Mechanical Elements (Tutorials)

First-year sciences and technologies
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Objectifs

Explain the fundamentals of stitch mechanics by breaking them down into three main parts: Kinematics, Dynamics, and Work and Energy.

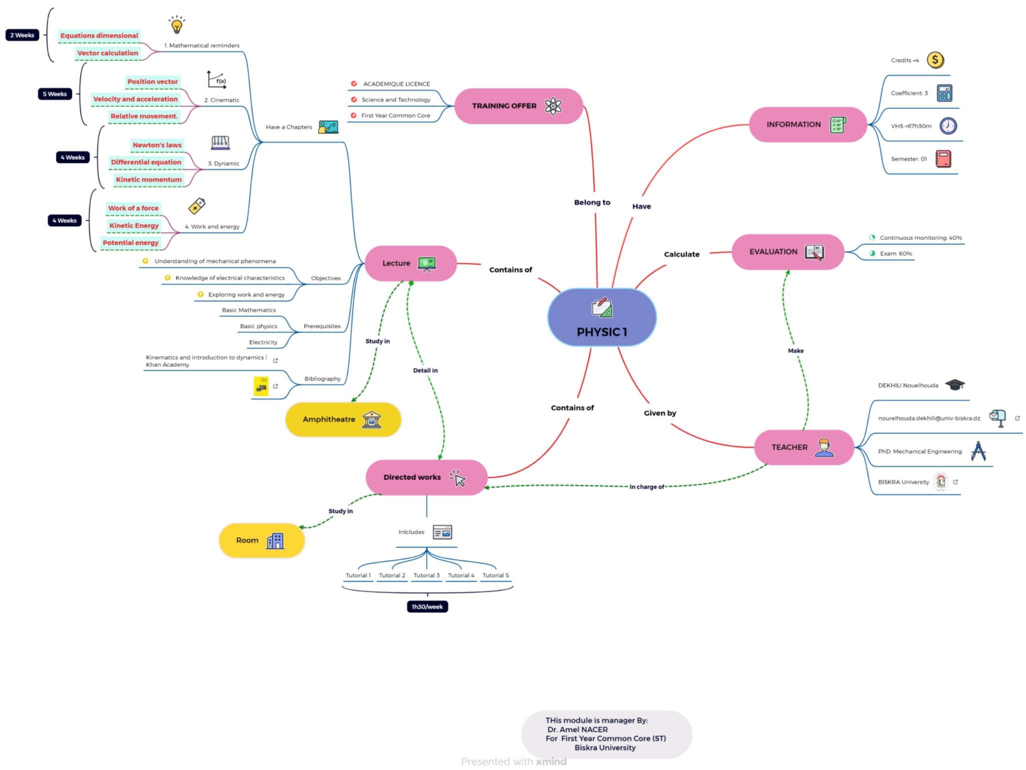
1. Analyze the concepts of Kinematics, Dynamics, and Work and Energy within the context of stitch mechanics.
2. Emphasize the necessity of having specific background knowledge to effectively comprehend stitch mechanics.
3. Apply basic mathematical and physical principles to understand stitch mechanics.

Prerequisites

1. Understanding of basic principles of physics such as mechanics, dynamics, forces, and motion is essential for comprehending mechanical elements.
2. Proficiency in mathematics, including algebra, trigonometry, calculus and geometry.
3. Familiarity with engineering mechanics concepts.

Introduction

Mechanical elements are fundamental components in mechanical engineering, playing a crucial role in the design and operation of various machinery. These elements encompass a wide range of devices that transmit power, support loads, and facilitate movement within mechanical systems. Key aspects include understanding machine elements, power transmission devices, and basic mechanical components. This involves considerations of design, calculations, and problem-solving in mechanical engineering applications [1]**



Mind map of the module

Chapter II: Kinematics of the material point

I

1. Goals

1. Define kinematics and the concept of a material point.
2. Explain the difference between kinematics and dynamics.
3. Analyze the motion of a material point to determine its displacement, velocity, and acceleration at different points in time.

Here are some questions for studying Kinematics of the Material Point readiness *:

- Define and differentiate between scalar and vector quantities. Provide examples of each.
- Define vectors and vector operations (addition, subtraction, scalar multiplication, dot product, cross product).
- Differentiate between scalar and vector quantities. Provide examples of each.

2. Characteristics of the motion

The aim of point kinematics is to study the motion of a point in time independently of the causes that produce the motion. The objectives are to determine kinematic quantities such as acceleration vectors, velocity, position and the equation of time of the trajectory of this point relative to a reference frame chosen by the observer [3]*.

In kinematics, the two fundamental concepts are space and time, because the motion takes place in space as a function of time. Mathematically solving kinematics problems in physics will involve understanding, calculating, and measuring several physical quantities:

- Position vector (OM): determines the object's physical location in space relative to an origin in a defined coordinate system.
- Velocity vector (V):which determines the variation in magnitude and position of the position vector.
- Acceleration vector (a) : which determines the variation in magnitude and position of the velocity vector.

3. Motions in various coordinate systems and bases

In mechanics, before studying the motion of a system, it is necessary to indicate the coordinate system in which the motion will be describe. We will explain the motion in different coordinate systems and bases, i.e. the set of three vectors on which we will give the expressions of the position vector, velocity vector and acceleration vector.

The elementary surface area and volume will also be given.

3.1. Cartesian coordinates

Consider an orthonormal basis denoted((u_x)⃗,(u_y)⃗,(u_z)⃗). This base does not change over time.

Knowing the position vector (OM)⃗ also makes it possible to locate the point M, which is given by:

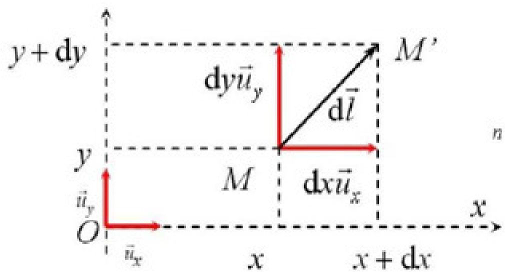
$$\vec{r} = \overrightarrow{OM} = \overrightarrow{x\,u_x} + \overrightarrow{y\,u_y} + \overrightarrow{z\,u_z}$$

Its modulus is given by :

$$|\vec{V}| = \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2}$$

And its module:

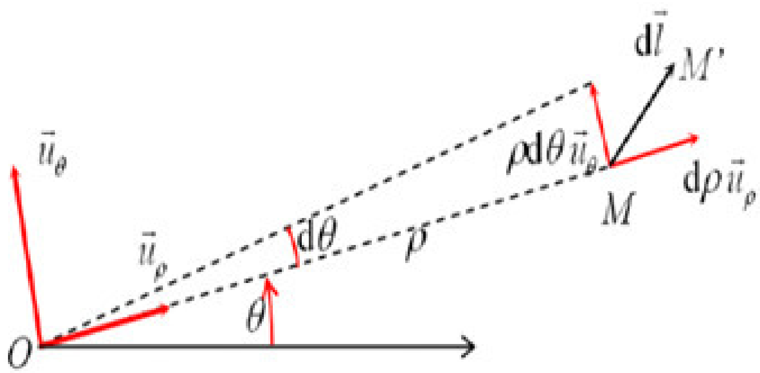
$$|\vec{a}| = \sqrt{(a_x)^2 + (a_y)^2 + (a_z)^2}$$



3.2. Polar coordinates (in a plane)

The position vector in this frame of reference is written as:

$$\vec{\rho} = \overrightarrow{OM} = \|\overrightarrow{OM}\|\,\vec{u}_\rho = \rho\,\vec{u}_\rho$$



Relationship between polar and Cartesian coordinates :

$x = \rho\cos(\theta)$

$y = \rho\sin(\theta)$

Then:

$\vec{u_x}=(\cos\theta)\,\vec{u}_\rho+(\sin\theta)\vec{u}_\theta$

$\vec{u_y}=(\sin\theta)\,\vec{u}_\rho+(\cos\theta)\vec{u}_\theta$

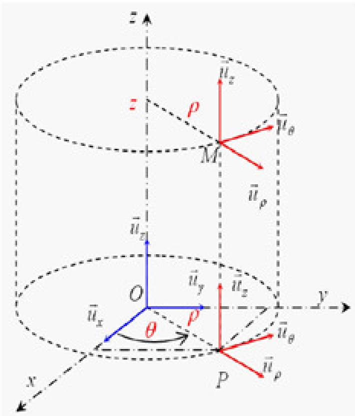
So:

$\vec{u_\rho}=(\cos\theta)\,\vec{u}_x+(\sin\theta)\vec{u}_y$

$\vec{u_\theta}=(-\sin\theta)\,\vec{u}_x+(\cos\theta)\vec{u}_y$

3.3. Cylindrical coordinates (in space)

To obtain the cylindrical coordinate system, all we need to do is add a third axis to the polar coordinate system (in the xOy plane): the Oz axis with its Cartesian z coordinate (called the coordinate).



The cylindrical coordinates are (ρ,θ,z), and the position vector is written as: $\vec{OM}=\rho\vec{u_\rho}+z\vec{k}$ and $\vec{V}=d\vec{OM}/dt$. And for acceleration:

$$\vec{a}=\frac{d\vec{V}}{d\vec{t}}$$

3.4. Spherical coordinates (in space)

Spherical coordinates are used to locate a point on a sphere of radius OM= r.

This is typically the case for locating a point on the Earth, for which all you need to do is specify two angles: latitude and longitude. These unit vectors are: $\vec{u_r}$, $\vec{u_\theta}$, $\vec{u_\varphi}$. M is defined by the length.

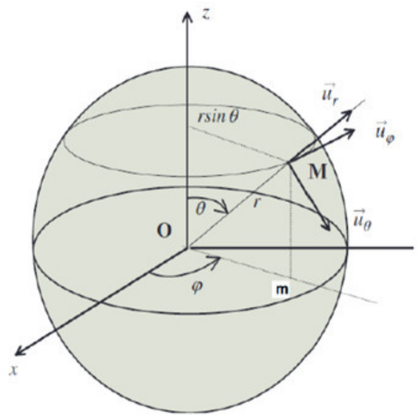
$\vec{r}=\vec{OM}=r\vec{u_r}$ And the two angles φ and θ.

$x=r\cos\theta\sin\varphi$, $y=r\sin\theta\,\sin\varphi$ and $z=r\sin\theta$. The position vector is written:

$\vec{OM}=r\vec{u_r}+r\theta\vec{u_\theta}+r\varphi\sin\theta\vec{u_\varphi}$

In the spherical coordinate system, the velocity is given by the following relationship

$\vec{V}=\dot{r}\vec{u_r}+r\dot{\theta}\vec{u_\theta}+r\dot{\varphi}\sin\theta\vec{u_\varphi}$



3.5. Tutorials

3.5.1. Exercise 1

Rectangular coordinats (x, y, z) of a point are given. Find the cylindrical coordiantion (ρ,φ, z) of the point:

P1: (1,√3,2) ; P2: (1,1,5) ; P3: (-2√2,2√2, 4)

3.5.2. Exercise 2

Cylindrical coordiantion (ρ,φ, z) of a point are given. Find the rectangular coordinats (x, y, z) of the point:

P1 : (4,π/6,3) ; P2 : (2,π,-4) ; P3: (-2√2 ,2√2,4)

3.5.3. Exercise 3

Rectangular coordinats (x, y, z) of a point are given. Find the spherical coordiantion (r, θ, φ) of the point:

P_1: (4,0,0) ; P2: (-1,2,1) ; P3: (0,3,0)

3.6. Models Answers

3.6.1. Exercise 1

P(1,√3,2) $\rho = \sqrt{x^2 + y^2} = \sqrt{1^2+(\sqrt{3})^2} = \sqrt{4} = 2$

$\varphi = tg\text{-}1((\sqrt{3})/1) = \pi/3$

z = z

P_1 (2, π/3,2)

3.6.2. Exercise 2

P_1 (4,11,3) $x=\rho\ \cos\varphi = 4\cos\pi/6 = 4(\sqrt{3})/2 = 2\sqrt{3}$

$y = \rho\sin\varphi = 4\sin\pi/6 = 2$

z = 3

P_1 (2,2√3,3)

3.6.3. Exercise 3

P1(4,0,0) $r = x^2+y^2+z^2 = 42+02+0^2 = \sqrt{42} = 4$

$\theta = tg\text{-}1\ (4/0) = \pi/2$

$\varphi = tg\text{-}1(y/x) = tg\text{-}1(0/4) = tg\text{-}1(0) = 0$

P1 (4,π/2,0)

Evaluations

II

1. Exercice

[solution n°1 p.13]

Find the spherical coordinates of the following point: M(4,2,3).

2. Exercice

[solution n°2 p.13]

Find the cylindrical coordinates of the following point: M(2,3,4).

3. Exercice :

Let: $\vec{B} = (x\vec{i}) + \vec{y}j + z\vec{k}$ and $\vec{A} = \vec{i} + 2\vec{j} - \vec{k}$

Calculate the values of x, y and z such that $\vec{B}$ is the Unit victor for $\vec{A}$.

4. Exercice :

Let the following victors in the base $(\vec{i}, \vec{j}, \vec{k})$: $\vec{A} = -\vec{i} + 2x\vec{j}$ and $\vec{B} = 2\vec{i} + 2\vec{j}$

1. Calculate the scalar product between$\vec{A}$ and $\vec{B}$
2. Find the values of x so that the angle between $\vec{A}$ and $\vec{B}$equals$\pi/2$

5. Exercice

[solution n°3 p.13]

Which of the following equations represents average velocity?

- [ ] v=t/s
- [ ] v=1/2(u+v)
- [ ] v=u+at

6. Exercice

[*solution* n°4 p.13]

Velocity is defined as

- The rate of change of displacement with respect to time
- The change in position of an object per unit time
- The speed of an object in a specific direction
- The acceleration of an object due to gravity

7. Exercice

[*solution* n°5 p.13]

What does kinematics study ?

- Forces acting on an object
- Motion of objects without considering its causes
- Interactions between different objects
- Energy transformations in a system

Solutions des exercices

> **Solution** n°1

Exercice p. 11

Find the spherical coordinates of the following point: M(4,2,3).

M(√29, 56.15°,26.37°)

> **Solution** n°2

Exercice p. 11

Find the cylindrical coordinates of the following point: M(2,3,4).

M(√13,56.30°,4)

> **Solution** n°3

Exercice p. 11

Which of the following equations represents average velocity?

- [x] v=t/s
- [ ] v=1/2(u+v)
- [ ] v=u+at

> **Solution** n°4

Exercice p. 12

Velocity is defined as

- (•) The rate of change of displacement with respect to time
- ( ) The change in position of an object per unit time
- ( ) The speed of an object in a specific direction
- ( ) The acceleration of an object due to gravity

> **Solution** n°5

Exercice p. 12

What does kinematics study ?

- ( ) Forces acting on an object

- ◉ Motion of objects without considering its causes
- ○ Interactions between different objects
- ○ Energy transformations in a system

Glossaire

Kinematics

Kinematics, a branch of physics, studies the motion of objects without considering the forces causing that motion.

Vector

A vector is an object characterized by both magnitude and direction. Vectors are represented as arrows, where the length of the arrow corresponds to the vector's magnitude, and the direction of the arrow indicates its orientation.

Abréviations

Div : Divergence,

Grad : Gradient

L : L: Length

M : Mass

SA : Sacral Angle

T : Time

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