MACHAKOS UNIVERSITY

University Examinations for 2019/2020Academic 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)

i. Piezoelectric

ii. 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 $f = 2cos5t$

i. Draw the electrical analogy of the circuit

ii. Determine the

I. Steady state values of speed, amplitude and average power dissipation

II. Value of phase angle between speed and force

III. Resonance frequency (10 marks)

d) Figure 1shows a horn speaker

i. 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.

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

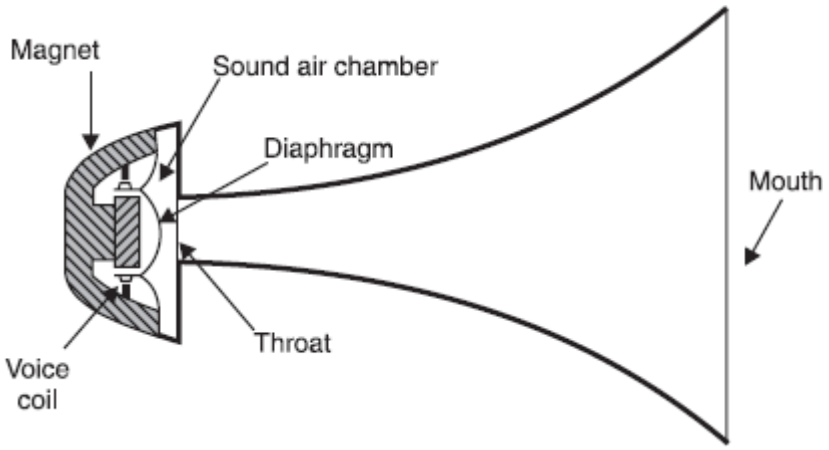

Figure 1

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.

I. Physical dimension

II. 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)

i. Outer ear

ii. Middle ear

iii. Inner ear

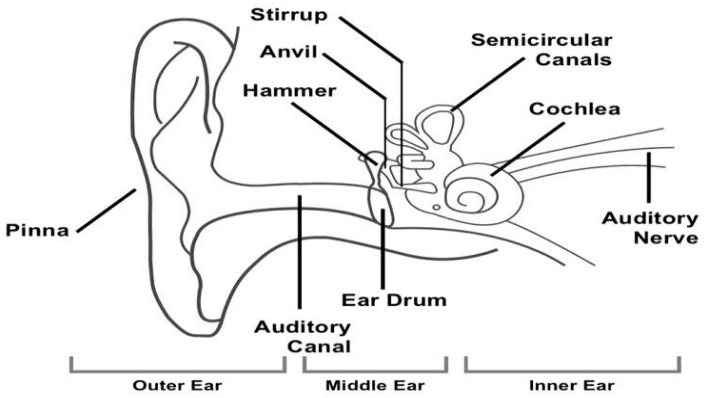

Figure 2

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 $\frac{\partial \rho}{\partial t} + \nabla.(\rho\vec{u}) = 0$

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 $U = U_0 e^{jwt}$ is of the form

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

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

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

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 $l_x = 25m,\ l_y = 16m,\ l_z = 6m$. 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 $0.5m^2$/person

iii. Critical distance of a dipole source for this room (16 marks)

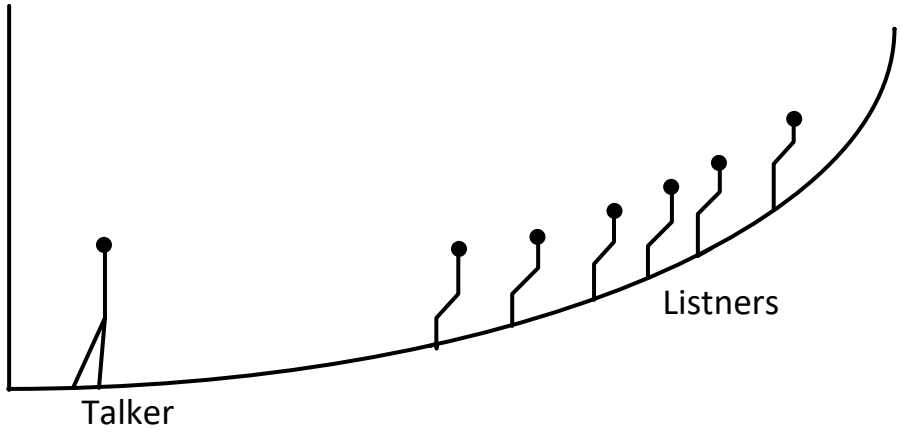

Figure 3