Physics 3
780

# CAMEROON GENERAL CERTIFICATE OF EDUCATION BOARD

## General Certificate of Education Examination

**JUNE 2008**                                              **ADVANCED LEVEL**

| Subject Title | Physics |
|---|---|
| Paper No | Paper 3 |
| Paper Code | 780 |

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### Two and a half hours

### Answer all questions

*Section I of the paper is designed to be answered in one hour and Section II is designed to be answered in one and a half hours. You are advised to divide your time accordingly, and the invigilators should announce when one hour has elapsed.*

*You are reminded of the necessity for good English and orderly presentation in your answers.*

*In calculations you are advised to show all the steps in your working, giving your answers at each stage.*

*Non-Programmable calculators may be used.*

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## SECTION I
### (One hour)

Read the following passage and answer the questions that follow.

Today the use optical amplification in communication systems has improved communication greatly. Light pulses can be launched into optical fibres easily. As the pulse is propagated along the fibre, its energy is dissipated as a result of absorption and scattering. Beyond a certain transmission distance, the number of photons contained in a pulse becomes too small for the detection, at the receiving end and the pulse is virtually lost in the detector's noise.

The receiving electronics are then unable to decide whether this signal pulse represents one "1" or zero "O". Optical communication standards require the probability of "misread" bits to be less than one part in a million. To meet that requirement, each bit must contain a minimum of photons. Theoretically, that minimum is between 9 and 40 photons per bit depending on the detection technique.

Because the laser power available from semiconductor used in communication is generally limited to about 1 millivolt, the photon per bit limit, determines the maximum possible distance. At a rate of 10 billion bit per second, for example, the maximum distance is 100-200 km. Within that distance, the signal can be detected electronically processed and re-emitted as a fresh light pulse into another strand of fibre. By placing such electronic regenerators in sequence, one can make very long fibre optic system. The first fibre optic cable deployed across the Atlantic ocean was laid in the late 1980s. It spans 6700 km and has electronic regenerators every 70 km.

Assume now that light pulse are optically amplified at periodic locations along the fibre, with amplified gain compensating for the loss incurred in each strand. Such optical regeneration has two important advantages over electronic regeneration.

First, optical amplifiers are not limited in frequency, having an operating bandwidth greater than 1000 GHz. Secondly, they can amplify signals at different wavelengths simultaneously and so can generate several optical channels at once.

In contrast to electronic regenerators, optical amplifiers are insensitive to the type of signal modulation-amplitude, frequency or phase. Optical amplifiers are insensitive to bit rate which are fixed in electronic amplifiers. For this reason, optical devices are said to be bit-rate transparent. Thus, to meet some future increase in traffic demand, one could, in principle, upgrade an amplifier-based system designed to operate at 2.5 gigabit per second to day to a rate of 5 or 10 gigabit per second.

In the normal regime of light propagation, optical regeneration cannot be iterated forever. Each amplifier in the chain contributes an unavoidable amount of noise. This background noise accumulates along the system and increases the probability of detection error. By contrast in the non-linear or soliton propagation

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regime, this effect can totally be suppressed. In either case the beauty of the optical regeneration is that physics happens to work right for transmission distances as large as the earth.

## QUESTIONS

1.    Explain the meaning of each of the following phrases or words as used in the passage:
    (a)    detector's noise
    (b)    Electronic regenerators
    (c)    bit-rate transparent
    (d)    transmission distance

(8 marks)

2    (a)    Describe possible physical processes that take place within an optical fibre, which render the signals difficult to detect after some distance.
    (b)    State and explain two possible remedies to the problem of attenuation in optical fibres.

(10 marks)

3.    (a)    How are optical amplifiers different from electronic amplifiers
    (b)    Compare the different approaches to optical regeneration.

(6 marks)

4.    It is possible to completely suppress noise in some fibre optics systems. Suggest and explain briefly how this can be done.

(4 marks)

5.    An optical fibre communication system uses a carrier frequency 700 GHz. What are the minimum and maximum frequencies?

(2 marks)

Turn over

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## SECTION II

### (One and a half hours)

Read the following account of an experimental investigation and answer the questions that follow.

Einstein formulated the theory of relativity which suggests a relationship between the mass, m, of a body in motion and its rest mass $m_o$ as follows.

$$m = \frac{m_o}{\sqrt{\left(1 - \dfrac{v^2}{c^2}\right)}}$$

where $v$ is the speed of the body and $c$ is the speed of light in a vacuum. In an experiment, to verify this relationship, electrons are accelerated to high speed and their masses measured when in motion. The table shows how the velocity varies with mass of an electron.

| $v/10^8$ m s-1 | 0.29 | 0.44 | 0.54 | 0.72 | 1.02 | 1.14 | 1.32 | 1.41 |
|---|---|---|---|---|---|---|---|---|
| $m/10^{-31}$ kg | 4.5 | 4.7 | 4.8 | 5.1 | 6.1 | 6.9 | 9.3 | 12.9 |

6. Plot a suitable graph to obtain values for c and $m_0$.

(15 marks)

7. (i) Plot a graph of m against $v$.
   (ii) Determine the slope at $v = 1.3 \times 10^8$ m s$^{-1}$?

(8 marks)

8. What is the total momentum of an electron at a speed $1.3 \times 10^8$ m s$^{-1}$?   (3 marks)

9. From your graph, explain whether $v$ may be greater than c. How does this compare with what you would predict from the equation?

(4 marks)