MEC3403

Dynamics II

Faculty of Engineering and Surveying

Introductory book

Semester 2 2010

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Table of contents

	Page
Essential information	1
Course introduction	2
Course leader	2
Course outline	2
Course resources	3
Study schedule	4
Assessment	5
Course objectives and assessment	5
Assignment	7
Past examination	11

Essential information

The following links provide important information that will assist you with your study. Please make sure you read this information carefully before commencing study. (Detailed information on these topics is also provided in the printed handout ‘Essential introductory information’.)

- Getting started
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/getting_started.pdf>
- Course specification
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/course_specification.pdf>
- Support
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/support.pdf>
- UConnect
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/u_connect.pdf>
- Assignment submission
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/assignment_submission.pdf>
- Grading levels
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/grading_levels.pdf>
- Course evaluation
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/course_evaluation.pdf>
- Residential schools
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/residential_school.pdf>
- Library
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/library.pdf>
- Referencing APA
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/apa_referencing_guide.pdf>

Referencing Harvard AGPS
<http://usqstudydesk.usq.edu.au/file.php/1/sitefiles/DeC/essential_info/harvard_referencing_guide.pdf>

Course introduction

Course leader

Ahmad SHARIFIAN (Examiner) and Nam MAI-DUY (Assistant Examiner) are responsible for the teaching of this course. Their contact details are given below:

Dr. A. Sharifian:
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Course outline

Our environment is **naturally dynamic**. We are constantly dependent on objects and systems that **vary with time**. For example, the car's and satellite's motion relative to the earth, the spacecraft's motion relative to the solar system.

Furthermore, moving parts exist in many systems which may be stationary or moving in an overall sense: moving parts in the running engine of a 'stationary' car, or the components of a robot in operation on a travelling spacecraft, etc.

The principles and methods covered in this course are essential to the understanding of mechanical systems such as those mentioned above.

The course consists of 7 modules, which cover the following topics:

Module 1 – Kinematics
Module 2 – Kinematics analysis of mechanisms
Module 3 – Dynamics analysis of planar mechanisms
Module 4 – Rigid body dynamics
Module 5 – System modeling
Module 6 – Vibration of single degree of freedom systems
Module 7 – Vibration of multi-degree-of-freedom systems

The content of this course encompasses vector mechanics for general three-dimensional systems of rigid bodies including the theory of vibration and its applications.

Course resources

1. **Introductory book**

   This book contains the course specification, timetable, assessment information, assignment and sample examination.

2. **Study book**

   This book contains a guide to the study of the selected reading materials. It includes tutorial problems and additional reading materials (other than those found in the recommended textbook).

   Report of any errors would be most appreciated.

3. **Textbook and materials required to be purchased or accessed**

   Balachandran, B & Magrab, EB 2004, *Vibrations*, Thomson Publication.

   Student edition of MATLAB (Manual and CD), Prentice Hall.

Study schedule

Week	Module	Activity/Reading	Assessment
1 19–23 July	1	Review of mathematics and kinematics	Tutorials 1a and 1b
2 26–30 July	2	Kinematics analysis of mechanisms	Tutorials 2a and 2b
3 3–6 August	3	Dynamics analysis of planar mechanisms	Tutorials 3a and 3b
4 9–13 August	3	Dynamics analysis of planar mechanisms	Tutorials 4a and 4b
	Reminder: 13/08/2010 is the last date to drop S2 courses without academic or financial penalty.		
5 16–20 August	4	Rigid body dynamics	Tutorials 5a and 5b
6 23–27 August	4 & 5	Rigid body dynamics System modeling	Tutorials 6a and 6b
7 30 Aug – 3 Sept	5	System modeling	Tutorials 7a and 7b
8 6–10 September	6	Vibration of single degree of freedom systems	Tutorials 8a and 8b **Assignment (30%)** **Due:** 10 September 2010
9 13–17 September	BREAK		
10 20–24 September	BREAK		
11 27 Sept – 1Oct	6	Vibration of single degree of freedom systems	
12 4–8 October	6	Vibration of single degree of freedom systems	
13 11–15 October	6 & 7	Vibration of single degree of freedom systems Vibration of multi-degree-of-freedom systems	
14 18–22 October	7	Vibration of multi-degree-of-freedom systems	
15 25–29 October	7	Vibration of multi-degree-of-freedom systems	
16–17 1–12 November	EXAMINATION PERIOD		

Assessment

This section provides the details of the first assessment for this course, which is an assignment.

It is important that you follow the directions for assignment submission in the Essential Information Section.

Course objectives and assessment

On completion of this course, students should be able to:

1. analyse the kinematics and kinetics of 3D rigid bodies
2. demonstrate an understanding of and apply Lagrange's equations and/or Newton's laws of motion to model the dynamic behaviours of engineering systems
3. solve the mathematical models of engineering systems to determine their dynamic characteristics
4. determine and assess the vibrational behaviour of systems of discrete bodies having single and multiple degree-of-freedoms, with or without viscous damping
5. demonstrate an understanding of and apply the principles of vibration theory, vibration measurements and control
6. develop simple computer programs to analyse the dynamics of engineering systems.

Table 1: Assessment of course objectives

	Course objectives					
	1	2	3	4	5	6
Assignment question 1	X					X
Assignment question 2	X					
Assignment question 3	X	X				X
Examination question 1	X	X				
Examination question 2		X				
Examination question 3			X	X		
Examination question 4				X	X	

The course covers the following topics in 7 separate modules:

Module 1 – Kinematics
Module 2 – Kinematics analysis of mechanisms
Module 3 – Dynamics analysis of planar Mechanisms
Module 4 – Rigid body dynamics
Module 5 – System modeling
Module 6 – Vibration of single degree of freedom systems
Module 7 – Vibration of multi-degree-of-freedom systems

The coverage of the assignment and examination questions in terms of the topics presented in modules 1 to 7 is tabulated in table 2.

Table 2: Assessment with respect to modules

	Modules						
	1	2	3	4	5	6	7
Assignment question 1	X						
Assignment question 2	X	X					
Assignment question 3	X	X	X				
Examination question 1			X	X			
Examination question 2					X	X	
Examination question 3					X	X	
Examination question 4					X	X	X

Assignment

Due date: 10 September 2010

Weighting: 30%

Question 1 (60 marks, week 2)

A smooth tube containing a particle P lies on a horizontal plane (x,y) as shown in Figure 1. Assume that

- at time $t = 0$, P is located at $r = r_0$ (r_0 is a given positive number), and
- the tube is rotating about the vertical line through 0 (0z axis) with angular displacement $\theta = \omega_0 t$ (ω_0 is a given positive number).

Consider three possible cases of the motion of P relative to the tube

i. P is stationary ($r = r_0$ at all times),
ii. P is released and a radial force is applied to make P move away from the centre 0 with constant velocity v_0 (v_0 is a given positive number), and
iii. P is released and there is no radial force applied.

For each case,

a) Compute the absolute velocity and acceleration vectors of P in terms of r_0, ω_0, v_0, t, $\vec{i}$ and $\vec{j}$
b) Plot the absolute path of P for $0 \le t \le 2$, $r_0 = 1$, $v_0 = 1$ and $\omega_0 = \pi / 2$

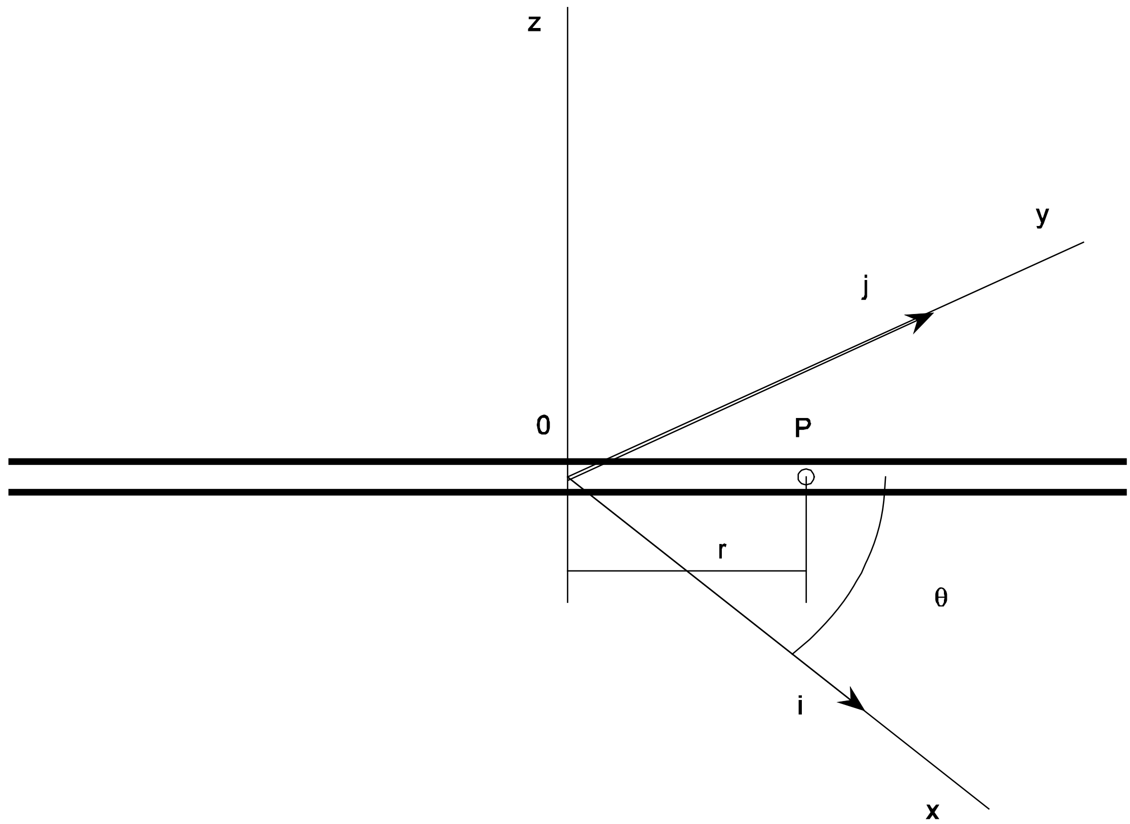

Figure 1

Question 2 (120 marks, week 4)

Figure 2 shows a planar mechanism consisting of a rotating arm (Link 1), a piston of the hydraulic cylinder (Link 2) and a slider (Link 3). Assume that Link 1 is rotating in a anticlockwise direction at constant angular velocity ω_1, and let θ_1 be the angular displacement of Link 1, $r_1 = AB$ and $r_2 = BC$. Derive the following

a) velocity of point B of Link 3 relative to Link 1 ($\dot{r}_1$) in terms of r_1, θ_1 and ω_1
   velocity of point C in terms of r_1, θ_1 and ω_1

b) acceleration of point B of Link 3 relative to Link 1 in terms of r_1, θ_1, ω_1 and $\dot{r}_1$
   acceleration of point C in terms of r_1, θ_1, ω_1 and $\dot{r}_1$

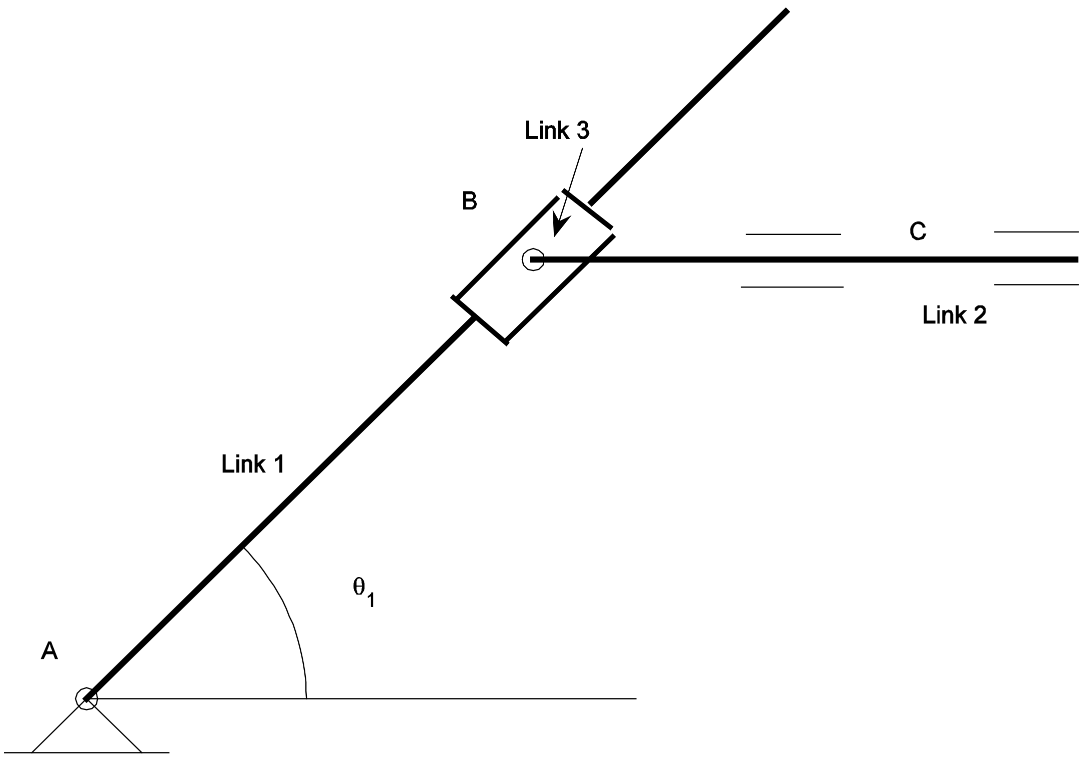

Figure 2

Question 3 (120 marks, week 6)

A four-bar linkage is given in Figure 3. Assume that Link 1 is rotating counter-clockwise with angular displacement $\theta_1 = (\pi/6)t$. The mass centres of Link 1, Link 2 and Link 3 are located at A, the midpoints of BC and CD, respectively (i.e. $G_1 \equiv A, \quad G_2B = G_2C,$ and $G_3C = G_3D$).

Given

$$AB = 1, \quad BC = CD = 2, \quad AD = 2, \quad h = 1$$
$$m_1 = 1, \quad I_{G1} = 1, \quad m_2 = 2, \quad I_{G2} = 2, \quad m_3 = 3 \text{ and } I_{G3} = 3.$$

a) Use MATLAB to plot the path of point G_2 for $0 \le t \le 12$

b) At $t = 2$, determine
- angular velocities of Link 2 and Link 3
- angular accelerations of Link 2 and Link 3
- velocity and acceleration vectors of the mass centres of Link 2 and Link 3
- force vectors at B, C and D
- torque T required to drive Link 1

c) Write a MATLAB program to plot the torque T versus θ_1 for $0 \le t \le 12$ (you are required to submit the softcopy of your program)

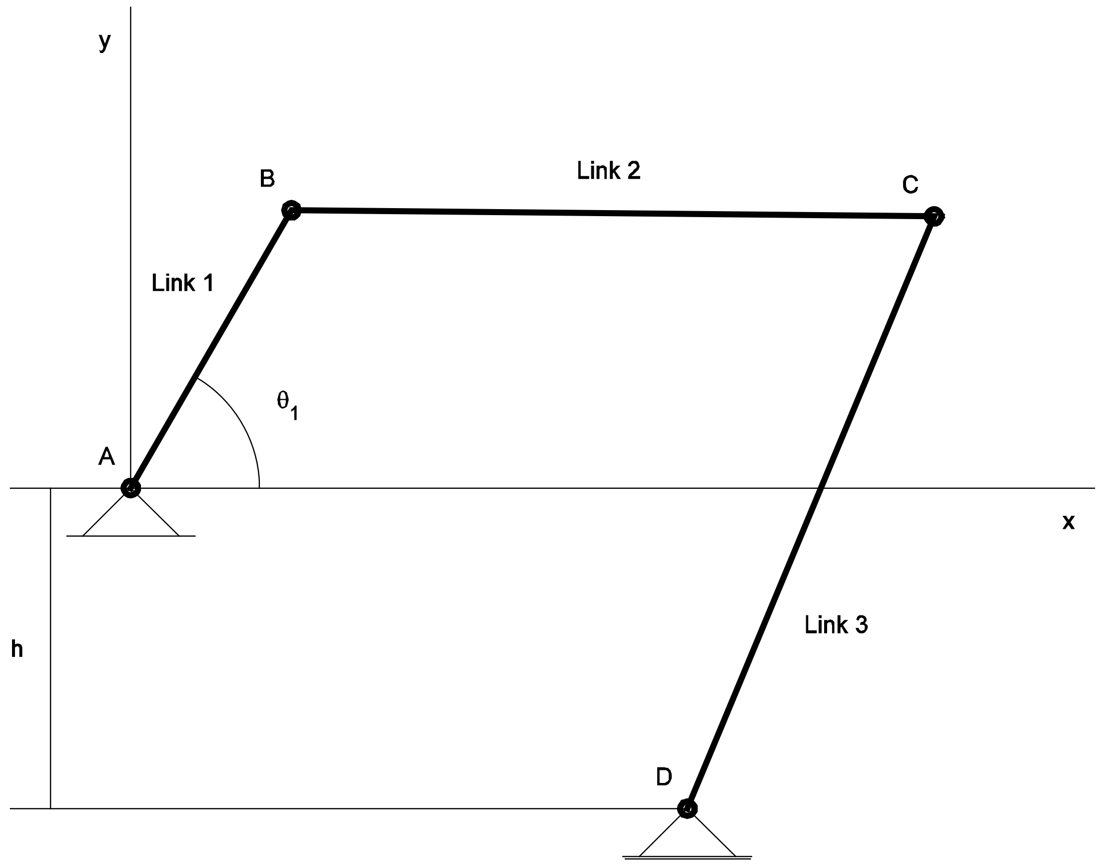

Figure 3

Past examination

STUDENT NAME:	*STUDENT NO.:*

UNIVERSITY OF SOUTHERN QUEENSLAND

FACULTY OF ENGINEERING AND SURVEYING

Course No: MEC3403 **Course Name: DYNAMICS II**

Assessment No:	Internal X External X	**This examination carries 70% of the total assessment for this course**
Examiner: AHMAD SHARIFIAN		**Moderator: NAM MAI-DUY**

Examination Date: NOVEMBER, 2009

Time Allowed: Perusal – Ten (10) minutes
Working – Two (2) hours

Special Instructions:

This is an **OPEN** examination.
Candidates may have access to any printed or written material and a calculator during an examination.
NO electronic devices are permitted.

Students are permitted to write on the question paper during perusal time.

Attempt **ALL FOUR** questions, which are **NOT** of equal value.

All examination question papers must be submitted to supervisors at the end of every examination and returned to USQ.

Start each question on a new page and label each question clearly.

QUESTION 1 **(250 Marks)**

Part I: 150 marks

Consider the rotor modeled by three concentrated masses as shown in Figure 1a.

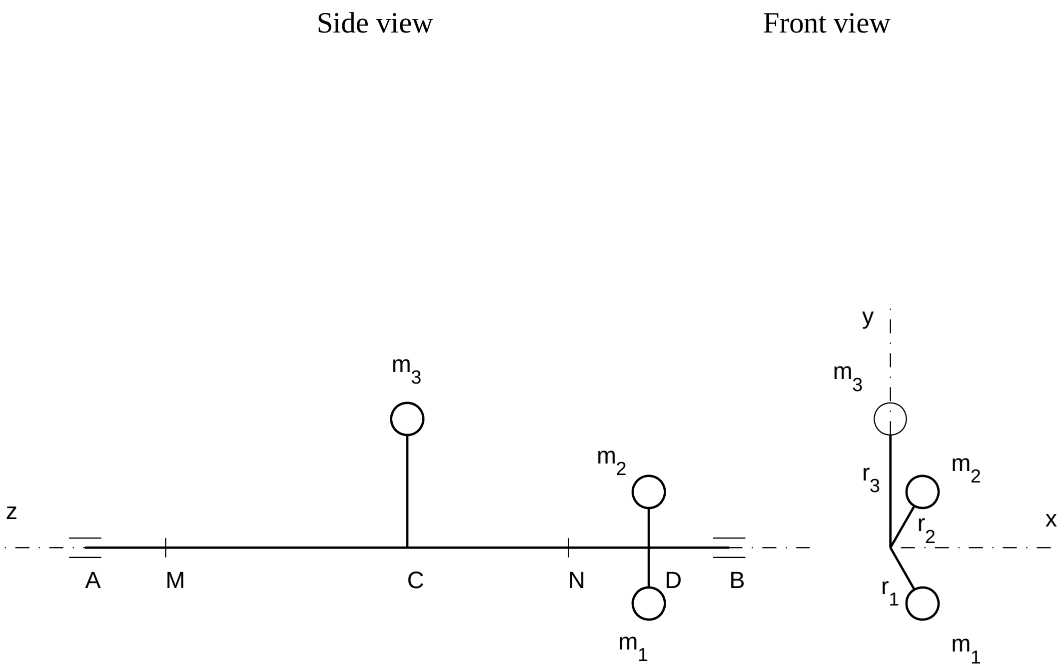

Figure 1a

$m_1 = 1\,\text{kg}, \quad m_2 = 1\,\text{kg}, \quad m_3 = 1\,\text{kg},$
$r_1 = 20\,\text{cm}, \quad r_2 = 20\,\text{cm}, \quad r_3 = 40\,\text{cm},$
$\text{MC} = 0.75\,\text{m}, \quad \text{CD} = 0.75\text{m}, \quad \text{ND} = 0.25\text{m}$
(Assume that the mass of the shaft AB is negligible).

For the position shown (i.e. $\theta_1 = -60^o$, $\theta_2 = 60^o$ and $\theta_3 = 90^o$), determine the corrections needed to balance the rotor dynamically for the following two cases:

(i) Adding two concentrated masses m_{c1} and m_{c2} to the two transverse planes D and C, respectively. (50 marks)

(ii) Adding two concentrated masses m_{c1} and m_{c2} to the two transverse planes N and M, respectively. (100 marks)

<u>QUESTION 1</u> (Cont'd)

Part II: 100 marks

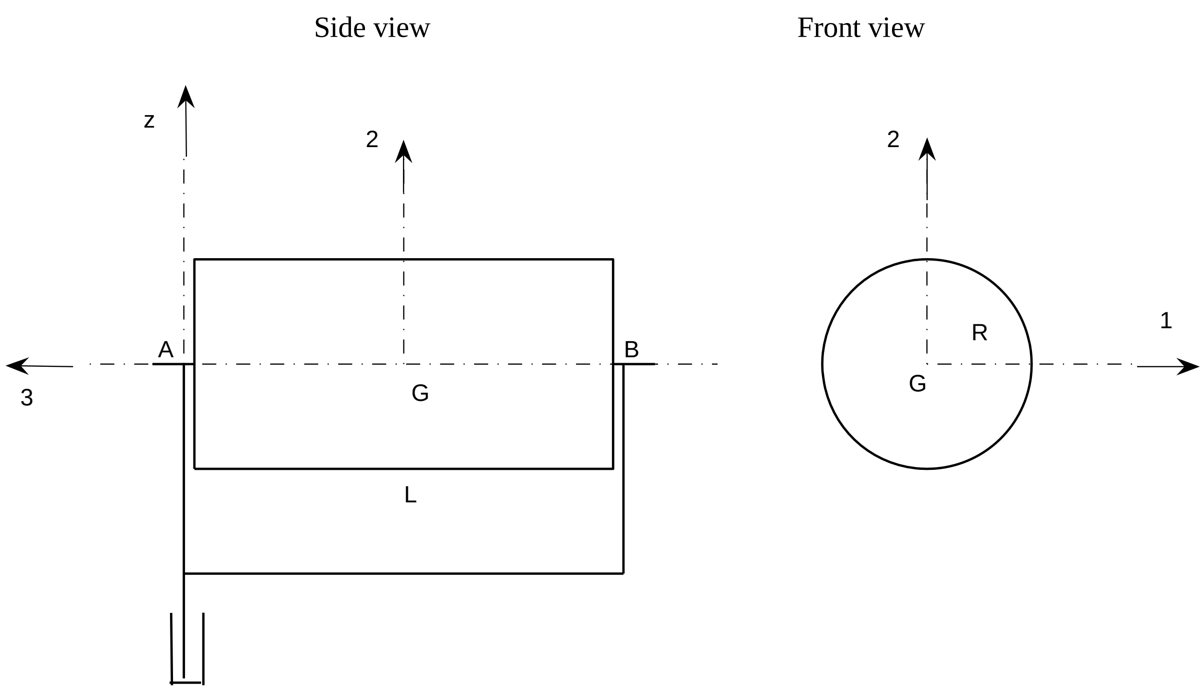

Figure 1b

Figure 1b shows the circular cylinder of mass $m = 16\,\mathrm{kg}$, length $L = 2\,\mathrm{m}$ and radius $R = 0.5\,\mathrm{m}$ turning with constant angular velocity of $\omega = 4$ rad/s about the horizontal shaft AB ($\vec{\omega} = +4\vec{e}_3$). The supporting vertical shaft rotates about the fixed z axis with constant angular velocity of $\Omega = 2$ rad/s ($\Omega = +2\vec{k}$). It is noted that the two bearings at A and B are attached rigidly to the supporting vertical shaft; G is the centre of mass of the cylinder; GA and GB can be approximately taken as $L/2$; and $\vec{e}_3$ and $\vec{k}$ are the two unit vectors which are associated with the 3-axis and the z-axis, respectively.

(i) Find the gyroscopic moment vector exerted on the cylinder

(50 marks)

(ii) Find the dynamic force vectors acting on the bearings A and B. The bearing A cannot support a force in the 3 direction, whereas the bearing B does.

(50 marks)

<u>QUESTION 2</u> **(100 marks)**

The system properties are m=0.4 kg, k=1400 N/m, and c is such that the system is critically damped. The block is given an initial velocity of 10 m/s to the left with the spring compressed by 30 mm. Assume that the surface is sufficiently smooth so that friction may be neglected.

a) Determine the ensuing displacement $x(t)$ of the spring. (70 marks)

b) Determine the earliest time at which x=0. (30 marks)

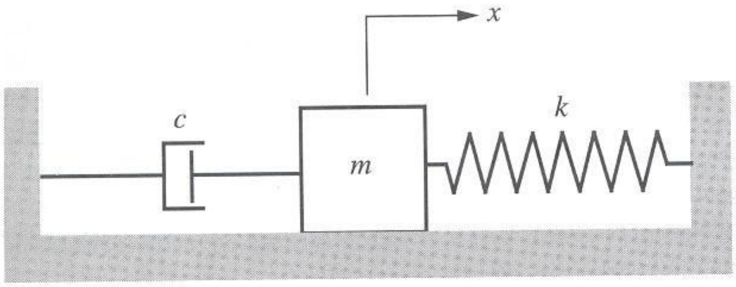

Figure 2

<u>QUESTION 3</u> **(150 marks)**

Consider a simple model of an airplane wing given in Fig. 3. The wing is approximated as vibrating back and forth in its plane, massless compared to the missile carriage system of mass m. The Elastic modulus and moment of inertia of the wing are approximated by E and I, respectively, and l is the length of the wing. The wing is modeled as simple cantilever for the purpose of estimating the vibration resulting from the release of the missile, which is approximated by the impulse function F.δ(t). Calculate the response for the case of an aluminum wing 4 m long with m=1000 kg, ξ=0.01, E= 69 $\times 10^9$ Pa, and I=0.5 m^4. Model F as 1000 N lasting over 10^{-4} s.

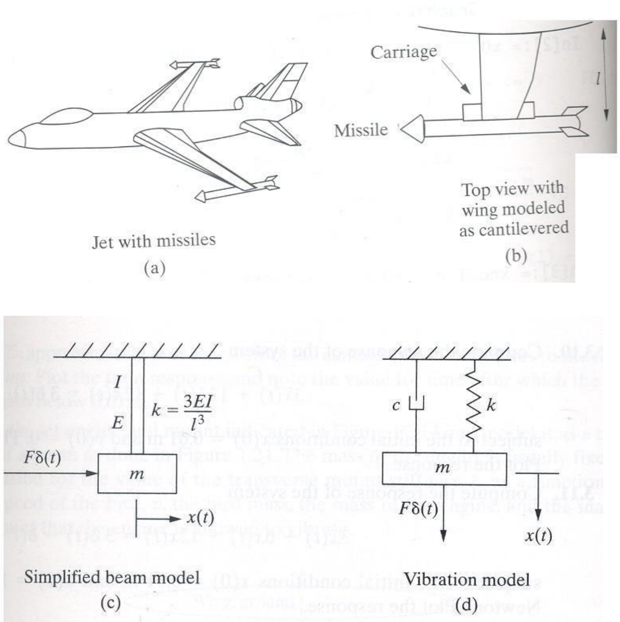

Figure 3

QUESTION 4 **(200 marks)**

Two subway cars of Fig. 4 have 2000 kg mass each and are connected by a coupler. The coupler can be modeled as a spring of stiffness of K=280,000 N/m.

a) Write the equation of motion. (50 marks)

b) Calculate the natural frequencies of the system. (50 marks)

c) Find the modal matrix of the system. (50 marks)

d) Plot the normalized mode shapes of the system. (50 marks)

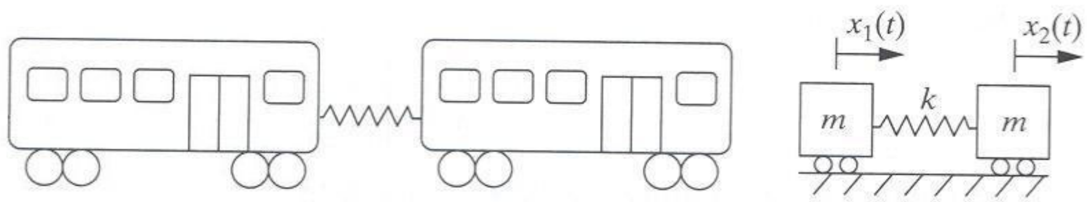

Figure 4

END OF EXAMINATION