UNIVERSITI SAINS MALAYSIA

Peperiksaan Kursus Semasa Cuti Panjang
Sidang Akademik 2007/2008

June 2008
Jun 2008

EMM 322/3 – Noise & Vibration
Hingar & Getaran

Duration : 3 hours
Masa : 3 jam

INSTRUCTIONS TO CANDIDATE:
ARAHAN KEPADA CALON :

Please check that this paper contains **EIGHT (8)** printed pages, **THREE (3)** pages appendix and **SIX (6)** questions before you begin the examination.
*Sila pastikan bahawa kertas soalan ini mengandungi **LAPAN (8)** mukasurat bercetak, **TIGA (3)** mukasurat lampiran dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan.*

Answer **FIVE (5)** questions.
*Jawab **LIMA (5)** soalan.*

Appendix/*Lampiran :*

1. Fundamental Equations in Vibration [1 page/*mukasurat*]
2. Figure Q5[b] : Equal Loudness Curves
   Table Q5[c] : Attenuation associated with weighting filters [1 page/*mukasurat*]
3. Table Q6[b] : Sound absorption coefficient
   Figure Q6[b] : Optimum Reverberation Time at 500 Hz
   Table Q6[b] : Optimum Reverberation Time T/T_{500} [1 page/*mukasurat*]

Answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.
*Calon boleh menjawab semua soalan dalam **Bahasa Malaysia** ATAU **Bahasa Inggeris** ATAU kombinasi kedua-duanya.*

Each question must begin from a new page.
Setiap soalan mestilah dimulakan pada mukasurat yang baru.

Q1. [a] **A railroad car of mass 2000 kg travelling at a velocity 10 m/s is stopped at the end of the tracks by a spring-damper system, as shown in Figure Q1[a]. If the stiffness of the spring is 40 N/mm and the damping constant is 20 N-s/mm, determine:**

(i) The maximum displacement of the car after engaging the springs and damper.

(ii) The time taken to reach the maximum displacement.

Sebuah kepala keretapi berjisim 2000 kg yang bergerak dengan halaju 10 m/s dihentikan di hujung landasan oleh sebuah sistem spring-peredam seperti yang tertera di Rajah S1[a]. Jika kekakuan spring ialah 40 N/mm dan pekali redaman peredam 20 N-s/mm, tentukan:

(i) Anjakan maksima kepala keretapi itu selepas ia melekat pada spring dan peredam.

(ii) Masa yang diambil untuk sampai kepada anjakan maksima itu.

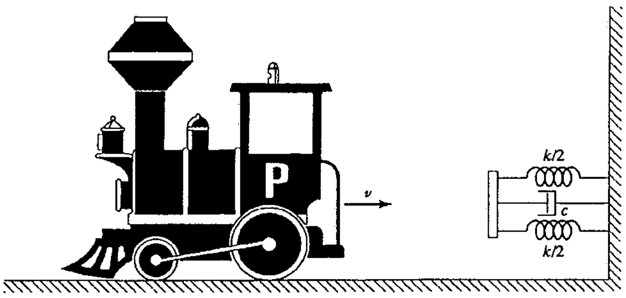

Figure Q1[a]

Rajah S1[a]

(50 marks/*markah*)

[b] **One of the tail rotor blades of a helicopter has an unbalanced mass of 0.5 kg at a distance 0.15 m from the axis of rotation, as shown in Figure Q1[b]. The tail section has a length of 4 m, a mass of 240 kg, a flexural stiffness of 2.5 MN-m^2, and a damping ratio of 0.15. The mass of the tail rotor blades including their drive system is 20 kg.**

(i) Draw the free body diagram of the tail section.

(ii) Derive the forced response of the tail section when the blades rotate at 1500 rpm.

Salah satu bilah rotor ekor sebuah helikopter mempunyai jisim tak seimbang 0.5 kg pada jarak 0.15 m dari paksi putaran, seperti yang tertera dalam Rajah S1[b]. Bahagian ekor adalah sepanjang 4 m, jisim 240 kg, dan kekakuan flexural 2.5 MN-m^2, dan nisbah redaman 0.15. Jisim bilah-bilah rotor ekor itu termasuk sistem pemacu ialah 20 kg.

(i) Lukis rajah badan bebas bahagian ekor itu..

(ii) Terbitkan tindak balas paksaan bahagian ekor itu jika bilah-bilah berputar pada 1500 rpm.

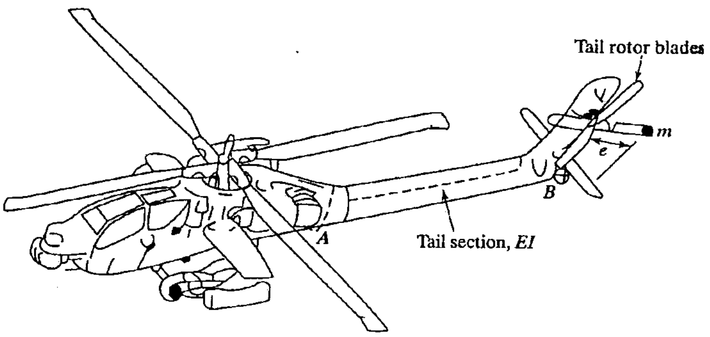

Figure Q1[b]
Rajah S1[b]

(50 marks/*markah)*

Q2. [a] A single-story building frame is subjected to a harmonic ground acceleration, as shown in Figure Q2[a].

(i) Find the steady-state motion of the floor (mass m).

(ii) Find the horizontal harmonic displacement of the floor when A = 100 mm/s^2. Assume: m = 2000 kg, k = 0.1MN/m, ω = 25 rad/s; $x_g(t=0)=\dot{x}_g(t=0)=x(t=0)=\dot{x}(t=0)=0$.

(iii) If the ground is subjected to a horizontal harmonic displacement with frequency ω = 200 rad/s and amplitude X_g = 15 mm, find the amplitude of the vibration of the floor. Assume the mass of the floor as 2000 kg and the stiffness of the columns as 0.5 MN/m.

Sebuah rangka bangunan setingkat mengalami pecutan harmonik tanah seperti yang tertera dalam Rajah S2[a].

(i) Tentukan pergerakan mantap lantai (jisim m).

(ii) Tentukan anjakan mengufuk harmonik lantai jika A= 100 mm/s^2. Andaikan: m = 2000 kg, k = 0.1MN/m, ω = 25 rad/s; $x_g(t=0)=\dot{x}_g(t=0)=x(t=0)=\dot{x}(t=0)=0$.

(iii) Jika tanah mengalami anjakan harmonik dengan frequensi ω 100 rad/sec dan amplitud X_g =15 mm, tentukan amplitud getaran lantai. Andaikan jisim lantai 2000 kg dan kekakuan tiang-tiang 0.5 MN/m.

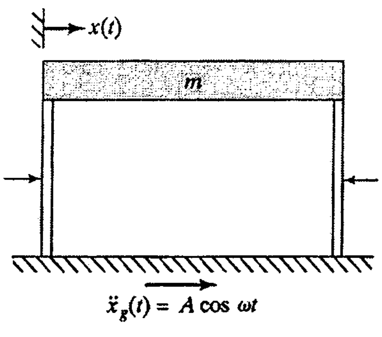

Figure Q2[a]
Rajah S2[a]

(50 marks/*markah)*

[b] **The landing gear of an airplane can be idealized as the spring-mass-damper system. If the runaway surface is described as $y(t) = y_0 \cos \omega t$, determine the values of k and c that limit the amplitude of vibration of the airplane (x) to 0.1 m. Assume m = 10000 kg, y_0 = 0.2 m and ω = 157.08 rad/s.**

Sebuah gear pendaratan bagi kapal terbang boleh dianggap sebagai sistem spring-jisim-peredam. Jika permukaan landasan diberikan sebagai $y(t) = y_0 \cos \omega t$, tentukan nilai-nilai k dan c yang menghadkan amplitud getaran kapal terbang (x) kepada 0.1 m. Andaikan m = 10000 kg, y_0 = 0.2 m and ω = 157.08 rad/s.

(50 marks/*markah*)

Q3. **[a]** **The drilling machine shown in Figure Q3[a] can be modeled as a two degree of freedom system as indicated in the figure. The bending stiffness of the column are given by**

$$k_{11} = \frac{768}{7}\frac{EI}{l^3}, \quad k_{12} = k_{21} = -\frac{240}{7}\frac{EI}{l^3}, \quad k_{22} = \frac{96}{7}\frac{EI}{l^3},$$

(i) **Draw free body diagram of m_1 and m_2**

Determine:

(ii) **the equations of motions for m_1 and m_2**
(iii) **the stiffness matrix and the mass matrix**
(iv) **the characterestic equation of the system**
(v) **the natural frequencies of the system**
(iv) **the amplitude of vibration of m_1 if a transverse harmonic force $F_t = \sin t$ N acts on m_2.**

Sebuah mesin gerudi yang tertera dalam Rajah S3[a] boleh dimodel sebagai sistem dua darjah kebebasan seperti yang ditunjukkan di dalam rajah itu. Kekakuan lentur tiang diberikan sebagai

$$k_{11} = \frac{768}{7}\frac{EI}{l^3}, \quad k_{12} = k_{21} = -\frac{240}{7}\frac{EI}{l^3}, \quad k_{22} = \frac{96}{7}\frac{EI}{l^3},$$

(i) *Lukis rajah badan bebas bagi m_1 dan m_2.*

Tentukan:

(ii) *persamaan-persamaan pergerakan for m_1 and m_2*
(iii) *matriks kekakuan dan matriks jisim*
(iv) *persamaan ciri sistem*
(v) *frekuensi-frekuensi jati sistem*
(vi) *Amplitud getaran jisim m_1 jika daya harmonik melintang $F_t = \sin t$ N bertindak ke atas m_2.*

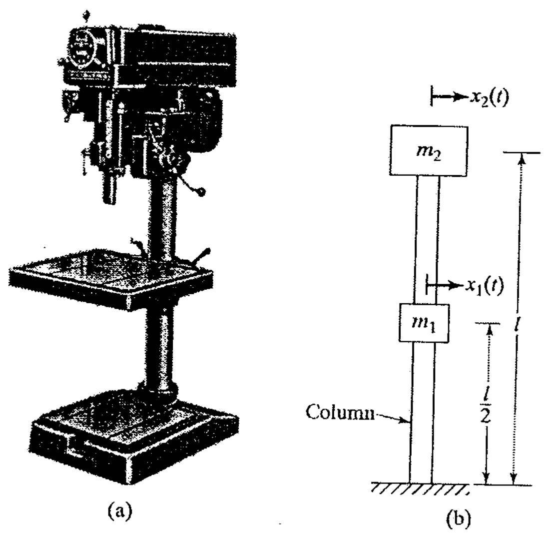

Figure Q3[a]
Rajah S3[a]

(60 marks/*markah)*

[b] **An air compressor of mass 200 kg, with an unbalance of 0.01 kg-m, is found to have a large amplitude of vibration while running at 1200 rpm. Determine the mass and spring constant of the absorber to be added if the natural frequencies of the system are to be at least 20 percents from the impressed frequency.**

Sebuah pemampat udara berjisim 200 kg, dengan tidak seimbang 0.01 kg-m, didapati mempunyai amplitude getaran ketika beroperasi pada 1200 rpm. Tentukan jisim dan kekakuan spring bagi peredam yang akan ditambahkan jika frequensi-freqeunsi asli sistem ditentukan sekurang-kurangnya 20 peratus dari frequensi yang dikenakan.

(40 marks/*markah)*

Q4. **[a]** **A measurement of acoustic pressure is shown in Figure Q4[a]. If the wave that travelling in air is represented as $p(x,t) = Ae^{j(\omega t-kx)}$, determine the amplitude A, angular velocity ω, wave number k, wavelength λ and the sound pressure level (SPL).**

Satu pengukuran tekanan akustik ditunjukkan dalam Rajah S4[a]. Jika gelombang itu bergerak dalam udara diwakilkan sebagai $p(x,t) = Ae^{j(\omega t-kx)}$, tentukan amplitud A, halaju sudut ω, nombor gelombang k, panjang gelombang λ dan paras tekanan bunyi (SPL).

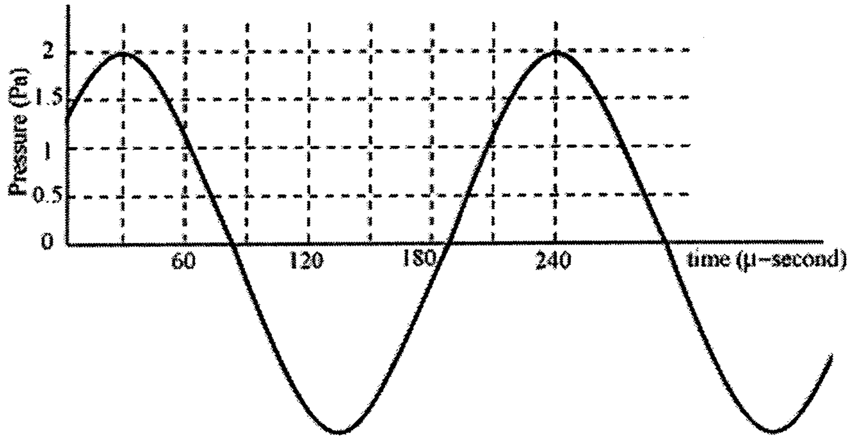

Figure Q4[a]
Rajah S4[a]

(50 marks/*markah*)

[b] **A plane wave in air has intensity of 20 W/m^2. Calculate the force on a perfectly reflecting wall of area 10 m^2 due to impact of the wave on the surface of the wall.**

Satu gelombang satah di udara mempunyai keamatan 20 W/m^2. Kirakan daya pada permukaan 10 m^2 yang memantul dengan sempurna selepas hentaman gelombang pada permukaan dinding itu.

(20 marks/*markah*)

[c] **Explain the characteristics of noise generated from internal combustion engines, the exhaust of jet engine, pneumatic chipping and stamping machine.**

Terangkan ciri-ciri hingar yang terhasil daripada enjin pembakaran dalam, ekzos enjin jet, penyerpih pneumatik dan mesin penekan.

(30 marks/*markah*)

Q5. [a] **An air-condition unit operates with an intensity level, IL = 83 dB. If it is operated in a room with an ambient IL = 68 dB, calculate the resultant IL.**

Sebuah penyaman udara beroperasi dengan paras keamatan, IL = 83 dB. Jika ia digunakan di dalam bilik dengan paras keamatan sekitar, IL = 68 dB, kirakan paras keamatan paduan.

(20 marks/*markah*)

[b] **Explain the relation between hearing sensitivity and sound frequencies based on equal loudness curves in Appendix 2.**

Huraikan hubungan antara kepekaan pendengaran dan frekuensi bunyi berdasarkan lengkungan sama kenyaringan pada Lampiran 2.

(40 marks/*markah*)

[c] **A result of the A-weighted sound pressure level measurement is shown in Figure Q5[c]. Determine the C-weighted sound pressure level for all components**

Satu keputusan pengukuran paras tekanan bunyi dengan pemberat-A ditunjukkan dalam Rajah S5[c]. Tentukan paras tekanan bunyi dengan pemberat-C bagi semua komponen.

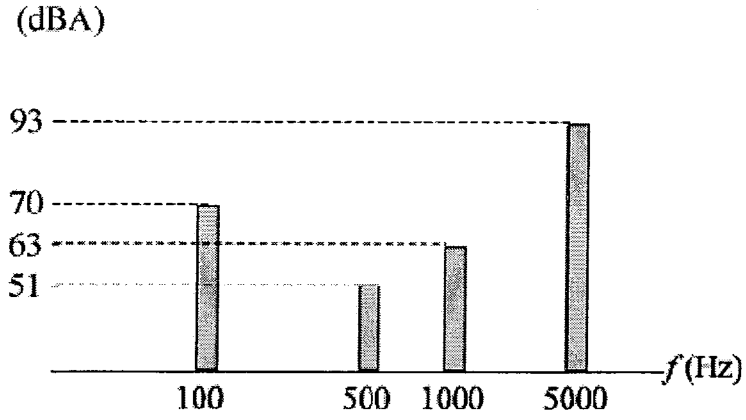

Figure Q5[c]
Rajah S5[c]

(40 marks/*markah*)

Q6. [a] **Based on the analysis of the direct and reverberant fields, the root mean square sound pressure at a distance r from the source is given by $p_{rms}^2 = \hat{W}\rho_0 c_0\left(\frac{4}{R}+\frac{Q}{4\pi r^2}\right)$, where W is sound power from the source, $\rho_0 c_0$ is the characteristic impedance, Q is directivity factor and R is room constant. Using this equation, derive an expression of the sound pressure level in terms of the sound power level. Also, explain two important observations from the derived expression.**

Berdasarkan analisis medan terus dan medan gemaan, tekanan punca min kuasa dua bunyi pada jarak r dari sumber diberikan oleh $p_{rms}^2 = W\rho_0 c_0\left(\frac{4}{R}+\frac{Q}{4\pi r^2}\right)$, dimana W ialah kuasa bunyi dari sumber, $\rho_0 c_0$ ialah impedans ciri, Q ialah faktor pengarahan dan R ialah pemalar ruang. Menggunakan persamaan ini, terbitkan ungkapan paras tekanan bunyi dalam sebutan paras kuasa bunyi. Seterusnya, terangkan dua pemerhatian penting daripada ungkapan yang diterbitkan.

(40 marks/*markah*)

[b] **A (10 x 25 x 4) m^3 room has to be used as a lecture room for 200 people. It has two 4 m^2 doors made of thick wood, and 16 glass windows that always open with size of 1.5 m^2 each. Other surfaces are made from concrete. (See Appendix 3)**

(i) **Determine the reverberation time for 500 Hz and 1000 Hz.**

(ii) **Explain whether the room is suitable for lecture if there is no acoustic correction.**

Sebuah bilik berukuran (10 x 25 x 4) m^3 akan digunakan sebagai bilik kuliah untuk 200 orang. Ada 2 pintu daripada papan tebal berukuran 4 m^2 setiap satu dan 16 tingkap cermin yang sentiasa dibuka berukuran 1.5 m^2 setiap satu. Permukaan-permukaan lain adalah daripada konkrit. (Lihat Lampiran 3)

(i) Tentukan masa gemaan bagi 500 Hz dan 1000 Hz.

(ii) Nyatakan sama ada bilik ini sesuai untuk syarahan jika tiada pembetulan akustik dilakukan.

(60 marks/*markah*)

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LAMPIRAN 1

Fundamental Equations in Vibration

1. $x(t) = e^{-\zeta\omega_n t}\left(A_1\cos(\omega_d t) + A_2\sin(\omega_d t)\right);\quad \omega_d = \sqrt{1-\zeta^2}\,\omega_n$.

2. $x_p = X\sin(\omega t - \varphi)$

$$X = \frac{F_0 / k}{\left((1-r^2)^2 + (2\zeta r)^2\right)^{1/2}}$$

$$\varphi = \tan^{-1}\frac{2\zeta r}{1-r^2}$$

3. $$\frac{F_T}{kY} = r^2\left[\frac{1+(2\zeta r)^2}{(1-r^2)^2 + (2\zeta r)^2}\right]^{1/2}$$

4. $$TR = \left[\frac{1+(2\zeta r)^2}{(1-r^2)^2 + (2\zeta r)^2}\right]^{1/2}$$

5. $$\frac{mX}{m_0 e} = \frac{r^2}{\left[(1-r^2)^2 + (2\zeta r)^2\right]^{1/2}}$$

6. $$\mathbf{A} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

$$\det(\mathbf{A}) = ad - bc$$

$$\mathbf{A}^{-1} = \frac{1}{\det(\mathbf{A})}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

LAMPIRAN 2

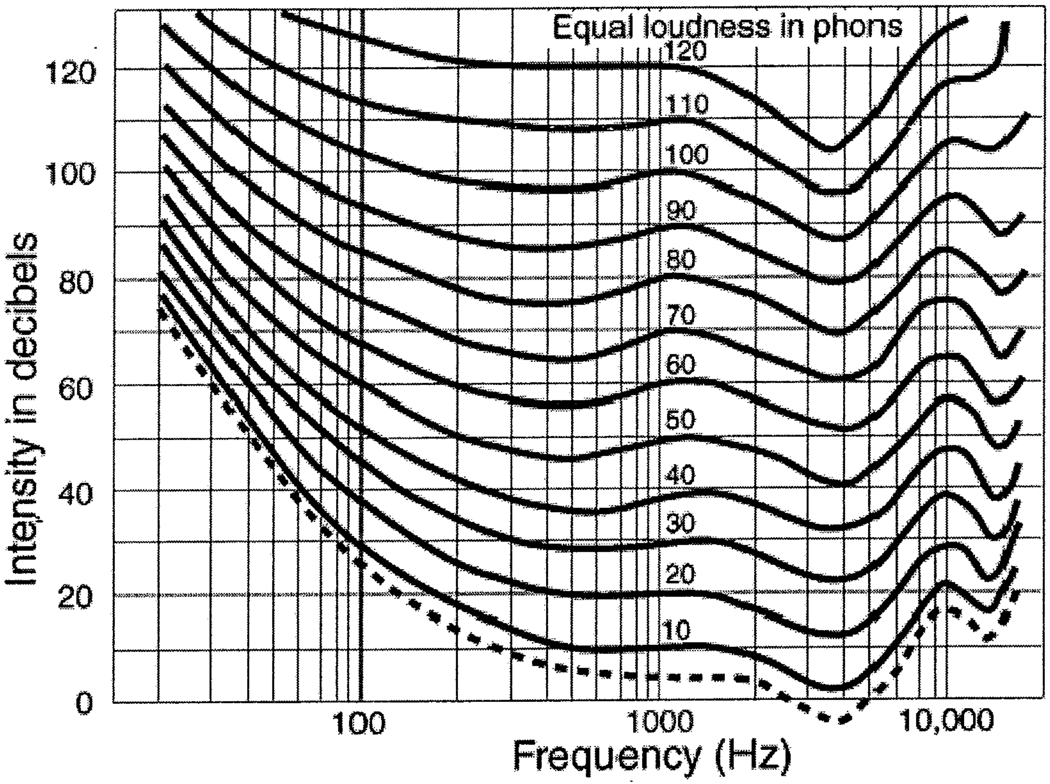

Figure Q5[b]: Equal Loudness Curves
Rajah S5[b]: Lengkungan Sama Nyaring

Table Q5[c]: Attenuation associated with weighting filters
Jadual S5[c]: Pengecilan berkaitan tapis memberat

Frequency (Hz)	A weighting (dB)	B weighting (dB)	C weighting (dB)
10	-70.4	-38.2	-14.3
25	-44.7	-20.4	-4.4
50	-30.2	-11.6	-1.3
100	-19.1	-5.6	-0.3
250	-8.6	-1.3	0
500	-3.2	-0.3	0
800	-0.8	0	0
1000	0	0	0
2000	+1.2	-0.1	-0.2
2500	+1.3	-0.2	-0.3
4000	+1.0	-0.7	-0.8
5000	+0.5	-1.2	-2.0
8000	-1.1	-2.9	-3.0

LAMPIRAN 3

Table Q6[b] Sound absorption coefficient
Jadual S6[b] Pekali penyerapan bunyi

Bahan	Pekali penyerapan α		
	250 Hz	500 Hz	1000 Hz
Konkrit	0.01	0.02	0.02
Papan tebal	0.18	0.10	0.07
Cermin	0.06	0.04	0.03
Orang dengan kerusi kayu	0.15	0.40	0.45

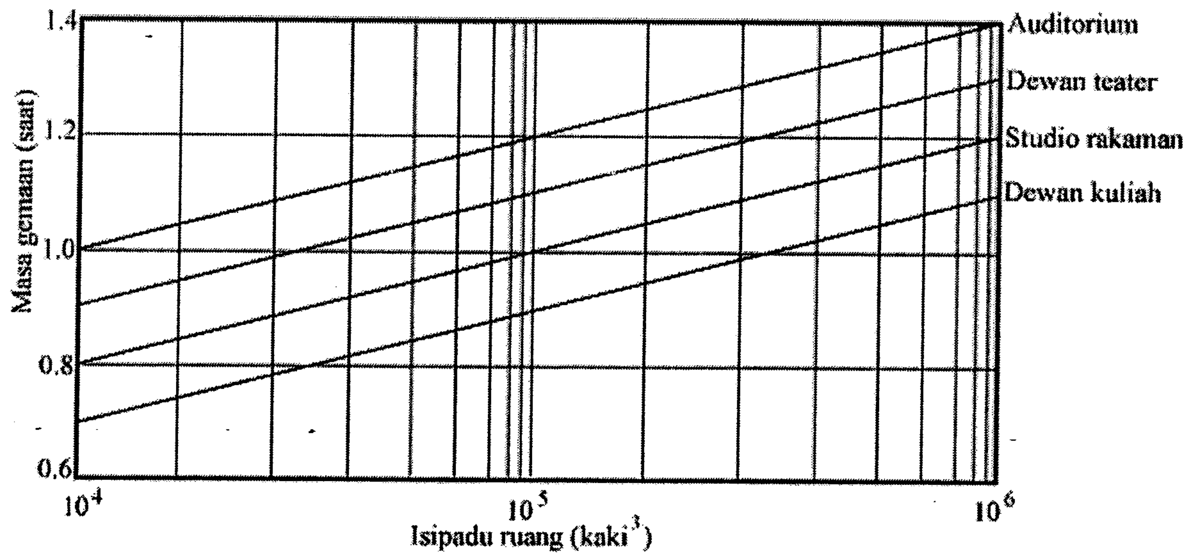

Figure Q6[b]: Optimum Reverberation Time at 500 Hz
Rajah S6[b]: Masa Gemaan Optimum pada 500 Hz

Table Q6[b]: Optimum Reverberation Time T/T_{500}
Jadual S6[b]: Masa gemaan optimum T/T_{500}

Frekuensi (Hz)	250	500	1000	2000
T/T_{500} (Ucapan)	1.0	1.0	0.9	0.9
T/T_{500} (Muzik)	1.2	1.0	0.95	0.9