



MACHAKOS UNIVERSITY

University Examinations for 2019/2020 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION
TECHNOLOGY)

SPH 317: ELECTROACOUSTICS

DATE: 9/11/2020

TIME: 8.30-10.30 AM

INSTRUCTIONS

Answer Question One and Any Other Two Questions

QUESTION ONE (30 MARKS)

- a) State any **two** characteristics of each of the following microphones (4 marks)
- Piezoelectric
 - Moving coil
- b) Describe loudness and state its units (4 marks)
- c) A mass of 0.5 kg hangs on a spring. The stiffness of the spring is 100N/m and the mechanical resistance is 1.4 kg/s. The force driving the system is $f = 2\cos 5t$
- Draw the electrical analogy of the circuit
 - Determine the
 - Steady state values of speed, amplitude and average power dissipation
 - Value of phase angle between speed and force
 - Resonance frequency(10 marks)
- d) Figure 1 shows a horn speaker
- Describe the operation of the speaker

- ii. The radiation resistance Z_r of the speaker is given by the expression. Determine the cut-off frequency and explain its significance.

$$Z_r = \frac{\rho_0 c}{s_0} \left[\sqrt{1 - \frac{m^2 c^2}{4\omega^2}} + j \frac{mc}{2\omega} \right] \quad (8 \text{ marks})$$

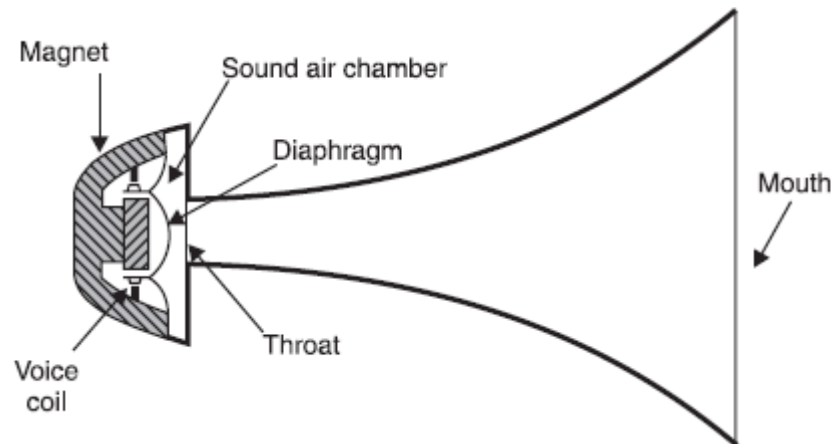


Figure 1

- e) Describe the significance of critical radius as used in room acoustics (4 marks)

QUESTION TWO (20 Marks)

- a) i Describe the following aspects of auditory stimulus, giving an example in each case.
- Physical dimension
 - Perception dimension
- ii Table 1 shows auditory perception dimension. (Copy and) Fill in the corresponding physical dimension (7 marks)

Perception Dimension	Physical dimension
Pitch	
Loudness	
Timbre	

- b) Figure 1 is a diagram of the internal structure of the human ear. Clearly describe the function of the: (11 marks)
- Outer ear
 - Middle ear
 - Inner ear

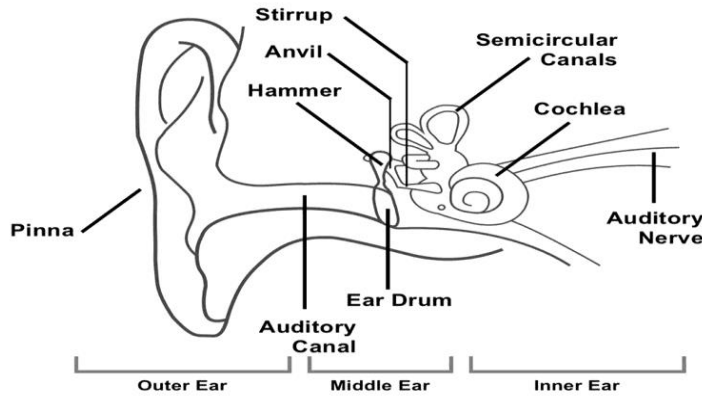


Figure 2

- c) Explain which one is louder, between 5dB sound at 300Hz and 5dB sound at 1 KHz. (2 marks)

QUESTION THREE (20 MARKS)

- a) Derive the linear acoustic wave equation. You may use the following **three** equations (7 marks)

- i. Equation of state $p = Bs$
- ii. Linear continuity equation $\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0$
- iii. Euler's equation/Linear Force equation $\rho_0 \frac{\partial u}{\partial t} = -\nabla p$

- b) Given that the acoustic pressure at a distance r from a small source radius r_0 and surface velocity $U = U_0 e^{j\omega t}$ is of the form

$$p = \frac{A}{r} e^{j\omega(t-r/c)}$$

Determine the expression for the:

- i. velocity potential
 - ii. particle velocity at any arbitrary distance from the source (8 marks)
- c) Consider a mass-spring system described by the equation

$$2 \frac{d^2 x}{dt^2} + 3 \frac{dx}{dt} + sx = 0$$

Determine s for which the system is

- i. Under damped
- ii. Over damped

- iii. Critically damped (5 marks)

QUESTION FOUR (20 MARKS)

- a) Describe the following requirements of a microphone
- i. Frequency response
 - ii. Directivity (6 marks)
- b) i Describe the three components of a basic microphone
- ii Distinguish between pressure gradient and velocity gradient microphones (5 marks)
- c) In a carbon microphone, for a small resistance x the resistance R varies linearly with x . The other characteristics are given as follows:
- R_0 = Static resistance
 - R = Dynamic resistance
 - h = distance constant (Ω/m)
 - x = distance moved by center diaphragm
- Derive the expression of the output current I from the microphone. (9 marks)

QUESTION FIVE (20 MARKS)

- a) Explain the significance of these in room acoustics
- i. Reverberation
 - ii. Flutter echoes (4 marks)
- b) A rectangular room has linear dimensions of $l_x = 25\text{m}$, $l_y = 16\text{m}$, $l_z = 6\text{m}$. The absorption coefficients of the floor, the ceiling and the walls are $\sigma_1 = 0.2$, $\sigma_2 = 0.7$, $\sigma_3 = 0.4$ respectively. Part of the section of an auditorium with talker position and listener position area is shown in Figure 3. Determine the:
- i. Reverberation time of the unoccupied rooms
 - ii. Reverberation time change when the room is occupied by 150 people. Assume an equivalent absorption area of $0.5\text{m}^2/\text{person}$
 - iii. Critical distance of a dipole source for this room (16 marks)

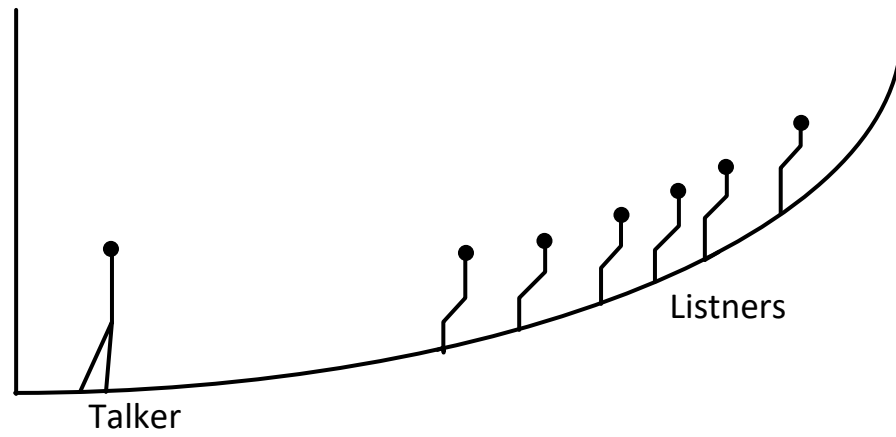


Figure 3