# MAASAI MARA UNIVERSITY

## REGULAR UNIVERSITY EXAMINATIONS

## 2023/2024 ACADEMIC YEAR

## FOURTH YEAR SECOND SEMESTER

## SCHOOL OF PURE, APPLIED AND HEALTHY SCIENCES

## BACHELOR OF SCIENCE(PHYSICS)

## COURSE CODE: PHY4250

## COURSE TITLE: Telecommunication and Fiber Optics

**DATE:15TH APRIL 2024 TIME: 1100-1300HRS**

**INSTRUCTIONS TO CANDIDATES**

**1. Answer Question ONE and any other Two questions**

**2. Use of sketch diagrams where necessary and brief illustrations are encouraged.**

**3. Read the instructions in the answer booklet keenly and adhere to them.**

This paper consists of XXXXXXXXX printed pages. Please turn over

## QUESTION ONE [20MARKS]

(a)Define the following terms. [**5marks**]

I. Telecommunication.
II. Signal-to-noise ratio
III. Modulation.
IV. Crosstalk.
V. Switching in light of transmission.

(b) With a sketch, briefly explain a simple telephone communication system. [**3marks**]

(c What is the loss in decibels on a signal line if a 10-mW (milliwatt), 1000-Hz signal is launched into a wire pair and is measured at 0.2 mW at the distant end of the wire pair? [**2marks**]

(d) The noise level of a certain voice channel is measured at −39 dBm, and the test tone signal level is measured at +3 dBm. What is the channel S/N? [**2marks**]

(e) A line-of-sight millimeter-wave radio link operates at 38.71 GHz. What is the equivalent wavelength at this frequency? [**2marks**]

(f)State two main advantages of fibre optic cable over co-axial cable. [**2marks**]

(g) Explain in detail how intelligence was conveyed over the electrical telegraph in the old days. [**4marks**]

## QUESTION TWO [15 MARKS]

(a) Explain the term acceptance angle of an optical fibre. [**3marks**]

(b) Explain dispersion with fibre-optic cable. [**3marks**]

(c) State four factors despite the maximum loss will enable an optical-fiber link to withstand and still operate satisfactorily. [**4marks]**

(d) For a 3-μm-diameter optical fibre with core and cladding indexes of refraction of 1.545 and 1.510, respectively. Determine its cut-off wavelength. [**5marks**]

## QUESTION THREE [15 MARKS]

(a) A communications system has an IRL of −115 dBW, a receive antenna gain of 29 dB, and line losses of 6.2 dB. What is the RSL of this system? [**3marks**]

(b) Discuss three basic impairments on a telecommunication transmission channel. [**6marks**]

(c) Calculate the critical propagation angle of an optical fibre with refractive indices of the core and cladding are 1.50 and 1.48, respectively.
[**4marks]**

(d) list two advantages of the Radio System.
[**2marks**]

**QUESTION FOUR [15 MARKS]**

(a) Discuss the design approach of the fibre-optic communication system. [**5marks**]

(b) Find the maximum possible core diameter which allows single-mode operation at a wavelength of 1.3 μm in a graded-index fibre having a parabolic refractive index profile core with core refractive index at the core axis of 1.5 and a relative index difference of 1%. [**5marks**]

(c) Draw a flow chart illustrating different switching systems for a telecommunication link. [**5marks**]

**//END**

**MARKING SCHEME**

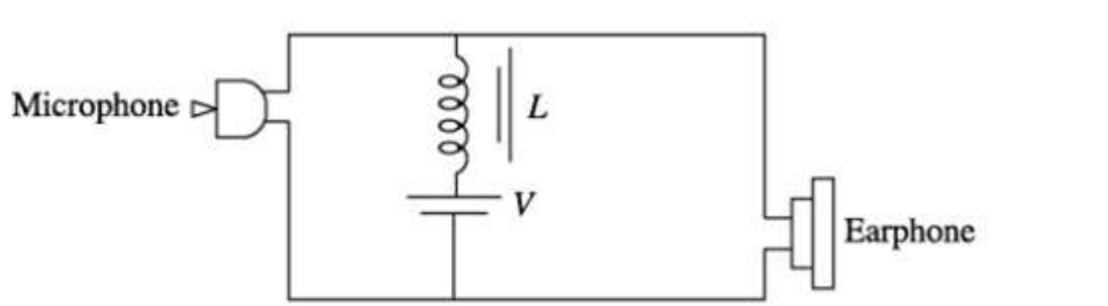
**QUESTION ONE**

(a)

I. Telecommunication means the exchange of information between two distant places. Telecommunications represent the transfer of information, from an entity at one place to an entity at another place, whereas the information can be in the form of data, voice or symbol. The entities can be human beings, computers, facsimile machines, telegraphy machines, phones or so on.
II. Signal-to-noise ratio expresses in decibels the amount that the signal level exceeds the noise level in a specified bandwidth.
III. Modulation is the process of encoding information onto a carrier signal for transmission over a communication channel
IV. Crosstalk is the unwanted coupling between signal paths
V. It refers to the process of controlling the transmission of light signals in optical communication systems.

(b)

In the simplest form of a telephone circuit. there is a one-way communication involving two entities. one receiving (listening) and the other transmitting (talking). This form of one-way communication is shown as simplex communication. The microphone and the earphone are the transducer elements of the telephone communication system. Microphone converts speech signals into electrical signals and the earphone converts electrical signals into audio signals. The most commonly used microphone is a carbon microphone. Carbon microphones do not produce high-fidelity signals but give out strong electrical signals at acceptable quality levels for telephone conversation.




(c )

$$L_{dB} = 10\ \log(P_1/P_2),$$

$$\begin{aligned} L_{dB} &= 10\ \log(10/0.2) \\ &= 10\ \log(50) \\ &\approx 17\ \text{dB} \end{aligned}$$

(d) Given:

Noise level = -39 dBm

Test-tone signal level = +3 dBm

The channel S/N ratio can be calculated as follows:

S/N = Signal Level - Noise Level

Substitute the given values:

S/N = (+3 dBm) - (-39 dBm)

S/N = 3 dBm + 39 dBm

S/N = 42 dBm

So, the channel signal-to-noise ratio (S/N) is 42 dBm.

(e)

$$F\lambda = 3 \times 10^8\ \text{m/sec},$$

$$\begin{aligned} 38.71 \times 10^9 \lambda &= 3 \times 10^8\ \text{m/sec} \\ \lambda &= 3 \times 10^8 / 38.71 \times 10^9 \\ \lambda &= 0.00775\ \text{m or } 7.75\ \text{mm}. \end{aligned}$$

(f) No equalization is necessary.

Signal repeaters are the order of 10-100 times that of coaxial cable.

(g)

To convey intelligence, the written word, a code was developed by Morse, consisting

of three elements:

a dot, where the key was held down for a very short period of time;

a dash, where the key was held down for a longer period of time;

and a space, where the key was left in the “up” position and no current flowed.

By adjusting the period of time of spaces, the receiving operator could discern the separation of characters (A, B, C, . . . , Z) and separation of words, where the space interval was longer.

Table 2.1 shows the landline and international versions of the Morse code.

By land-line, we mean a code used to communicate over land by means of wire conductors.

The international Morse code was developed somewhat later and was used by radio

**Table 2.1 Two Versions of the Morse Code**

| | A | B | | A | B |
|---|---|---|---|---|---|
| A | ·— | ·— | P | ····· | ·——· |
| Ä | | ·—·— | Q | ··—· | ——·— |
| Á | | ·——·— | R | · ·· | ·—· |
| Å | | ·——·— | S | ··· | ··· |
| B | —··· | —··· | T | — | — |
| C | ·· · | —·—· | U | ··— | ··— |
| CH | | ———— | Ü | | ··—— |
| D | —·· | —·· | V | ···— | ···— |
| E | · | · | W | ·—— | ·—— |
| É | | ··—·· | X | ·—·· | —··— |
| F | ·—· | ··—· | Y | ·· ·· | —·—— |
| G | ——· | ——· | Z | ··· · | ——·· |
| H | ···· | ···· | 1 | ·——· | ·———— |
| I | ·· | ·· | 2 | ··—·· | ··——— |
| J | —·—· | ·——— | 3 | ···—· | ···—— |
| K | —·— | —·— | 4 | ····— | ····— |
| L | ⸺ | ·—·· | 5 | ——— | ····· |
| M | —— | —— | 6 | ······ | —···· |
| N | —· | —· | 7 | ——·· | ——··· |
| Ñ | | ——·—— | 8 | —···· | ———·· |
| O | · · | ——— | 9 | —··— | ————· |
| Ö | | ———· | 0 | ⸻ | ————— |

Column A: the American Morse Code; Column B: the International Morse Code

**QUESTION TWO**

(a) •The maximum angle of incidence at the entrance aperture of the fibre for which the light ray suffers total internal reflection at the core-cladding interface and propagates through the fibre is called the acceptance angle.

•Sine of the acceptor angle of the optical fibre measures the light gathering or accepting the power of the fibre.

(b) Dispersion-limited means that a link's length is limited by signal corruption. As a link is lengthened, there may be some point where the bit error rate (BER) becomes unacceptable. This is caused by the signal energy of a particular pulse that arrives later than other signal energy of the same pulse. There are several reasons why energy elements of a single light pulse may become delayed compared to other elements. One may be that certain launched modes arrive at the distant end before other modes. Another may be that certain frequencies contained in a light pulse arrive before other frequencies. In either case, delayed power spills into the subsequent bit position, which can confuse the decision circuit. The decision circuit determines whether the pulse represented a 1 or a 0. The higher the bit rate, the worse the situation becomes. Also, the delay increases as a link is extended.

(c)

- a function of the type of fibre,
- wavelength5 of the light signal,
- the bit rate and error rate,
- signal type (e.g., TV video),
- power output of the light source (transmitter),
- the sensitivity of the light detector (receiver).

(d)

For single-mode step index fiber normalized frequency number (

$0 < V \leq 2.405$

$\therefore V_{max} = 2\pi a(NA)/\lambda_c$

$a \Rightarrow$ Core radius

For max V, the wavelength is taken as the critical wavelength.

Given:

Core diameter (d) = 3 μm

Core indexes ($n_1$) = 1.545

$$N.A = \sqrt{n_1^2 - n_2^2} = 0.326$$

$$\lambda_c = \frac{2\pi \cdot a \cdot (N.A.)}{V_{max}}$$

$$= \frac{2\pi \times 1.5 \times 0.326}{2.405}$$

$\lambda_c = 1.29$ μm

**QUESTION THREE**

(a) Given:

- Effective isotropic radiated power (EIRP) = -115 dBW

- Receive antenna gain = 29 dB

- Line losses = 6.2 dB

The formula for RSL is:

RSL = EIRP + Gain – Losses

Substitute the given values:

RSL = (-115 dBW) + (29 dB) - (6.2 dB)

RSL = -115 dBW + 29 dB - 6.2 dB

RSL = -115 dBW + 22.8 dB

Now, add the values together:

RSL = -115 dBW + 22.8 dB

RSL = -92.2 dBW.

(b) Three basic impairments that can affect telecommunication transmission channels are:

1. Attenuation: This refers to the loss of signal strength as it travels along the transmission medium. Attenuation can be caused by factors such as distance, material properties of the medium, and environmental conditions. As the signal propagates through the medium, it gradually loses power, which can result in degradation of the signal quality and ultimately limit the distance over which reliable communication can occur.

2. Noise: Noise refers to any unwanted electrical or electromagnetic interference that disrupts the signal being transmitted. It can originate from various sources including external electromagnetic radiation, thermal effects within electronic components, and crosstalk from adjacent channels or circuits. Noise can distort the original signal, reduce its clarity, and increase the likelihood of errors during reception.

3. Dispersion: Dispersion occurs when different frequency components of a signal travel at different velocities through the transmission medium. This can cause the signal to spread out over time and distort its waveform. There are different types of dispersion, including chromatic dispersion and modal dispersion, which can occur in optical fibres and affect the quality and integrity of the transmitted signal. Dispersion limits the achievable data rates and the distance over which signals can be effectively transmitted without significant degradation.

(c)

**Calculation:**

$\eta_1 = 1.50$

$\eta_2 = 1.48$

The critical propagation angle can be calculated using equation (1):

$\theta_C = \mathrm{Sin}^{-1}(1.48/1.5)$

$\theta_C = \sin^{-1}(0.986)$

$\theta_C = 80.64°$

Here $\theta_C$ is the angle that a light ray can make with the wall of the core.

Here $\theta_C$ is the angle that a light ray can make with the wall of the core.

Whereas from the figure θ is the maximum angle that the light beam makes with the axis of the optical fiber to achieve the total internal reflection.

$\theta = 90° - \theta_C$

$\theta = 90° - 80.64°$

$\theta = 9.4°$

(d)

- Cost-effectiveness
- Resilience
- Versatility

**QUESTION FOUR**

(a) The design approach of a fibre-optic communication system involves:

1. Establishing System Parameters: Determine the signal type (digital/analog), system length, growth requirements, survivability needs, and acceptable signal impairment levels.

2. Selecting Transmission Parameters: Choose fiber type (single-mode/multimode), transmission wavelength, source type, detector type, use of amplifiers, and modulation technique.

3. Optimizing Economic Alternatives: Consider cost-effective options for fiber parameters, transmission wavelengths, sources, detectors, and amplifiers while meeting performance requirements.

(b)

Sol

For lowest order or single-mode operation, V number is given by

α = various profile parameter of the fiber

α = 1 for triangular profile

α = 2 for parabolic profile

Given

Operation wavelength (λ) = 1.3 μm

Core refractive index ($n_1$) = 1.5

Relative index difference (Δ) = 0.01

α = 2 for parabolic profile

$$V = 2.405\sqrt{1 + \frac{2}{\alpha}}$$

$$V = 2.405\sqrt{1 + \frac{2}{2}}$$

$V = 2.405 \times \sqrt{2} = 3.401$

We know that

$$V = \frac{2\pi a}{\lambda} n_1 \sqrt{2\Delta}$$

The above equation can be rearranged as

$$a = \frac{V\lambda}{2\pi n_1 \sqrt{2\Delta}}$$

Putting all values in the above equation

$$a = \frac{3.401 \times 1.3 \times 10^{-6}}{2\pi \times 1.5 \sqrt{2 \times 0.01}}$$

$a = 3.316 \times 10^{-6}$ meter

$a = 3.316$ μm

diameter of core (d) = 2a

$d = 2 \times 3.316$ μm

$d = 6.632$ μm

(c)