National Exams May 2017

16-Mec-B11, Acoustics and Noise Control

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK EXAM. Candidates may use one of two calculators, the Casio or Sharp approved models.

3. FIVE (5) questions constitute a complete exam paper. The first five questions as they appear in the answer book will be the only questions marked.

4. Each question is of equal value.

Question 1 (20 marks)

Part A (10 marks):

Match the **Terms** with the appropriate **Definitions**. That is, put the appropriate letter representing the Terms together with the number representing the appropriate Definition.

Terms		Definitions	
A	**frequency weighting**	1	The level of a (steady or non-steady) sound which, in a stated time period and at a stated location, has the same (equivalent constant) sound energy as the time-varying sound. Unit: decibel (dB).
B	**hourly average sound level (L_{8hr})**	2	The sound level measured using A-weighting. Unit: decibel, dB(A).
C	**C-weighted sound level**	3	A standardized frequency response weighting applied to measured acoustic signals to mimic the response of the human ear.
D	**background noise**	4	Ten times the logarithm (to the base 10) of the ratio of a given sound power to the reference sound power of 10^{12} W. unit: decibel (dB)
E	**average sound pressure level (L_{eq})**	5	The (A-weight) average sound level time-averaged over an 8-hour time period. Unit: decibel (dB)
F	**octave**	6	The sound level measured with a sound-level meter using c-weight. Unit: decibel (dB)
G	**sound intensity (I)**	7	A spectrum in which the bands that are displayed as a function of frequency are one octave wide.
H	**sound power level (Lw)**	8	The total noise from all sources other than a particular sound that is of interest.
I	**octave-band spectrum**	9	The frequency interval between two sounds whose frequency ratio is 2.
J	**A-weighted sound level (L_A)**	10	The average rate of sound energy transmitted in a specified direction through a unit area (normal to this direction) at the specified point. Unit: watts per square meter (W/m^2)

Part B (10 marks):

Discuss the importance of all the following terms. Give an example if possible.

i). Time domain, frequency domain, and Fourier series.

ii). Standing wave, electrical-acoustical analogy, and acoustic impedance.

iii) Frequency response function.

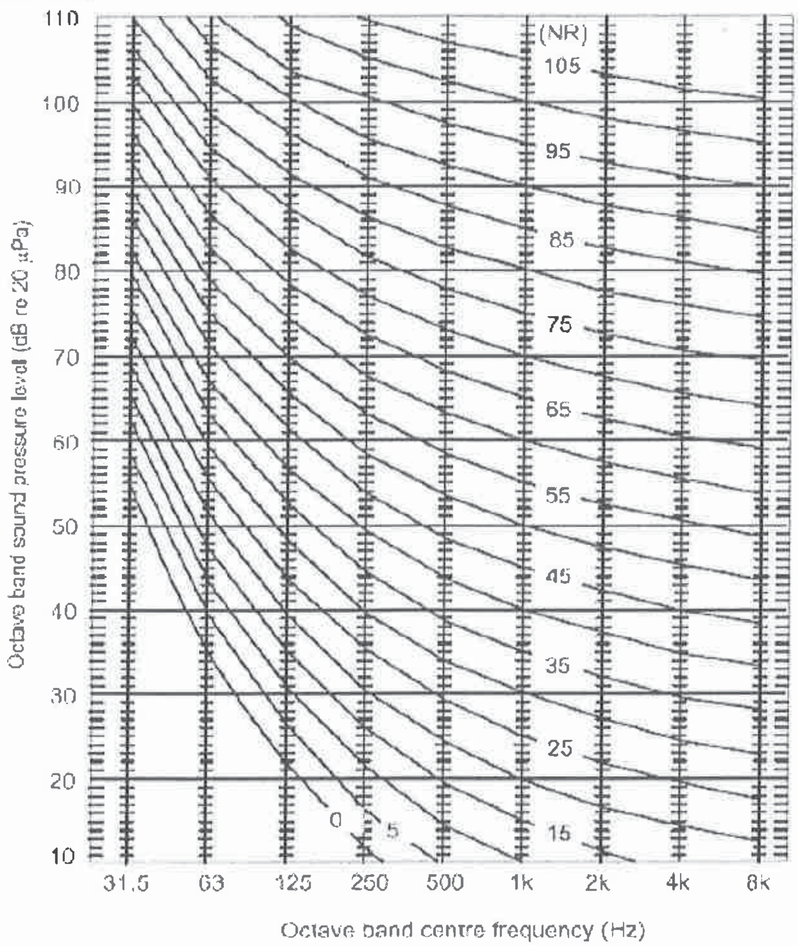
iv) The function of the diaphragm in a condenser microphone.

Question 2 (20 marks)

Four identical motor-pump sets are operating all at the same time and are located relatively close to one another within a large space. The overall A-weighted sound pressure level at a distance of 2 meters from this group of pumps is recorded as 98dB.

i. Assuming negligible background noise, determine the sound pressure level at the same location when all but one pump are turned off (only one pump left operating).
ii. If the noise generated by the pumps has a dominant octave band of 2,000Hz (all other octave bands are significantly lower), state the **Noise Rating** for this space (with all pumps operating). See figure below.
iii. Determine how long a worker could remain in this space (at two meters from pumps, with all pumps operating, and no hearing protection). Use OSHA criterion: base level = 85 dB(A) and 5 dB(A) exchange rate.
iv. Determine how long a worker could remain in this space if only one pump were operating.
v. Suggest two changes to this working environment that would allow workers to remain longer in this space.

Noise Rating Curves:



Question 3 (20 marks)

Part A (5 marks)

You and a friend are camped on the shores of charming Echo Lake. The lake is 500m wide where you are camping and your friend is in a kayak in the middle of the lake. You call him/her to announce lunch is ready. The air temperature is a comfortable 22°C (295.2°K). The gas constant for air is 287 J/Kg-°K (8.3145 J/mol-°K) and the specific heat ratio for air is γ = 1.4. The molar weight of dry air is 0.029 kg/mol. Ignore any local atmospheric/weather conditions and answer the following questions.

i. How long does your voice take to reach your friend?
ii. How long before you hear your echo from across the lake?
iii. How much time elapses between when your friend hears your call and he/she hears the echo?

Part B (15 marks)

A microphone manufacturer wants to design piston-type sound generators to calibrate their products. They utilize the working principle of the piston sound generator which is driven by a motor. The design requirements are:

1) The sound generator (open at one end) produces a pure tone of 50 Hz in the form of a sinusoidal sound wave;
2) The sound pressure levels (rms) in the cylinder at the open end are 94 dB and 104 dB respectively for different amplitude calibrations;
3) The temperature of testing room is 22 C°.

Determine the following parameters:

iv. What is the motor rotating speed in RPM?
v. What are the peak amplitudes of the sound pressure in the cylinder at the open end (corresponding to the two sound pressure levels)?
vi. What are the sound pressure distributions (the mathematical expressions that describe the sound wave) at the cylinder open end?
vii. What are the peak velocities of the moving piston in the cylinder at both sound pressure levels? (Note: at $22\,C^{\circ}$, ρc = 407 rayls)

Question 4 (20 marks)

Part A (5 marks)

Consider a dipole sound source (in a completely free field, no reflections) that is made up of two monopole sources which individually radiate 10 mW of sound power at 1000 Hz and are separated by 0.05 m.

i. What is the sound intensity at 1.0 m from the dipole source in a direction that is 45° from the plane containing the dipoles?
ii. What is the sound pressure level at this same point?
iii. What are the sound intensity and the sound pressure level at a point 1.5 m from the dipole in a direction that is 90° from the plane containing the dipoles?

(Question 4 continues on next page)

Part B (5 marks)

A 10 meter length of pipe (line source) containing stream (turbulent flow) is located at an elevated position (well above the ground and away from any walls). It emits a sound power level of 110 dB in the 1000 Hz octave band.

iv. Calculate the sound pressure level at 50 m from the mid-point of the pipe.
v. Calculate the sound pressure level at 120 m from the mid-point of the pipe.
vi. Calculate the sound pressure level at 120 m from the mid-point of the pipe given that the pipe is resting on a hard concrete floor.

Part C (10 marks)

A square opening that is 1m x 1m in size (plane source) is located in the side of a building and is leaking noise into the surrounding community. The internal room surfaces are sufficiently hard so that the sound field incident at the opening may be considered diffuse. The centre of the opening is 2.0m above ground level. The sound power radiated through the opening in the 2kHz octave band is 0.02 Watts. The ground outside the opening is a parking lot (hard and flat). There is a neighbourhood 150m away from the opening, in a direction normal to the plane of the opening. The following questions refer only to the 2kHz octave band. Clearly state all your assumptions.

vii. Calculate the sound power level of the noise radiated through the opening.
viii. Calculate the sound pressure level at a height of 2.0m and at a distance of 6m from the opening (no excess attenuation).
ix. Calculate the excess attention, A_g, due to ground reflection for sound travelling from the opening to the nearest house (150m away).
x. Calculate the loss due to atmospheric absorption (in dB) between the opening and the nearest house. Assume Relative Humidity = 25%, and a temperature of 20°C. (see table below)
xi. Ignoring all other losses not mentioned above, calculate the total sound pressure level at the nearest house. Because of the distance you should assume the source to be a point source.
xii. If a second opening of the same size (and radiating the same power) were introduced, (close to the existing opening), what would be the total sound pressure level at the nearest house?

Table 5.3 Attenuation due to atmospheric absorption (calculated from Sutherland and Bass, 1979)

Relative humidity (%)	Temperature (°C)	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
		m (dB per 1000 m)						
25	15	0.2	0.6	1.3	2.4	5.9	19.3	66.9
	20	0.2	0.6	1.5	2.6	5.4	15.5	53.7
	25	0.2	0.6	1.6	3.1	5.6	13.5	43.6
	30	0.1	0.5	1.7	3.7	6.5	13.0	37.0
50	15	0.1	0.4	1.2	2.4	4.3	10.3	33.2
	20	0.1	0.4	1.2	2.8	5.0	10.0	28.1
	25	0.1	0.3	1.2	3.2	6.2	10.8	25.6
	30	0.1	0.3	1.1	3.4	7.4	12.8	25.4
75	15	0.1	0.3	1.0	2.4	4.5	8.7	23.7
	20	0.1	0.3	0.9	2.7	5.5	9.6	22.0
	25	0.1	0.2	0.9	2.8	6.5	11.5	22.4
	30	0.1	0.2	0.8	2.7	7.4	14.2	24.0

Question 5 (20 marks)

The transmission loss of an enclosure wall which contains a 0.5m wide × 0.5m high window and a 1m wide × 2m high door is to be determined. The transmission loss of the well-sealed door is 25dB and that of the window is 28 dB. The wall size (including window and door) is 6m wide × 3m high.

i. What will be the required transmission loss of the enclosure wall (excluding the window and door) if the overall transmission loss (including the window and door) is to be 30 dB?
ii. What is the greatest overall transmission loss for the wall, incorporating the windows and door, that is theoretically possible?
iii. What would be the effect of a 25 mm high crack underneath the door on the overall transmission loss of the construction in part (i)? Calculate the overall transmission loss in the 500 Hz band considering this crack. (Hint: effective crack height is 50 mm due to reflection from the floor.)

Question 6 (20 marks)

A machine to be operated in a factory produces 0.01 W of acoustic power. The room where the machine will operate has internal dimensions of 10m x 10m x 4m. All surfaces except the concrete floor can be lined with acoustic material. The machine is to sit on the concrete floor in the middle of the room. Note: assume that the concrete floor has an absorption coefficient of 0.01

i. Specify the absorption coefficient for the lining material (to be placed on the walls and ceiling) so that the sound pressure level in the reverberant field (that is, the SPL primarily due to the reverberant field) of the factory is about 83 dB.
ii. Specify the radius of an area around the machine beyond which the sound pressure level will drop below 90dB.
iii. Estimate the required room constant if the reverberant sound pressure level (that is, the SPL primarily due to the reverberant field) is to be 85 dB.

Question 7 (20 marks)

As illustrated in the figure below, a machine is located in a room having a total surface area of 900 m^2 and an average absorption coefficient of 0.05. The machine has a sound power level of 105 dB and a directivity factor (D_f) of 2.0. The machine is located 4 m from the wall of the operator's room. The operator's room has a total surface area of 100 m^2 and an average surface absorption coefficient of 0.35. The transmission loss for the wall between the machine room and the operator's room is 30 dB. The surface area (S_w) of the wall between the two rooms is 16 m^2. The operator is located 1.5m from the wall.

(Question 7 continues on next page)

i. Derive expressions for the steady-state sound pressure levels in the machine room and in the operator's room in terms of sound power level of the machine (L_w), room constant (R_1 and R_2), transmission loss of the wall (TL), and surface area (S_w) of the wall. (Hints: 1. Consider the sound pressure of both direct field and reverberant field. 2) For transmitted power, $W_2 = \tau S_w W / R_1$, τ is the transmission coefficient of the isolation wall).

ii. Determine the steady-state sound pressure level in the machine room and in the operator's room.

iii. What are your choices to reduce the noise level in the operator's room? List all of your possible choices and discuss them.