NUS National University of Singapore

ME2115/ME2115E/TME2115 -

Mechanics of Machines

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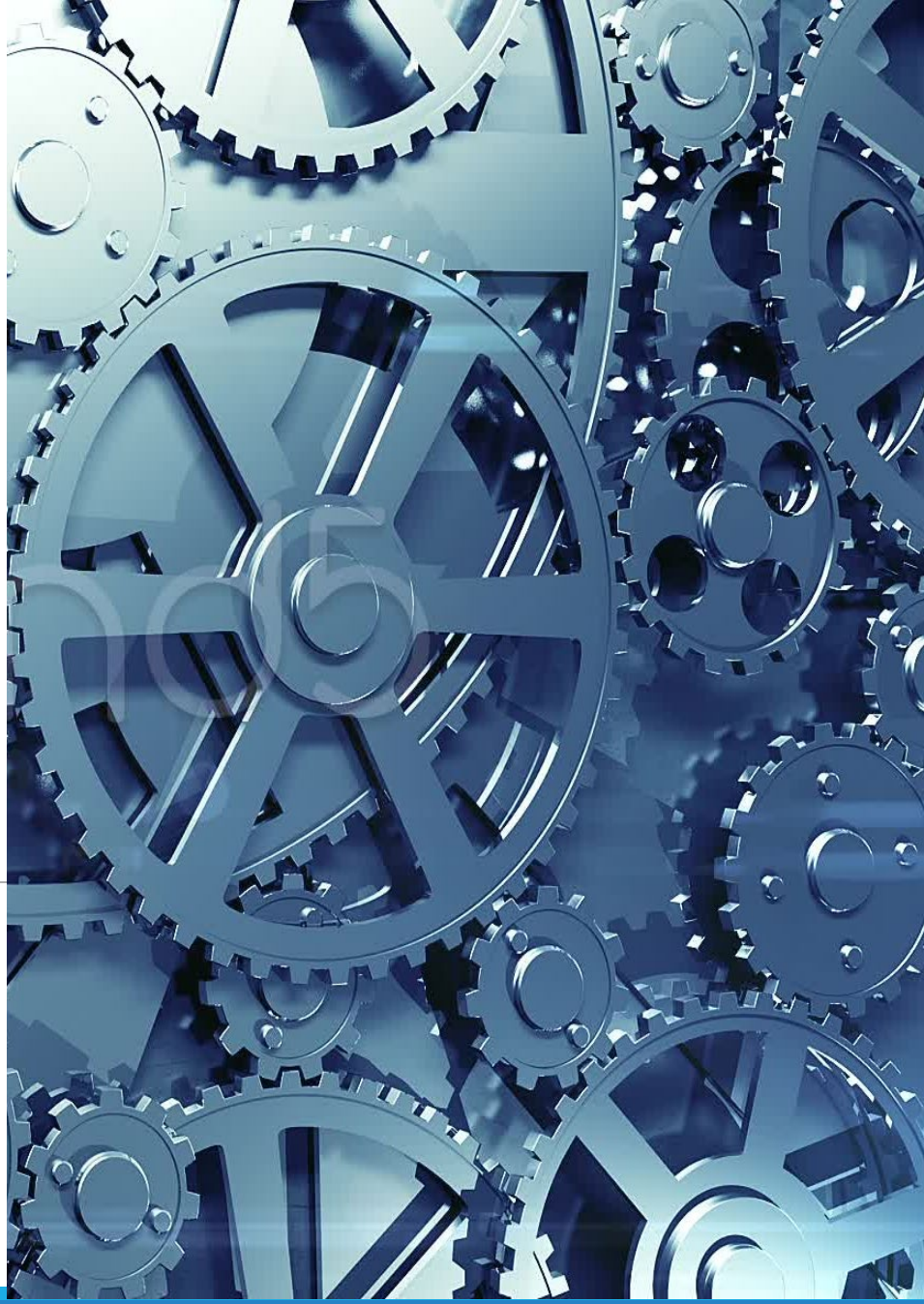


Introduction

LECTURES – You are expected to attend all lectures. There are 3h lectures per week. Please do read the lecture notes and recommended materials before class, which is especially important for e-learning.

TUTORIALS – You are expected to attend all tutorials. There are 5 tutorials for this module, and each session is about 1 hour. Tutorials will start in Week 3. Tutorial questions are given to you 1-week early and you should attempt them before attending the tutorial lesson. Your tutors and instructors will facilitate learning by clarifying any doubts and answering queries that you may have. The contact of tutors can be found in LumiNUS/Module details/Facilitators.

Laboratory session – The first lab session is a physical experiment (**E1-02-03**) and you need to book a time slot. The second one is a simulation using SOLIDWORKS software (download link will be provided in recess week).

WEBSITE – The module information, such as lecture notes, tutorials/solutions, announcement, and practice problems, can be obtained from the LumiNUS.

NOTICE – You are expected to devote sufficient time to master the module materials. It is unreasonable to expect that good performance can be achieved without study and that is especially true for this module. You should devote about 2 hours outside of class for every hour in class.

Grading format

The grading is based on two lab reports, participation of self-evaluation quizzes, and final exam

- Lab 1: Vibration lab (E1-02-03; from week 3) (14%)
- Lab 2: SOLIDWORKS-motion study assignment (Simulation, Take- Home Assignment) (20%)
- Online self-evaluation quizzes (6% for participation)
- 2-hour Final exam (60%): pen-and-paper; closed-book (one page of A4-size cheat-sheet)

Online self-evaluation new

In order to provide personalized, continuous, and detailed feedback for each student, we will provide 6 self-evaluation quizzes in the LumiNUS after completing each chapter for your practice and self-evaluation. The instructors will also provide more personalized practice questions to the student according to his/her self-evaluation results.

Please note that the results of such self-evaluation have no credit, but participation of all self-evaluation quizzes will be given 6 marks. We believe that good understanding of the concepts and ability of solving practice problems will be of great help for the final exam*. Thus, we strongly suggest students to do such test questions on their own. We then can provide personalized practice questions to help you to master the concepts chapter by chapter.

Statistics on relationship between self-evaluation participation and final marks

Quiz 1	Quiz 2	Quiz 3	Quiz 4	Quiz 5	Quiz 6	Quiz 7
11	7	10	3	4	7	5
11	8	10	4	0	6	7
10	9	7	4	4	4	3
11	8	8	5	4	5	4
11	8	8	4	3	4	7
10	7	6	4	0	4	0
0	8	6	3	3	0	3
10	2				2	0
10	8				2	3
10	8				2	4
9	6				4	5
11	8				5	4
5	1				0	0
11	6	0	0	0	5	2
9	8	8	0	0	0	0
12	9	5	4	0	6	3
11	7	8	4	0	5	1
11	9	4	0	0	6	0
9	7	5	0	0	3	0
11	7	6	4	4	0	0
11	7	6	4	4	5	4
12	7	7	4	2	2	4
9	6	7	3	4	3	3

80%

0 means not taken

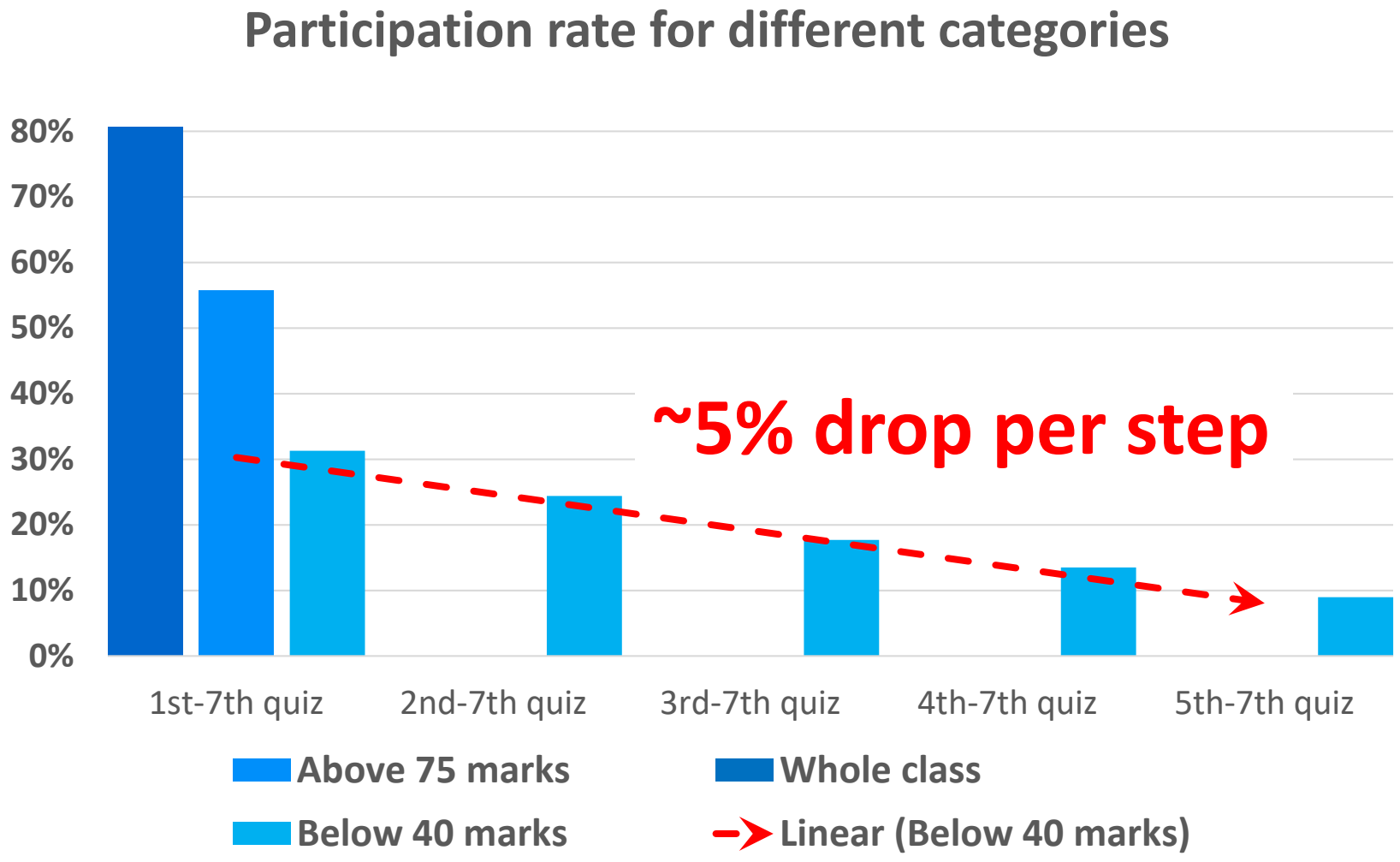
Quiz 1	Quiz 2	Quiz 3	Quiz 4	Quiz 5	Quiz 6	Quiz 7
0	9	7	4	0	5	3
9	7	0	5	0	0	0
10	6	9	5	0	0	0
8	4	4	3	0	3	0
7	0	0	0	0	0	0
0	4	5	0	0	3	0
12	6	0	0	0	2	0
9	4	0	0	0	0	0
10	0				0	0
0	0				0	0
8	8				0	0
12	9				0	0
0	0				0	0
8	0				0	0
0	1				0	0
12	0	0	0	0	0	0
11	9	0	4	0	4	0
12	7	2	0	0	0	0
12	6	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
8	0	0	0	0	0	0
11	6	7	3	0	3	0
12	7	8	0	0	0	0
11	0	0	0	0	0	0
9	0	0	0	0	0	0

30%

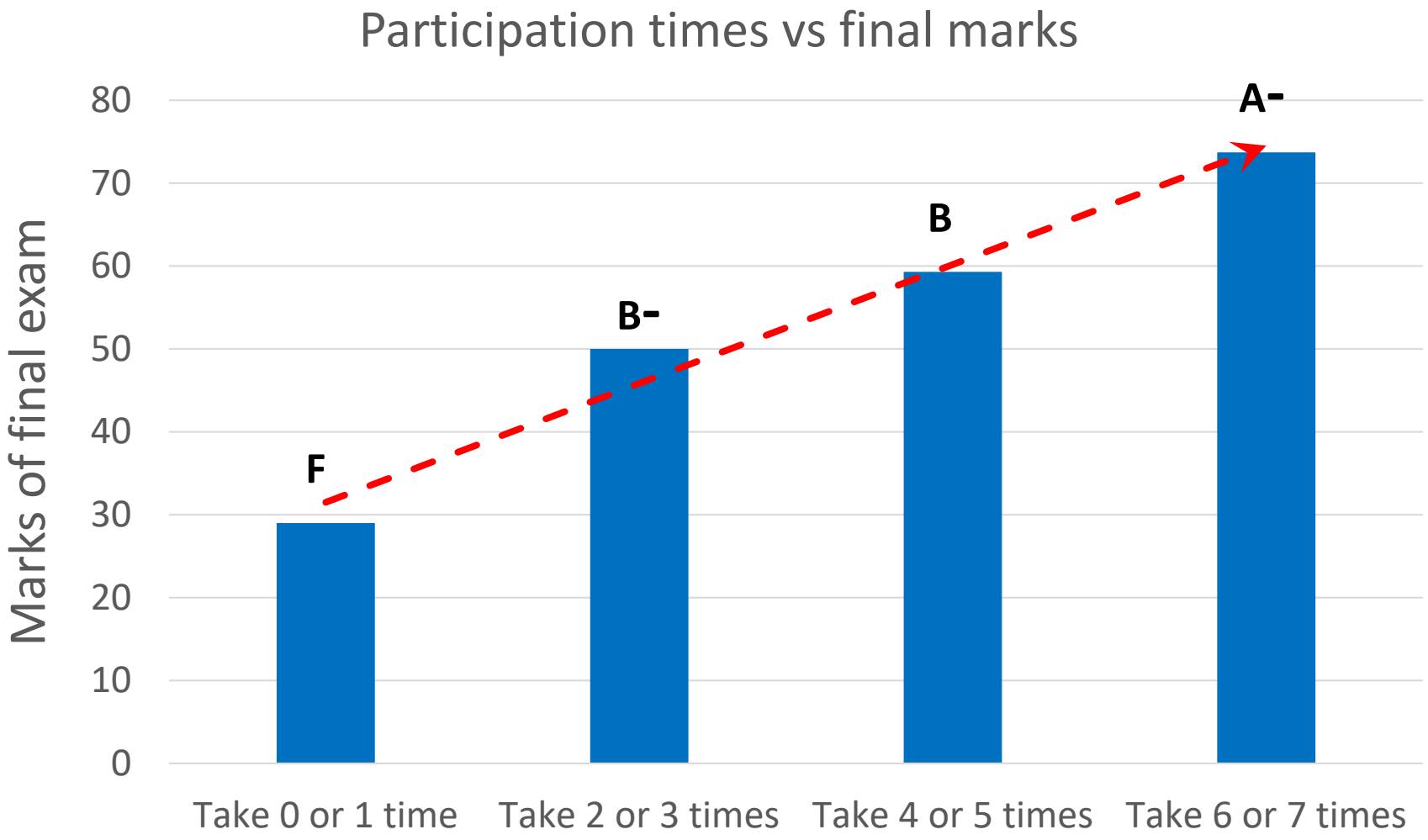
Above 75 (final marks)

Below 40 (final marks)

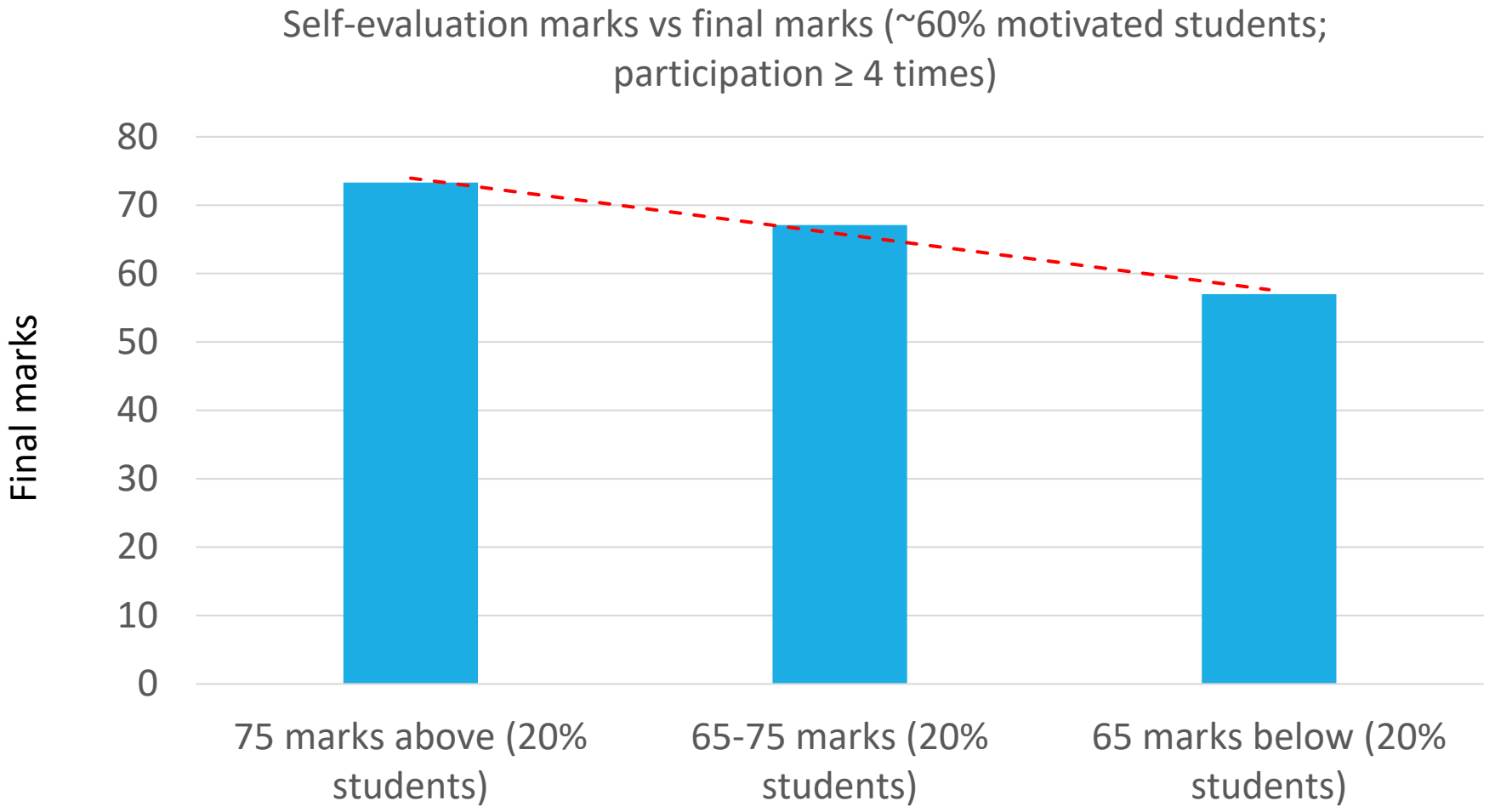
Statistics on relationship between self-evaluation participation and final marks



Statistics on relationship between self-evaluation participation and final marks



Statistics on relationship between self-evaluation participation and final marks



Conclusion: a strong relationship between the self-evaluations and final!
Student performance, question difficulty

Laboratory session

- The first lab session is a physical experiment and you need to book the time slot.
- For changing of lab schedule after you have booked the time slot, please contact any of the lab technicians** at E1-02-03 (+65 65162235).
- Dr ONG Eng Teo is the coordinator for the second virtual lab of SOLIDWORKS. Please contact him if there is any query.

**You can find the contact details of lab coordinator and technicians in LumiNUS/Module details/Facilitators

OBJECTIVE

The primary objective of this module is to introduce students to the fundamental concepts and principles of **dynamics & vibration** of **machines** and their applications to solve practical problems.

More importantly, it is hoped that the students will develop the ability to analyse any problem from a simple and rational perspective using well-understood, basic principles.

The study of mechanics of machines provides the foundation for further study in many disciplines such as structural engineering, mechanical behaviour of materials.

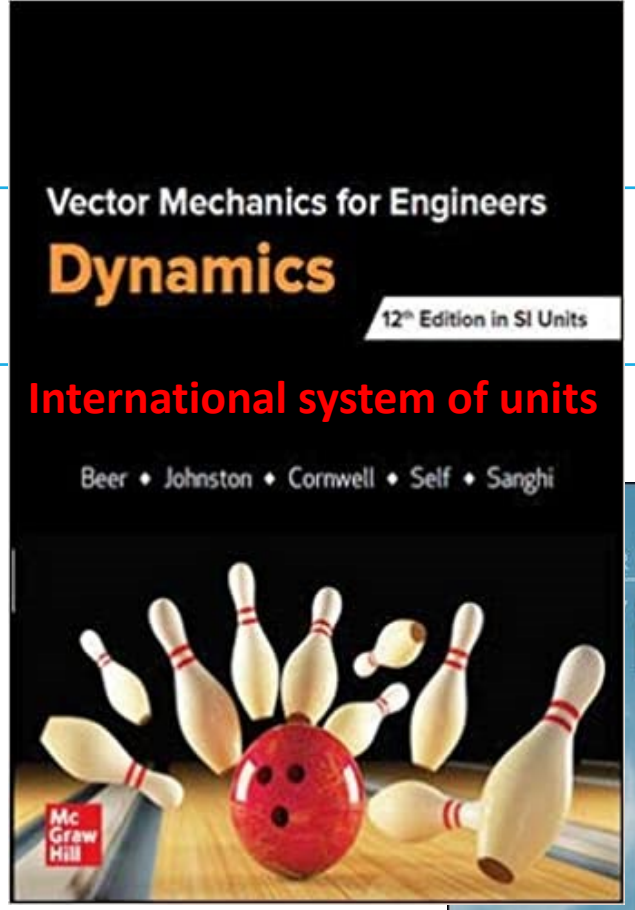
LEARNING OUTCOMES

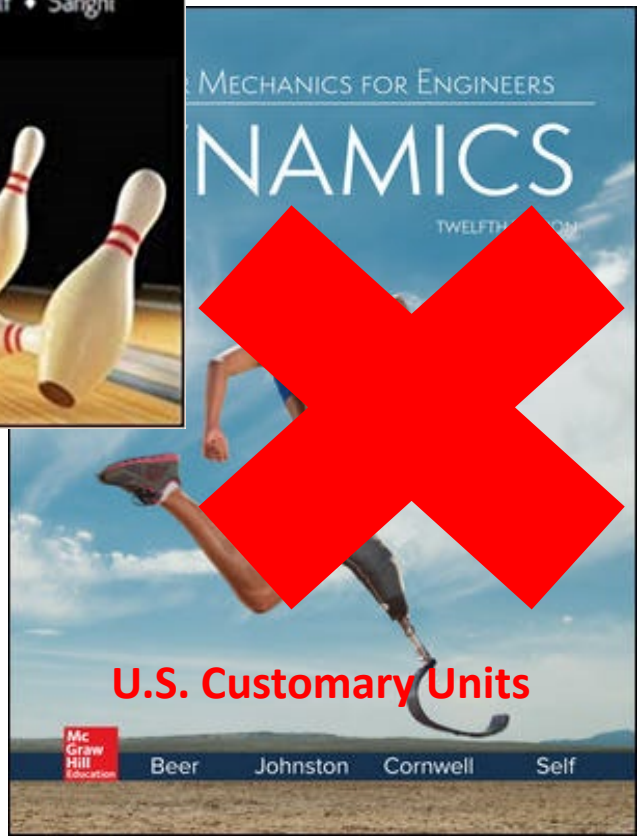
At the end of this course, students are expected to be able to

- Draw a free body diagram and identify the unknown reaction forces/moments acting on the free body
- Use vector algebra and write the equilibrium equations to solve dynamically determinate problems involving rigid bodies.
- Solve kinematics problems for the velocities and accelerations of rigid bodies in motion.
- Determine mass properties, such as centre of mass and moment of inertia.
- Solve kinetic problems for the forces and motion of rigid bodies.
- Understand the principle of work and energy, and using it to solve dynamic problems.
- Understand free vibration of single-DOF system, its characteristic parameters such as natural frequency, damping ratio, etc.
- Understand forced harmonic vibration of single-DOF system, i.e. its steady-state response to harmonic excitations.

Text book & references

The recommended text is Beer and Johnston (*Vector Mechanics for Engineers, Dynamics*, **SI Unit edition**). The latest is the 12th edition, but no big difference between 9th, 10th, 11thand 12th





References:

- Hibbeler, R.C. *Engineering Mechanics: Statics and Dynamics – in SI Units*. 14th ed., Prentice-Hall, Pearson Education, Singapore, 2016.
- James L. Meriam, L. G. Kraige, Jeffrey N. Bolton. *Engineering Mechanics: Dynamics - SI version*. 8th ed., Wiley, 2016.
- Shames, I.H., *Engineering Mechanics: Statics and Dynamics. SI Edition*, Prentice-Hall, Inc. New Jersey, USA, 2005.

SYLLABUS FOR PART I (16 hours)

Introduction to Mechanics, review of vectors, and Free body diagram (2 hours)

Fundamental concepts and principles of mechanics; Vector and its operation; How to draw F.B.D.

Review of kinematics of particles(2 hours) Chapter 11 (partial)

Rectilinear motion, curvilinear motion, relative motion and constrained motion of connected particles, components of velocity and acceleration in different coordinate systems

Kinematics of RBs and mass properties (6 hours) Chapter 15, 5, 9 (partial)

Rotation, absolute motion, relative motion, instantaneous centre of rotation, centre of gravity, mass moment of inertia.

Kinetics of Rigid Bodies (6 hours) Chapter 16 (partial)

Effect force diagram, plane motion of a rigid body, constrained plane motion.

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SYLLABUS FOR PART II (15 hours)

Review on basic mechanics from Part I (2 hours)
Recap some key concepts on mechanics study that will also be used in Part II.

Principle of work and energy (3 hours) **Chapter 17.1~17.5 only**
Kinetic energy of rigid body, potential energy by conservative forces, conservation of energy.

Free vibration without damping (3 hours) **Chapter 19.1~19.6**
Deriving equation of motion, characteristic equation, natural frequency.

Free vibration with damping (3 hours) **Chapter 19.8**
Damped free vibration motion, exponential decaying oscillation, damping ratio and oscillating frequency

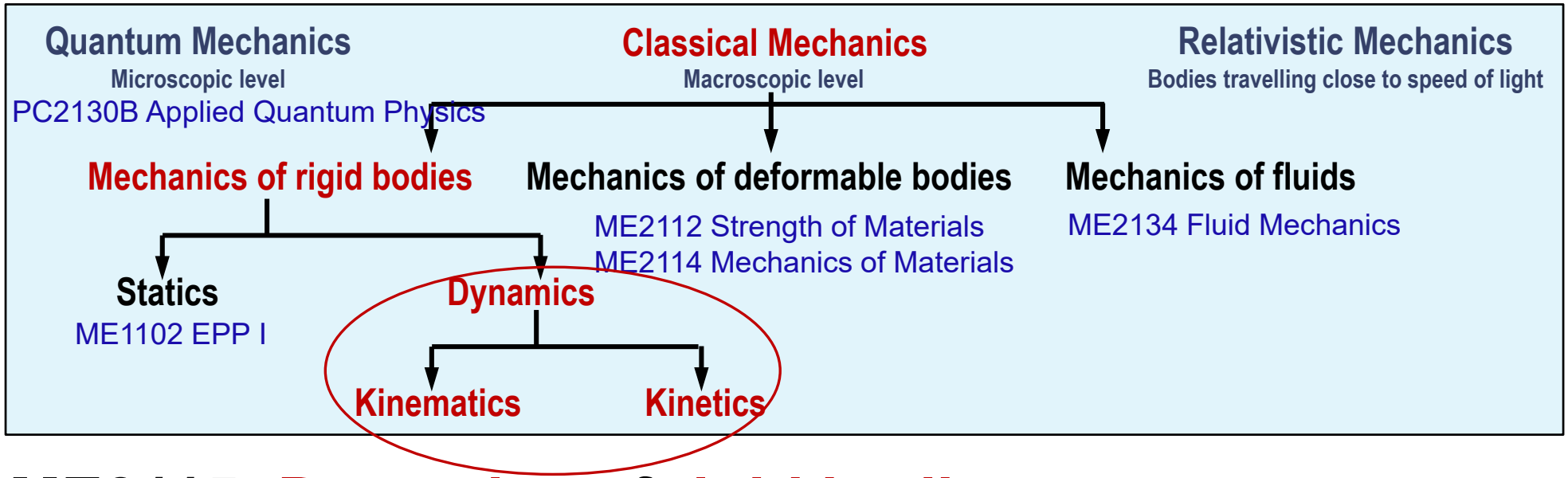
Forced harmonic vibration (4 hours) **Chapter 19.7 & 19.9**
Forced harmonic responses due to applied force and based excitation, resonance.

Schedule

Week	Date	Lecture	Tutorial	Remark
1	8 & 10 Aug	Introduction, vectors and units		No tutorial
2	15 &17 Aug	Review of kinematics of particles		No tutorial
3	22 & 24 Aug	Kinematics of rigid bodies	Tutorial 1	
4	29 & 31 Aug	Mass properties	Tutorial 1	
5	5 & 9 Sep	Kinetics of rigid bodies (I)	Tutorial 2	
6	12 & 14 Sep	Kinetics of rigid bodies (II)	Tutorial 2	
Rec	17 – 25 Sep			
7	26 & 28 Sep	Principle of work and energy (I)	Tutorial 3	
8	3 & 5 Oct	Principle of work and energy (II)	Tutorial 3	
9	10 & 12 Oct	Vibration (I)	Tutorial 4	
10	17 & 19 Oct	Vibration (II)	Tutorial 4	
11	24 & 26 Oct	Vibration (II)	Tutorial 5	24 Oct is PH, no class
12	31 Oct & 2 Nov	Vibration (IV)	Tutorial 5	
13	7 & 9 Nov	Study break		No class
	22 Nov 9-11am			2-h Final exam

What is Mechanics?

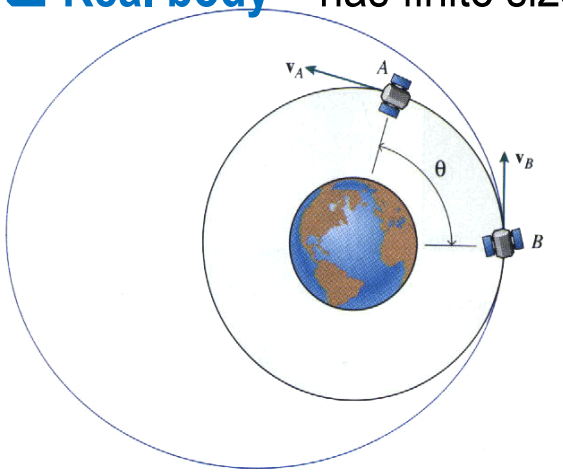
- Mechanics is that branch of science which describes and predicts the conditions of rest or motion of bodies under the action of forces.
- It is an applied science, not an abstract/pure science.
- Mechanics is the foundation of most engineering sciences and an indispensable prerequisite to their study.

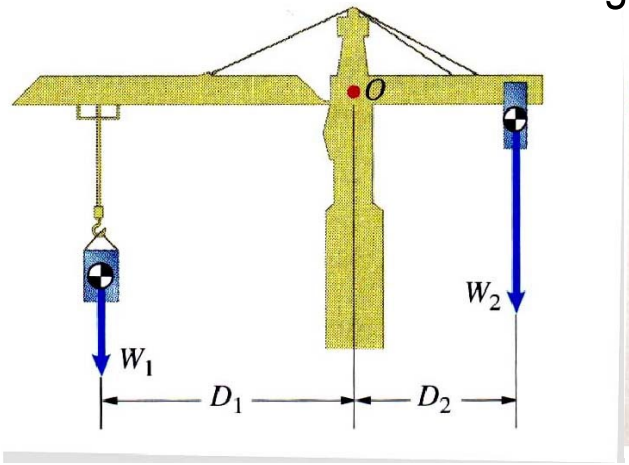


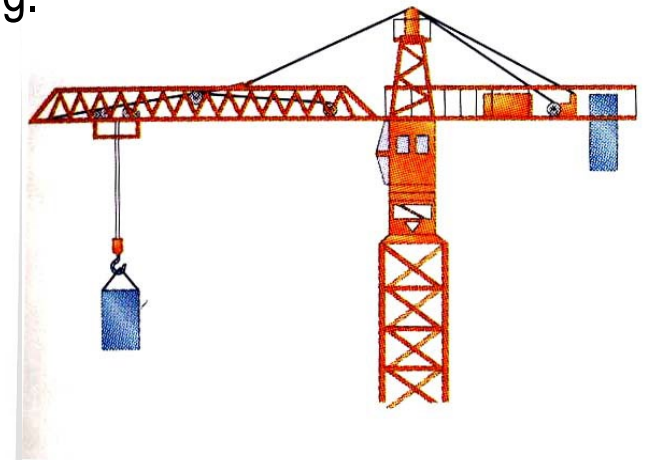
ME2115: Dynamics of rigid bodies

Bodies

- **Particle** – relatively small amount of matter which may be assumed to occupy a single point in space (has mass, but size can be neglected).
- **Rigid body (focus of ME2115)** – combination of large amount of particles occupying fixed position with respect to each other. Finite size and does not deform. (any two points on rigid body have fixed distance).
- **Real body** – has finite size, and is deformable under loading.







No very clear boundary between them

Motions

- **Statics** – Dealing with particles/rigid-bodies at rest.
- **Dynamics (focus of ME2115)** – Dealing with the analysis of particles/rigid-bodies in motion, which is subdivided by kinematics and kinetics.
- **Kinematics** – study of the geometry of motion. Kinematics is used to related ***r, v, a***, and *t*, without reference to the cause of the motion. For example, $x\text{-}x_0=vt$, $v\text{-}v_0=at$.
- **Kinetics** – study of the relation between the force (***f***), mass (*m*), and motion of the body (***a***). Kinetics is used to predict the motion caused by given forces or to determine the forces required to produce a given motion. For example, Newton's 2nd law $\boldsymbol{f}=m\boldsymbol{a}$.

Quantities and units

Basic Quantities:

x	*length*
m	*mass*
t	*time*
F	*force*

In Newtonian mechanics, these are absolute quantities, independent of each other. But force is dependent on the three.

Systems of Units:

In mechanics, we usually use SI units (MKS), i.e., three *basic units* of length (meter, *m*), mass (kilogram, *kg*), and time (second, *s*). The *derived unit* of the force is Newton (*N*). $1N = 1kg \cdot m/s^2$

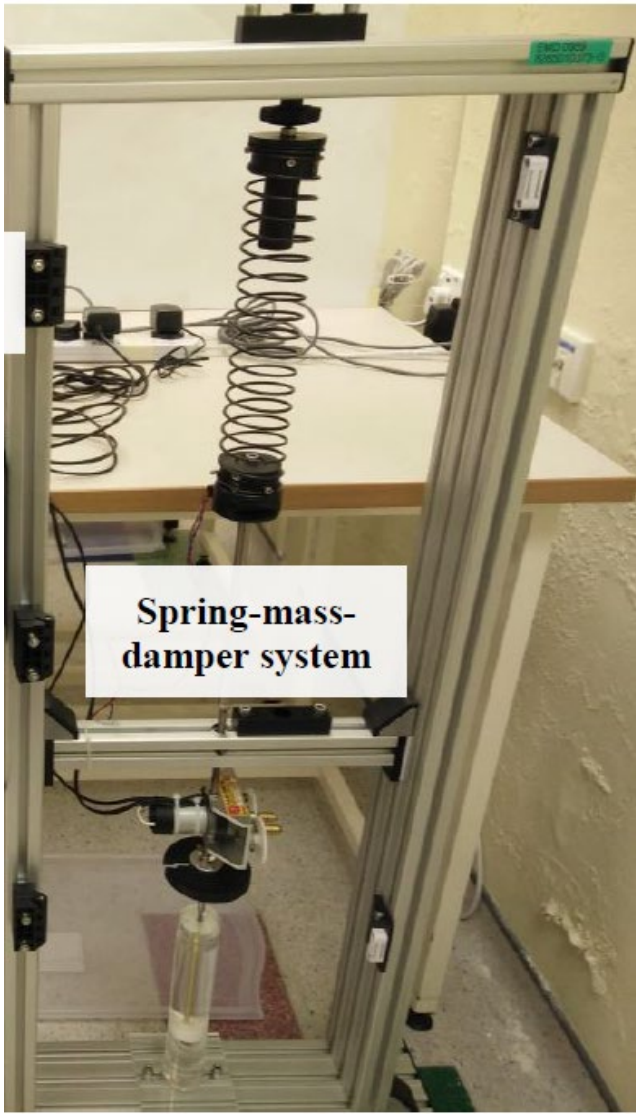
Remember to convert other units into SI units when solve mechanics problems!

How to study mechanics?

1) Theory $\boldsymbol{F} = m\boldsymbol{a}$ $\omega = \sqrt{k/m}$

2) Experiment

3) Computational simulation



Conclusion

- Machines and mechanisms can come in different shapes and sizes, and also various degrees of complexity.
- They can be planar or spatial. We will focus on the analysis of planar mechanisms in ME2115.
- They can be fabricated by traditional manufacturing processes (casting, machining etc), and more recently by 3D printing.

Summary of this module

- Using the vector approach to study dynamics of rigid bodies
- We will focus on the analysis of two-dimensional planar motion of mechanisms.
- All physical quantities are in SI units.