling frequency and suggest one reason why this frequency was chosen.

sampling frequency = ... kHz

....

....

....[3]

(ii) Show that the total number of bits produced by a 30-minute phone call is about 1.2×10^8.

[2]

(iii) Calculate the total bit duration resulting from a 30-minute phone call.

total bit duration = ... s [2]

(c) The modern digital telephone system uses time-division multiplexing in order to make the most efficient use of each line of communication.
Explain what is meant by the terms *multiplexing* and *time-division multiplexing*. State **one** reason why time-division multiplexing has become so important to modern communications.

multiplexing

....

....

time-division multiplexing

....

....

....

....

....

why important

....

....[5]

(d) Calculate the theoretical maximum number of callers who could use the same telephone line as the one in **(b)** using the process of time-division multiplexing.

maximum number = ... [2]

(e) Explain why the actual number of callers who could use the same line in practice would be less than your answer to **(d)**.

....

....

....[1]

[Total: 16]

2 Fig. 2.1 shows an experiment set up to determine the total length and type of an optic-fibre cable wound around a large drum. This avoids having to unwind the cable and measure it directly.

A diagram has been removed due to third party copyright restrictions

Details: A diagram of an experiment set up to determine the total length and type of an optic-fibre cable wound around a large drum

Fig. 2.1

The signal generator produces a regular series of 2 µs pulses separated by 38 µs, as shown in Fig. 2.2. These pulses are applied to the transmitting device, TX, which generates light into the optic fibre. At the other end of the fibre, a receiving device, RX, converts the light back to an electrical signal.

(a) State the name of the electronic components used to transmit and detect the light pulses.

(i) in the transmitter ....

(ii) in the receiver ....[2]

(b) The signal from the signal generator is shown in Fig. 2.2.

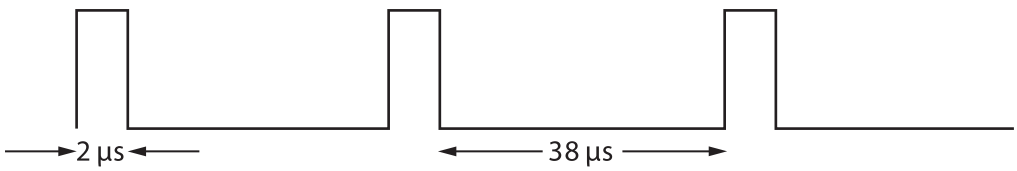

Fig. 2.2

Calculate the frequency of the signal generator output.

frequency = ... Hz [2]

(c) The oscilloscope in Fig. 2.1 is a dual-beam type where the two beams are swept across the screen at exactly the same time. The screen of the oscilloscope is shown in Fig. 2.3.

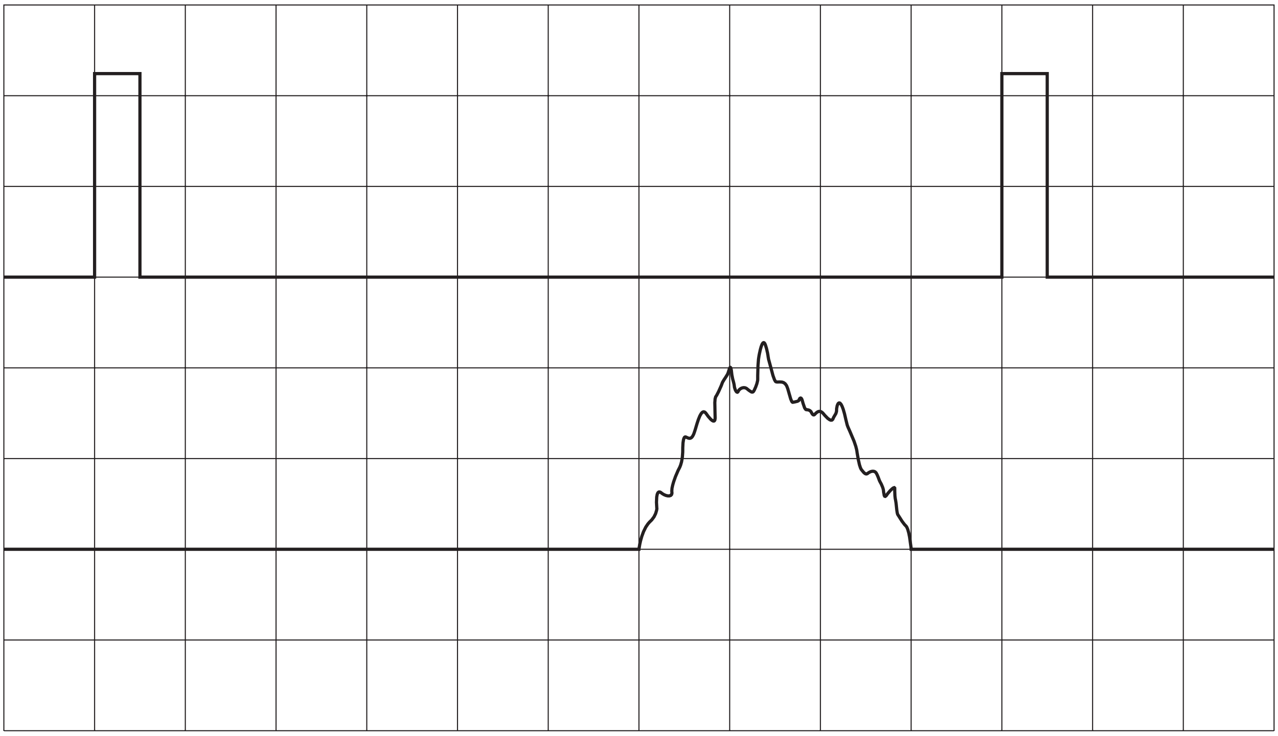

Fig. 2.3

The top trace in Fig. 2.3 shows the signal generator input signal with the Y-input of the oscilloscope set to 5 V div.$^{-1}$
The lower trace shows the signal emerging from the fibre wound around the drum with the Y-input set to 50 mV div.$^{-1}$

The time-base setting for this screen is 4 μs per division.

Calculate

(i) the time delay between the **start** of an input pulse and the **start** of the received pulse

time delay = ... μs [1]

(ii) the speed of light in the fibre if the refractive index of its core is 1.5

speed of light = ... m s^{-1} [2]

(iii) the total length of the optic-fibre.

total length of fibre = ... m [2]

(d) The received pulses in Fig. 2.3 differ from those that were transmitted into the fibre in three respects.

State and explain the **three** differences.
Conclude by suggesting the type of optic-fibre which you think is wound around the drum.

1. ....

....

....

....

2. ....

....

....

....

3. ....

....

....

....

conclusion ....

....[7]

[Total: 16]

3 Fig. 3.1 shows a diagram of the Earth and the path of a geostationary satellite around it.

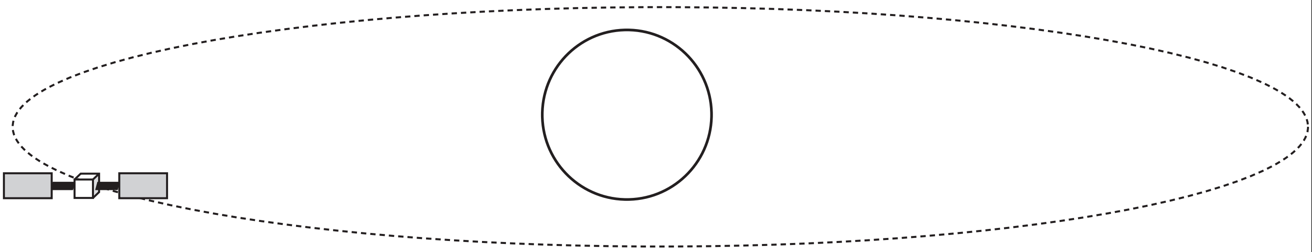

Fig. 3.1

(a) For the satellite to be in a geostationary orbit, **three** conditions must be satisfied regarding the period, the plane of the orbit and the direction of rotation. State and explain why each of these conditions is necessary.

period ....

....

plane ....

....

....

direction ....

....[5]

(b) Geostationary satellites are often used for broadcasting analogue television signals. Explain the advantages of satellite analogue TV over terrestrial analogue TV. Your answer should make reference to carrier frequencies and bandwidth as well as the area and ease of coverage

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....[5]

For Examiner's Use

(c) Fig. 3.2 shows a diagram of the Earth spinning on its axis.

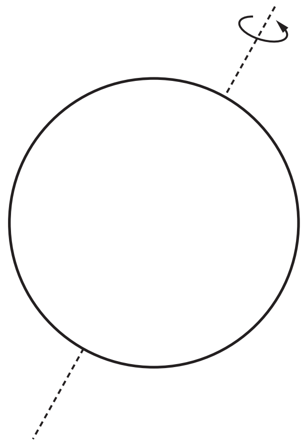

Fig. 3.2

(i) On Fig. 3.2, draw the path of a polar-orbiting satellite. [1]

(ii) State and explain why such satellites are placed in low-earth orbits.

....

....

....

....[3]

(iii) State **two** uses of polar-orbiting satellites

1. ....

....

2. ....

....[2]

[Total: 16]

4 Fig. 4.1 shows a circuit containing an op-amp being operated from a dual ±12 V supply.

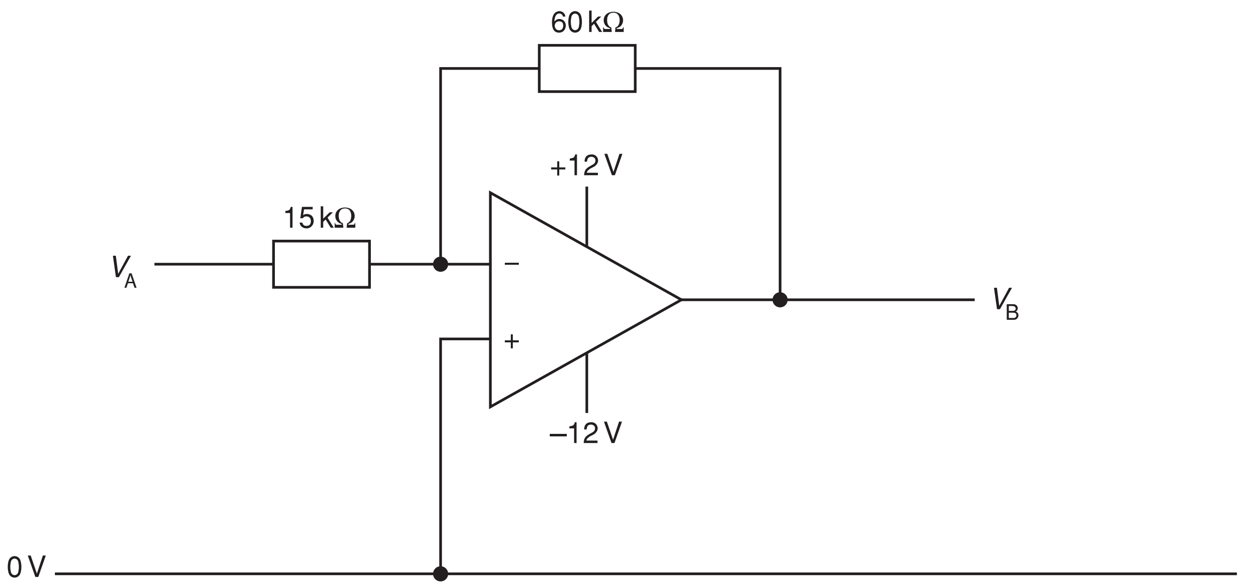

Fig. 4.1

(a) Complete the paragraph below by adding the correct missing words.

The circuit of Fig. 4.1 is known as a .... earth amplifier. This is because .... feedback is used to keep both .... to the op-amp at the same potential. As the .... input is directly connected to zero volts then the .... input must be .... [6]

(b) Define the *voltage gain* of the circuit of Fig. 4.1 in terms of V_A and V_B.

....[1]

(c) Calculate the voltage gain of the circuit of Fig. 4.1.

voltage gain = ... [2]

For Examiner's Use

(d) Fig. 4.2 shows a graph of the input signal V_A to the amplifier of Fig. 4.1.

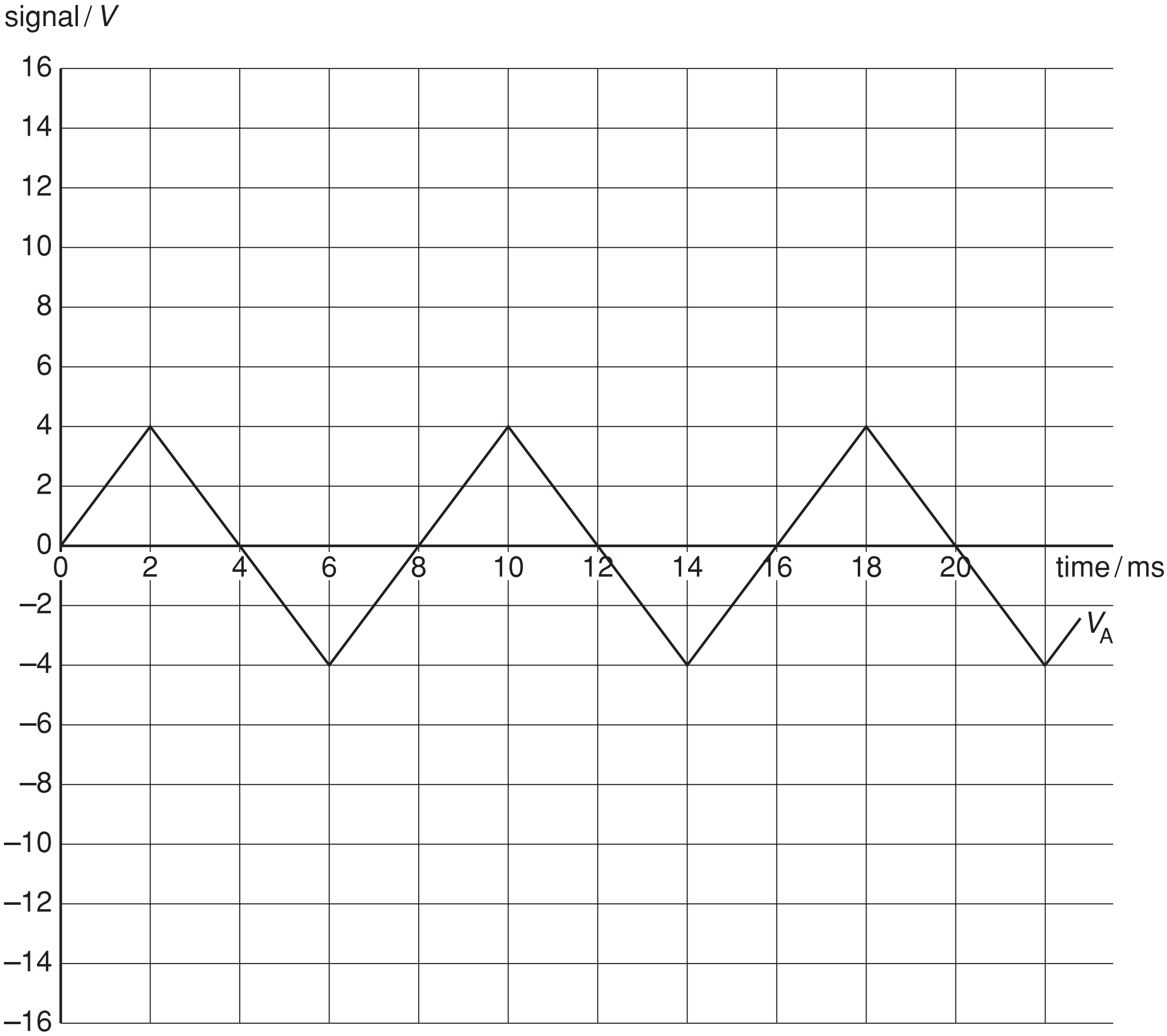

Fig. 4.2

Using the axes of Fig. 4.2, draw the corresponding output voltage V_B. [4]

[Total: 13]

For Examiner's Use

5 The internet has become one of the wonders of the modern world as more and more people learn how to access and use it through their personal computer at home.

(a) Outline how information is transferred using the internet from a home computer in London to a home computer in Paris.

....

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....

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....

....

....[5]

(b) Briefly describe **four** ways in which society has adapted to the availability of the internet.

1. ....

....

2. ....

....

3. ....

....

4. ....

....[4]

[Total: 9]

6 Most man-made objects launched into space are satellites placed in a particular orbit around the Earth to function as TV transmitters, telephone relays or weather stations. Some spacecraft, however, have been launched to travel into much deeper space to explore the outer planets of our solar system. All spacecraft, however, whether satellites or deep space probes, must communicate with Earth by transmitting a radio signal. The circuits producing the signal require battery power and batteries require recharging from an energy source.

Most satellites in orbit around the Earth derive their power from a panel of solar cells which convert sunlight into electrical energy. One such telecommunications satellite transmits a continuous 360 W signal powered from its battery for 24 hours per day. The battery is recharged from a solar panel which has an efficiency of 16% while in direct sunlight of light intensity 1.5 kW m^{-2}.

(a) Suggest what happens to the 84% of light energy which reaches the solar panel but is not converted to electrical energy.

....

....[1]

(b) **(i)** Calculate the minimum surface area of solar panel required to produce the 360 W for the transmitter.

surface area = ... m^2 [2]

(ii) Give **two** reasons why the surface area would have to be much greater than your answer above.

1. ....

....

2. ....

....[2]

For Examiner's Use

For a spacecraft launched into the outer regions of the solar system, it is not practical to have its battery recharged by solar panels. Such spacecraft use a Radioisotope Thermoelectric Generator (RTG). This generator has no moving parts and contains two different metals joined to form a closed electric circuit. When the two junctions between these metals are kept at different temperatures, an electric current is produced. One junction is cooled by space while the other is heated by the decay from a radioactive isotope. RTGs are very reliable sources of power.

Nowadays, RTGs use plutonium-238 which is an alpha emitter with a half-life of 88 years. Each alpha particle is emitted with a kinetic energy of 5.0 MeV.

(c) State **one** reason why solar panels are not practical in deep space.

....

....[1]

(d) Suppose such a spacecraft transmits for 120 minutes each day from a 12 V circuit which draws a current of 5.0 A while transmitting back to Earth. During the rest of the day, the transmitting circuit is shut down. The battery charging, however, carries on continuously.

(i) Show that the energy required per day for transmission is about 0.4 MJ.

[2]

(ii) The overall efficiency in the RTG battery charging system is 25%. Show that the steady power output required from the RTG is about 20 W.

[2]

(iii) Calculate the minimum activity of the source required (i.e. the number of 5 MeV alpha particles emitted per second) to generate this power.

activity = ... Bq [2]

For Examiner's Use

(e) (i) Show that the decay constant λ of Pu-238 is $2.5 \times 10^{-10}\ s^{-1}$.

[2]

(ii) Calculate the number N of nuclei of Pu-238 required to generate the activity calculated in (d)(iii).

N = ... [2]

(iii) Calculate the mass of Pu-238 corresponding to this number of nuclei.

mass = ... kg [2]

(f) Plutonium is one of the most dangerous chemical poisons known, as well as being a radioactive hazard. It has been estimated that 1 kg of this substance, suitably distributed, would be enough to kill everyone on Earth. Comment on the risks involved in using plutonium as a fuel for spacecraft.

....

....

....

....[2]

[Total: 20]

END OF QUESTION PAPER