OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A — 2825/05

Telecommunications

Monday **26 JANUARY 2004** Morning 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.
- 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	15	
2	15	
3	17	
4	14	
5	9	
6	20	
TOTAL	90	

This question paper consists of 16 printed pages.

SP (AT/SLM) S52020/5

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,	$= 10 \lg\left(\frac{I}{I_0}\right)$

For Examiner's Use

Answer **all** the questions.

1 Fig. 1.1 shows a signal transmitted from a radio station. The audio information and the carrier are both sinusoidal.

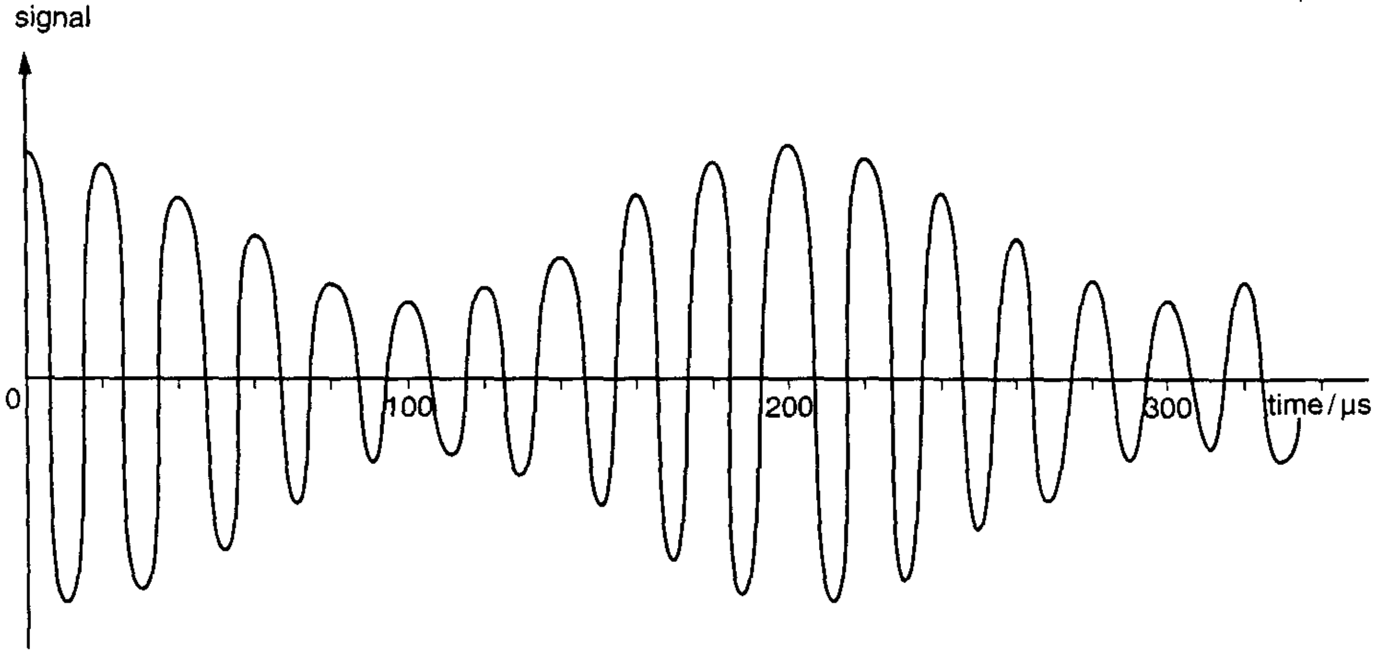


Fig. 1.1

(a) For the signal in Fig. 1.1,

(i) state the form of modulation

....[1]

(ii) calculate the carrier frequency of the radio signal

carrier frequency = ... Hz [2]

(iii) calculate the frequency of the audio signal.

audio frequency = ... Hz [1]

(b) On the axes of Fig. 1.2, draw the frequency spectrum of the signal of Fig. 1.1.

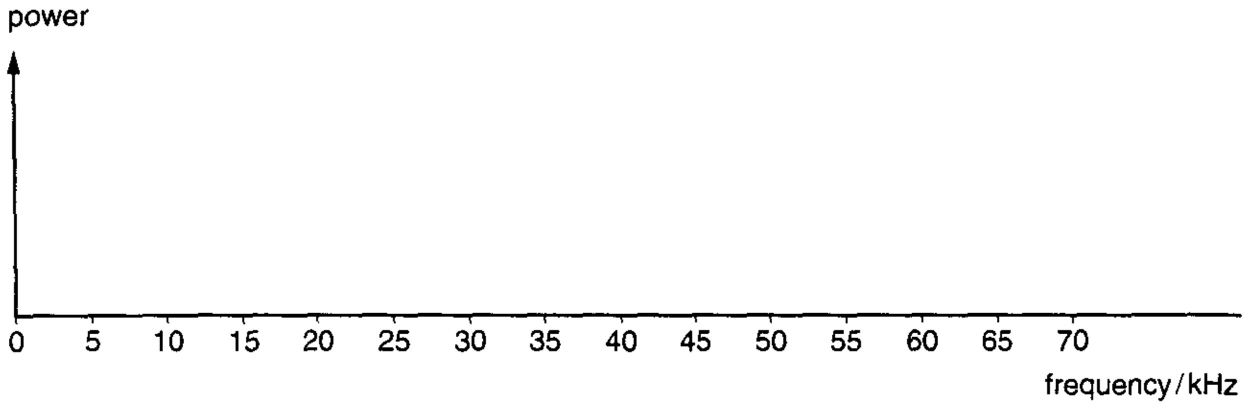


Fig. 1.2 [3]

(c) What is meant by *bandwidth* in telecommunications?

....[1]

(d) Calculate the bandwidth of the radio signal of Fig. 1.1. Explain how you arrived at your answer.

bandwidth = ... kHz

....[2]

(e) State why the bandwidth of radio stations is deliberately restricted. Explain the choice of modulation used on the LF and the VHF wavebands. Refer to typical carrier frequencies and bandwidths in your answer.

....

....

....

....

....

....

....

....

....

....

....[5]

[Total: 15]

[Turn over

For Examiner's Use

2 **(a)** Fig. 2.1 shows a component used in certain types of electronic circuit.

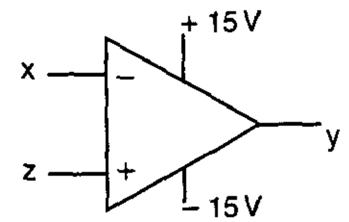


Fig. 2.1

(i) State the name of the component in Fig. 2.1.

....[1]

(ii) Identify the terminals marked x, y and z as one of the following

output = ... non-inverting input = ... inverting input = ... [1]

(iii) By referring to the voltages at the terminals x, y and z, explain how the component of Fig. 2.1 behaves.

....

....[2]

(b) Fig. 2.2 shows a circuit built around the component of Fig. 2.1.

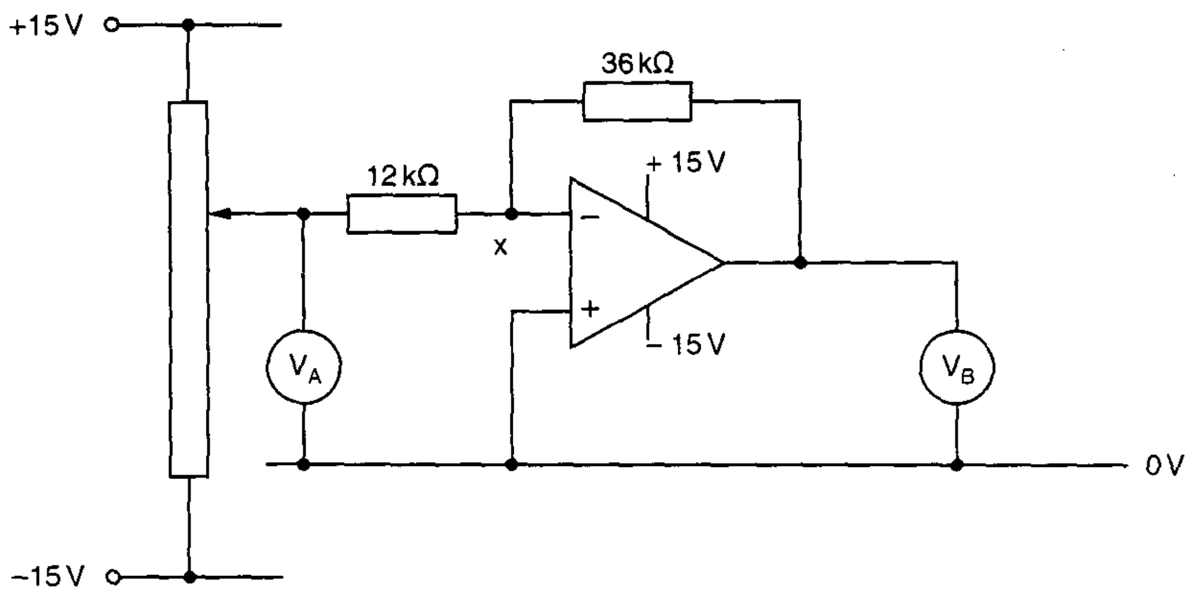


Fig. 2.2

For Examiner's Use

The wiper of the potentiometer is positioned so that the reading on voltmeter V_A is 3.0 V.

(i) Explain why the voltage at x is zero volts.

....

....

....[3]

(ii) Calculate the current in the 12 kΩ resistor. Show your working.

current = ... A [2]

(iii) Calculate the reading on the voltmeter V_B. Show your working.

reading = ... V [2]

(c) On the axes of Fig. 2.3, draw a graph to show how the voltage V_B varies with the voltage V_A as the wiper of the potentiometer in Fig. 2.2 is moved from −15V to +15V.

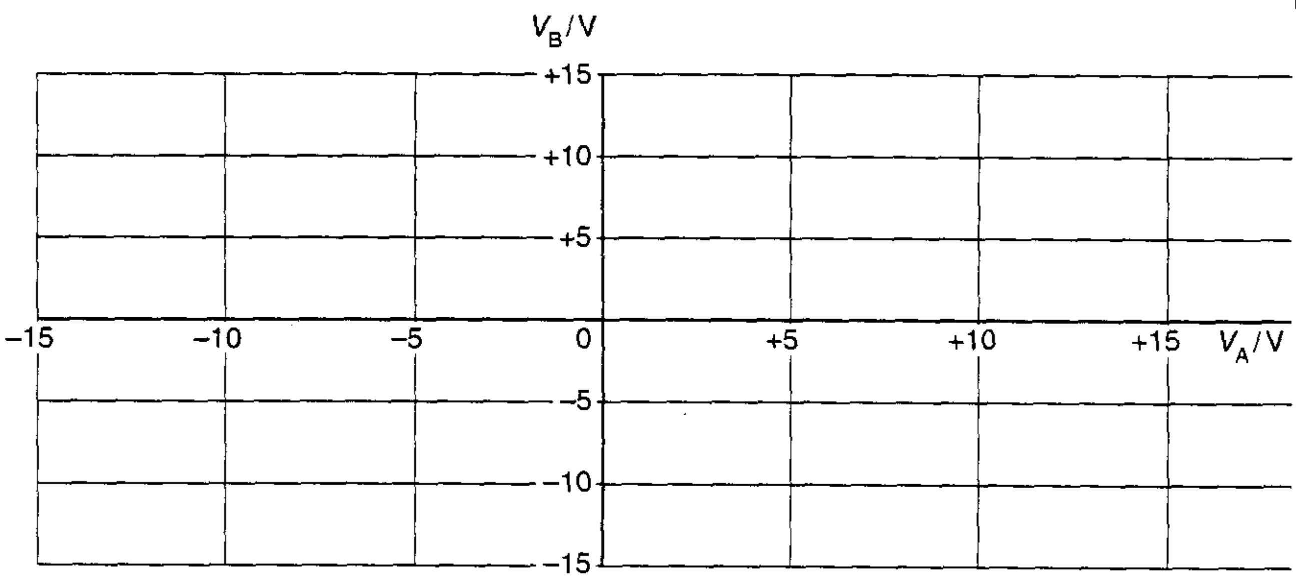


Fig. 2.3

[4]

[Total: 15]

[Turn over

For Examiner's Use

3 Fig. 3.1 shows a system to transmit on/off electrical pulses from a transmitting station TX to a receiving station RX.

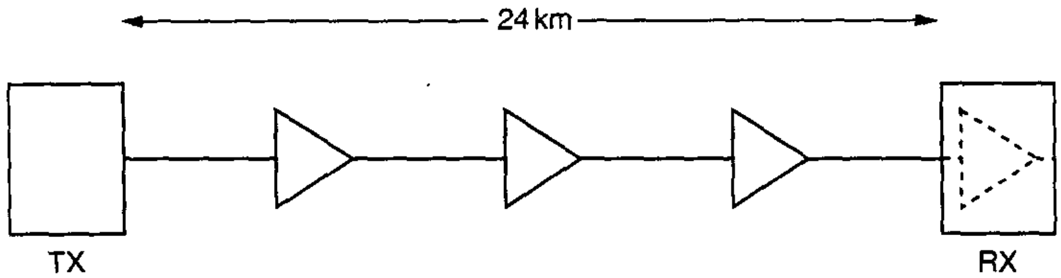


Fig. 3.1

The transmitter and receiver are 24 km apart and the cable is made up of four equal length sections with three identical repeater amplifiers positioned as shown. A similar repeater amplifier is located inside the receiving station. The output power from the receiving station amplifier is equal to the output power at the transmitter.

(a) Explain why the cable must be broken into four sections with four amplifiers rather than simply using a continuous 24 km length and a more powerful amplifier in the receiver.

....

....

....

....

....[3]

(b) Each of the four amplifiers has a power gain of 27 dB. Show that this causes the output power of each amplifier to be approximately 500 times greater than the input power.

[2]

(c) Calculate the attenuation per km of the cable in use.

attenuation = ... dB km^{-1} [2]

(d) Fig. 3.2 shows in more detail how the on / off signal is communicated through a wire-pair from the transmitter to the first amplifier.

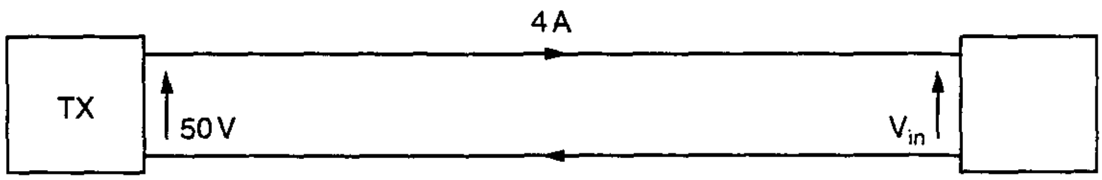


Fig. 3.2

When the transmitter is transmitting the on signal, the output voltage is 50V d.c. at 4.0 A. By the time the signal has reached the first amplifier, the current in the cable is unchanged but the power has fallen by 500 times. Calculate

(i) the power output of the transmitter

power output = ... W [2]

(ii) the voltage at the input to the first amplifier.

voltage input = ... V [2]

(iii) Show that the total resistance of the cable section between the transmitter and the first amplifier is approximately 12 Ω.

[2]

(iv) The conductor in the cable is made of metal of resistivity $1.8 \times 10^{-8}\,\Omega\,\text{m}$. Calculate the cross-sectional area of the conductor.

area = ... m^2 [4]

[Total: 17]

[Turn over

For Examiner's Use

4 Fig. 4.1 shows a diagram of how a long-distance telephone call is made between a caller and a listener.

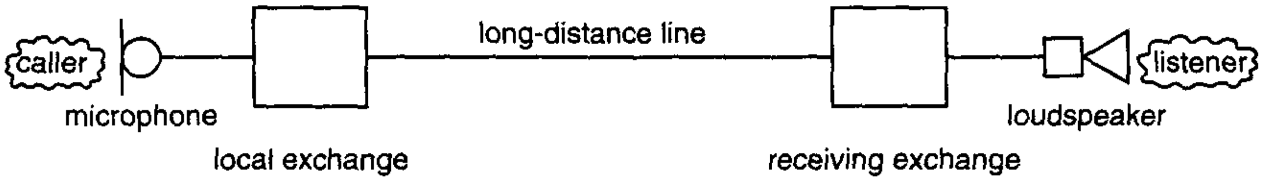


Fig. 4.1

The microphone produces an *analogue* signal which is processed by the local exchange and turned into a *digital* signal. The digital signal is then transmitted along the line to the receiving exchange where it is further processed to reproduce the original analogue signal for the listener.

(a) Explain what is meant by an *analogue* signal.

....

....[2]

(b) Explain what is meant by a *digital* signal.

....

....[1]

(c) State the name of the modulation process involved in the exchanges and long-distance line.

....[1]

(d) Describe how the local exchange processes the analogue signal and the receiving exchange processes the digital signal to allow this system to operate.

....

....

....

....

....

....

....

....

....

....[7]

For Examiner's Use

(e) Discuss the relative advantages and disadvantages of the process you have described in **(d)**.

....

....

....

....

....

....[3]

[Total: 14]

5 Fig . 5.1 illustrates three different ways by which electromagnetic waves may be propagated from a transmitting aerial T to a receiving aerial R at some other place on the Earth.
Complete the table of Fig. 5.1 for the three different modes of propagation of electromagnetic waves.

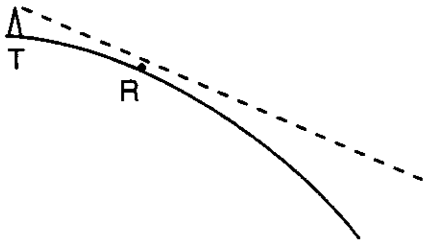
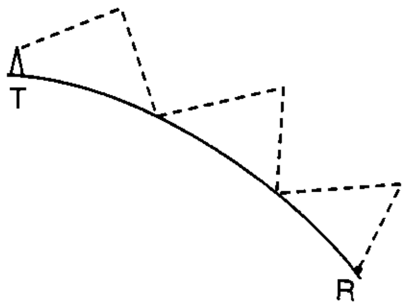
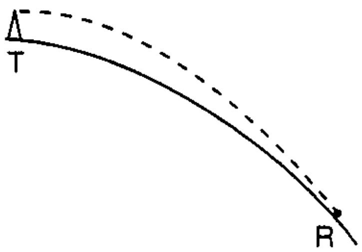
	mode of propagation	typical frequency	typical use
			
			
			

Fig. 5.1

[9]

[Total: 9]

[Turn over

For Examiner's Use

6 Scintillation counters have been widely used to detect particles in high energy physics experiments. A scintillation counter consists of a sheet of plastic scintillator material coupled to a photomultiplier tube, as shown in Fig. 6.1.

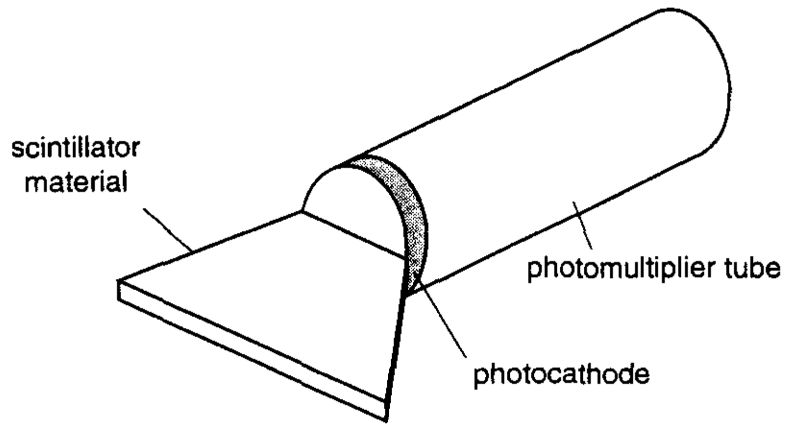


Fig. 6.1

The scintillator material produces a tiny flash of light when struck by a high energy particle. This light undergoes total internal reflection within the scintillator material until it reaches the photocathode of the photomultiplier tube. Fig. 6.2 shows this and also the internal structure of the photomultiplier tube.

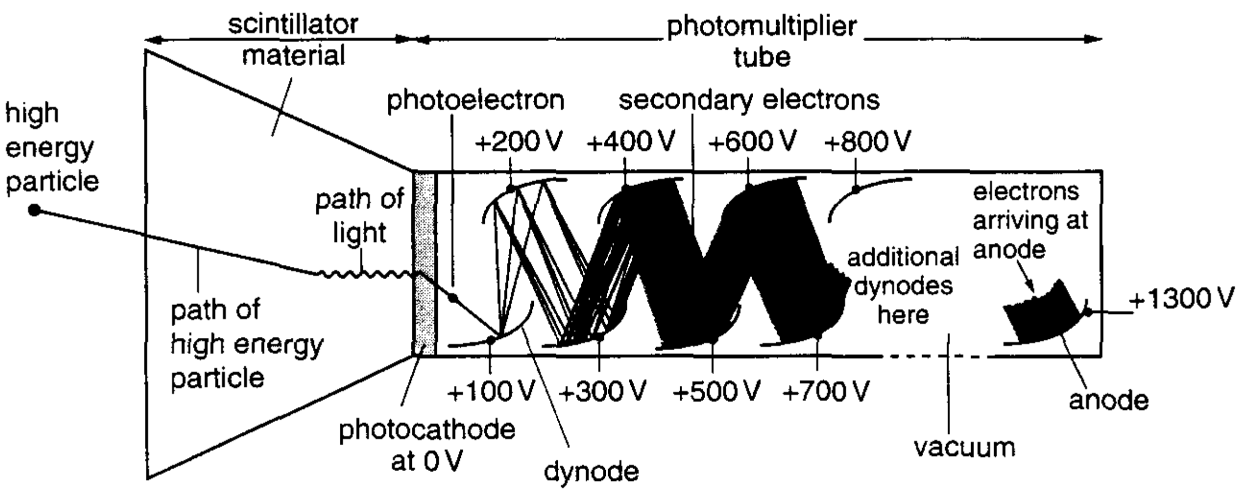
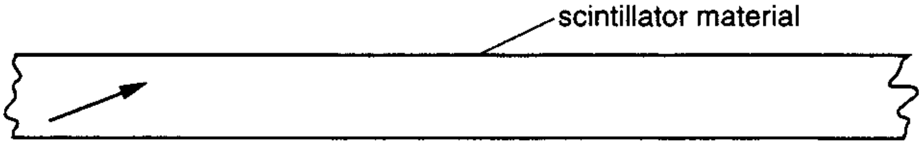


Fig. 6.2

When the flash of light reaches the photocathode, the photoelectric effect causes an electron, called a photoelectron, to be emitted from the photocathode. This electron is attracted by a potential difference between the photocathode and the first curved plate, called a dynode. When the electron hits the first dynode, with 100 eV energy in this case, several *secondary* electrons are emitted. These are accelerated to the next dynode, where the process is repeated. The pulse of charge at the final dynode, called the anode, can be measured by an electronic system.

(a) The diagram below shows a section of the scintillator viewed from the side.

(i) Explain, with the aid of the diagram, how the light may be transmitted along the scintillator by total internal reflection.



....

....

....

....[3]

(ii) The scintillator material has a refractive index of 1.58. Calculate the critical angle C for this material in air.

critical angle = ...° [2]

(b) In a particular experiment, a single high energy particle loses 1.5 MeV of energy in the scintillator material and in losing this energy produces 1.0×10^4 photons of wavelength 413 nm.

(i) Show that the energy of one photon of wavelength 413 nm is about 3.0 eV.

[2]

(ii) What percentage of the particle's energy loss has been converted into light in the scintillator material?

percentage = ...% [2]

For Examiner's Use

(c) The photocathode is coated with potassium which has a work function ϕ of 2.2 eV.

(i) Calculate the threshold wavelength for potassium.

threshold wavelength = ... nm [2]

(ii) Why would zinc, which has a work function of 4.3 eV, be unsuitable for the photocathode coating?

....

....[1]

(iii) Calculate the maximum speed v_{max} of the photoelectrons emitted from the potassium photocathode.

v_{max} = ... $m\,s^{-1}$ [3]

For Examiner's Use

(d) **(i)** In the photomultiplier tube, there are 13 dynodes, including the anode, and 3 secondary electrons are emitted at each dynode per incident electron. Calculate the number of electrons received at the anode for one electron leaving the photocathode.

number = ... [2]

(ii) This pulse of electrons lasts 3.0×10^{-9} s. Calculate the average current during this pulse.

average current = ... A [3]

[Total: 20]

END OF QUESTION PAPER

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