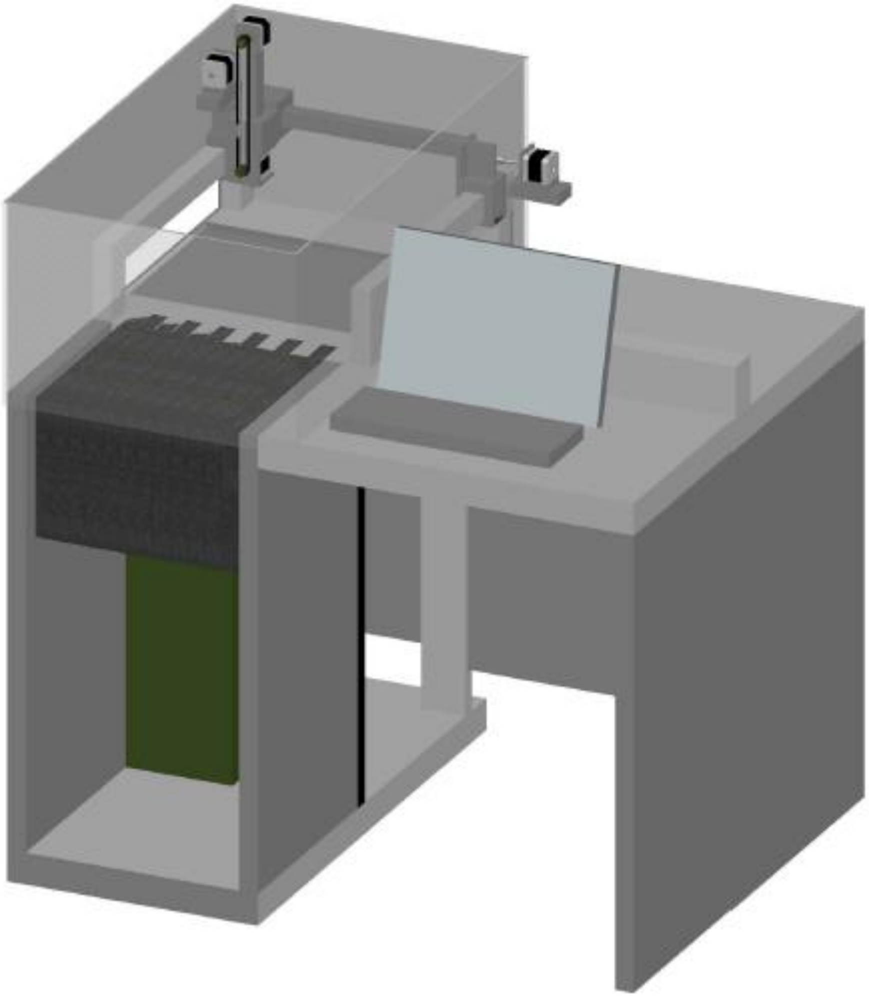
# MEC 3705 (ME375) – DYNAMICS



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# MEC3705 - COURSE OUTLINE

## PART I: Dynamics of Particles

- **Introduction to Dynamics**
- **Kinematics of Particles**
- **Kinetics of Particles**
- **Kinetics of Systems of Particles**

# MEC3705 - COURSE OUTLINE

## PART II: Dynamics of Rigid Bodies

- **Plane Kinematics of Rigid Bodies**
- **Plane Kinetics of Rigid Bodies**
- **Introduction to Three Dimensional Dynamics of Rigid Bodies**
- **Vibration and Time Response**

# TEXTBOOKS

- James L. Meriam and L. G. Krage*, Dynamics*, , Volume 2, 198- John Wiley & Sons

# Grades and distribution of marks

- Attendance (min 80%)

- Laboratory 15%
- Tutorials and Assignments 5%
- **Mid Term Exam 20%**
- Final Exam 60%

# Course management

- E-learning website
- Assignment shall be due the following week on the same day the assignment was given unless prior arrangement is made for any changes
- Quizzes will be handed in at the end of the session
- Labs will be due 7 days from date of experiment

# Conclusion

This has been the introduction to this course.

Questions?


Courtesy NASA

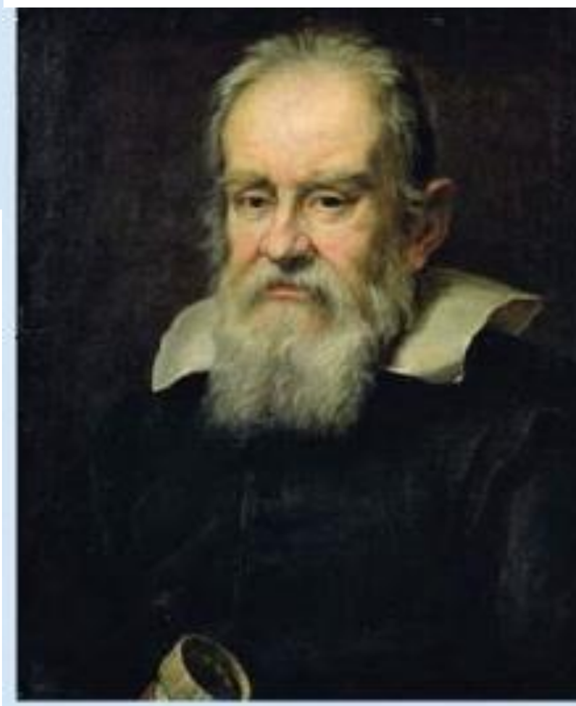
**A Delta II rocket with the Mars rover "Spirit" aboard lifting off from Cape Canaveral on June 10, 2003. The spacecraft was subject to the laws of motion as it passed through the Earth's atmosphere as part of its launch vehicle, traveled through space to the vicinity of Mars, entered the Martian atmosphere, and finally landed on the surface of Mars.**

## 1/1 History and Modern Applications

Dynamics is that branch of mechanics which deals with the motion of bodies under the action of forces. The study of dynamics in engineering usually follows the study of statics, which deals with the effects of forces on bodies at rest. Dynamics has two distinct parts: *kinematics*, which is the study of motion without reference to the forces which cause motion, and *kinetics*, which relates the action of forces on bodies to their resulting motions. A thorough comprehension of dynamics will provide one of the most useful and powerful tools for analysis in engineering.

## History of Dynamics

Dynamics is a relatively recent subject compared with statics. The beginning of a rational understanding of dynamics is credited to Galileo (1564–1642), who made careful observations concerning bodies in free fall, motion on an inclined plane, and motion of the pendulum. He was largely responsible for bringing a scientific approach to the investigation of physical problems. Galileo was continually under severe criticism for refusing to accept the established beliefs of his day, such as the philosophies of Aristotle which held, for example, that heavy bodies fall more rapidly than light bodies. The lack of accurate means for the measurement of time was a severe handicap to Galileo, and further significant development in dynamics awaited the invention of the pendulum clock by Huygens in 1657.



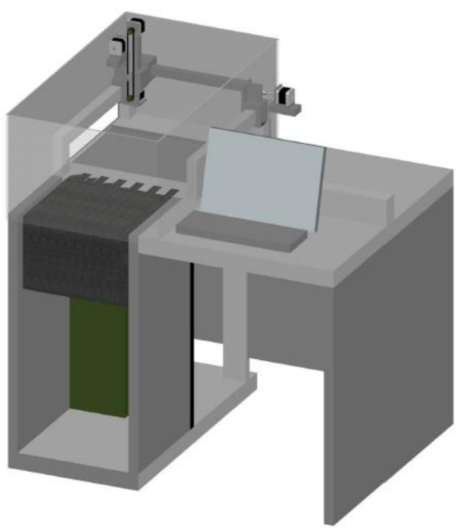
**Galileo Galilei**

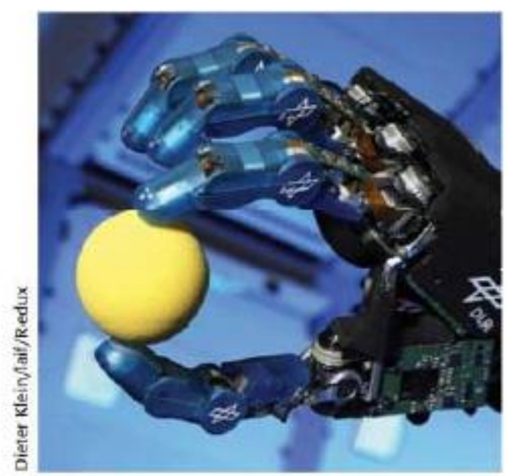
Portrait of Galileo Galilei (1564–1642) (oil on canvas), Sustermans, Justus (1597–1681) (school of)/Galleria Palatina, Florence, Italy/Bridgeman Art Library

Newton (1642–1727), guided by Galileo's work, was able to make an accurate formulation of the laws of motion and, thus, to place dynamics on a sound basis. Newton's famous work was published in the first edition of his *Principia*,* which is generally recognized as one of the greatest of all recorded contributions to knowledge. In addition to stating the laws governing the motion of a particle, Newton was the first to correctly formulate the law of universal gravitation. Although his mathematical description was accurate, he felt that the concept of remote transmission of gravitational force without a supporting medium was an absurd notion. Following Newton's time, important contributions to mechanics were made by Euler, D'Alembert, Lagrange, Laplace, Poinsot, Coriolis, Einstein, and others.

## Applications of Dynamics

Only since machines and structures have operated with high speeds and appreciable accelerations has it been necessary to make calculations based on the principles of dynamics rather than on the principles of statics. The rapid technological developments of the present day require *increasing application of the principles of mechanics, particularly dynamics.* These principles are basic to the analysis and design of moving structures, to fixed structures subject to shock loads, to robotic devices, to automatic control systems, to rockets, missiles, and spacecraft, to ground and air transportation vehicles, to electron ballistics of electrical devices, and to machinery of all types such as turbines, pumps, reciprocating engines, hoists, machine tools, etc.






**Robot hand**


A Delta II rocket with the Mars rover "Spirit" aboard lifting off from Cape Canaveral on June 10, 2003. The spacecraft was subject to the laws of motion as it passed through the Earth's atmosphere as part of its launch vehicle, traveled through space to the vicinity of Mars, entered the Martian atmosphere, and finally landed on the surface of Mars.

# PART I

## DYNAMICS OF PARTICLES

# INTRODUCTION

- Dynamics is that branch of mechanics which deals with the motion of bodies under the action of forces

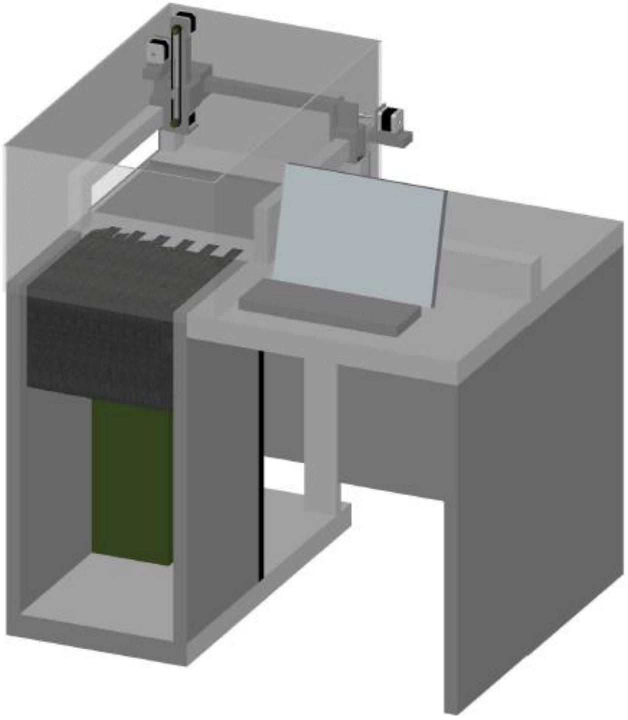
- Dynamics has two distinct parts
- – kinematics, study of motion without reference to the forces on bodies which cause the motion and

- - kinetics, relates the action of forces on bodies to resulting motions

## 1.1 Basic Concepts:

- **Space** – is a geometric region occupied by bodies.
- ***Position in space -*** is determined relative to some geometric reference system by means of linear or angular measurements
- **Time** - is a measure of the succession of events and is considered an absolute quantity in Newtonian mechanics.
- **Mass -** is the quantitative measure of the inertia or resistance to change in motion of a body.
- **Force** - vector action of one body on another

- Pick and place Machine at UNZA



## Basic concepts continued..

- **A particle** is a body of negligible dimensions, also when dimensions of a body are irrelevant to the description of its motion or action of forces

- A **rigid body** is a body whose changes in shape are negligible compared with the overall dimensions of the body or the changes in position of the body as a whole

- **Vector and scaler** dynamics involves the use of vector calculus. It is important to use identifying marks between vectors and scalers.

- **Vector will be in bold face in these slides**

- **Intro continued …**

## 1.2 NEWTON'S LAWS OF MOTION.

- **Law I**. A particle remains at rest or continues to move in straight line with constant velocity if there is no unbalanced force acting on it

- **Law II**. Acceleration of a particle is proportional to the resultant force acting on it and is in the direction of this force

- **Law III**. Forces of action and reaction are equal in magnitude, opposite in direction and collinear

- **Newton’s laws continued…**

- **The second law forms the basis for most of the analysis in dynamics**

$$\boldsymbol{F} = m\boldsymbol{a} \qquad (1/1)$$

- ***a*** is acceleration measured from non accelerating frame of reference

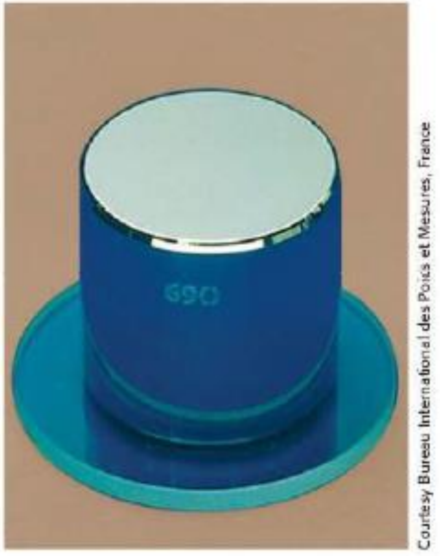
- The first law is a situation when ***F*** = *0* and therefore ***a*** = 0

- The third law was thoroughly covered in statics – *the principle of action and reaction*

- **1.3 Units (the SI units)**

- The three basic fundamental quantities of mechanics, their symbol and SI units:

- Mass (M) - Kg (kilogram)
- Length (L) – m (metre)
- Time (T) – s (second)



The standard kilogram

- **All other units will be derived units from the above three**

## 1.4 Gravitation

- **Newtons law of gravitation governs the mutual attraction of bodies as**

$$\boldsymbol{F} = \frac{Gm_1m_2}{r^2} \qquad (1/2)$$

- F - mutual force of attraction
- G - is a universal constant
- *m1, m2* = masses of two particles
- *r* = distance between centers of the particles

- **Gravitation continued …**

- $G = 6.67x10^{-11} m^3/(kg.s^2)$ universal gravitational constant

- The force of gravitational attraction of the earth on a body depends on the position of the body relative to the earth

- The earth is not a perfect sphere

- **Gravitational force**

- Every object allowed to fall in vacuum at a given position on the earth will have same acceleration *g*.

- Combining (1/1) and (1/2) and cancelling the mass representing the falling object

$$g = \frac{Gm_e}{R^2}$$

- The mass - $m_e$ and *R* - mean radius of the earth has been found to be

$$5.976x10^{24}kg$$

and

$6.371x10^{6}m$ respectively

## Gravitation continued ..

- Variation of *g* with altitude can easily be determined by gravitational law

- If *g0 represents absolute acceleration due to gravity at see level, the absolute value at height h is*

$$g = g_0 \frac{R^2}{(R + h)^2}$$

- *Acceleration due to gravity gives weight **W** = m**g***

## Effect of a Rotating Earth

The acceleration due to gravity as determined from the gravitational law is the acceleration which would be measured from a set of axes whose origin is at the center of the earth but which does not rotate with the earth. With respect to these "fixed" axes, then, this value may be termed the *absolute* value of $g$. Because the earth rotates, the acceleration of a freely falling body as measured from a position attached to the surface of the earth is slightly less than the absolute value.

Accurate values of the gravitational acceleration as measured relative to the surface of the earth account for the fact that the earth is a rotating oblate spheroid with flattening at the poles. These values may

be calculated to a high degree of accuracy from the 1980 International Gravity Formula, which is

$$g = 9.780\,327(1 + 0.005\,279 \sin^2 \gamma + 0.000\,023 \sin^4 \gamma + \cdots)$$

where $\gamma$ is the latitude and $g$ is expressed in meters per second squared. The formula is based on an ellipsoidal model of the earth and also accounts for the effect of the rotation of the earth.

## Problem formulation

1. Given data
2. Results desired
3. Necessary diagrams
4. Calculations
5. Answers and conclusions
6. .

The definition of the system to be analyzed is made clear by constructing its ***free-body diagram***. This diagram consists of a closed outline of the external boundary of the system. All bodies which contact and exert forces on the system but are not a part of it are removed and replaced by vectors representing the forces they exert on the isolated system. In this way, we make a clear distinction between the action and reaction of each force, and all forces on and external to the system are accounted for. We assume that you are familiar with the technique of drawing free-body diagrams from your prior work in statics.

Courtesy of Scaled Composites, LLC

SpaceShipOne became the first private manned spacecraft to exceed an altitude of 100 kilometers. This feat was accomplished twice within 14 days in 2004.

# References


- J.L. Meriam and L. G. Krage, Dynamics second edition /6th Edition