Mechanical Elements (Tutorials)

First-year sciences and technologies
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Table des matières

Objectifs

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

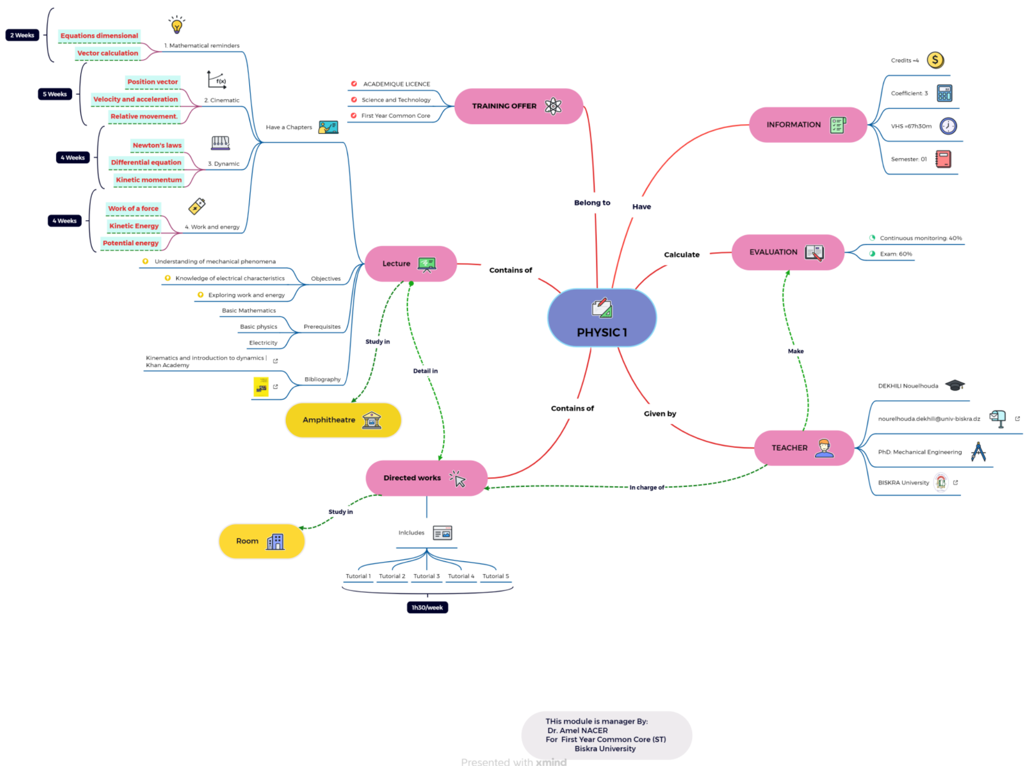
1. Analyze the concepts of Kinematics, Dynamics, and Work and Energy within the context of stitch mechanics.
2. Emphasize the necessity of having specific background knowledge to effectively comprehend stitch mechanics.
3. Apply basic mathematical and physical principles to understand stitch mechanics.

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 I: Dimensional analysis and Vector calculus

I

1. Goals

1. Define dimensional analysis and vector calculus.
2. Comprehend the geometric interpretation of vectors and vector calculus operations such as gradient, divergence, and curl.
3. Develop mathematical models using vector calculus to describe and analyze complex physical systems.

Dimensional analysis is a powerful tool used in engineering and physics to understand and analyze physical phenomena by examining the relationships between different physical quantities. By considering the dimensions of variables involved, dimensional analysis helps derive relationships that are independent of specific unit systems, allowing for the simplification and generalization of complex problems :

- Solve the equation : 2 x^2 + 5x -8 =0
- A ladder is leaning against a wall. The ladder forms an angle of 30° with the ground. If the length of the ladder is 10 meters, find the height at which the ladder touches the wall *.

2. Dimensional Analysis

2.1. Fundamental (primary/basic) physical quantities

The International System (IS) is made up of the units of the rationalised MKSA system (m: metre, kg: kilogram, s: second and a: ampere) and includes additional definitions for the unit of temperature and the unit of luminous intensity [2]*.

	Symbol	Dimensions
Length	m	L
Mass	Kg	M
Time	S	T
Electtric current	A	I
Temperature	K	H
Amount of sustance	mol	N
Luminous intensity	cd	J

2.2. Derived (secondary) physical quantities

These are quantities whose definitions are based on other physical quantities (base quantities)

Physical quantity	Dimenional formula
Area	$[M^0L^2T^0]$
volume	$[M^0L^3T^0]$
Density=mass/volume	$[M^1L^{-3}T^0]$
Speed or velocity=dx/dt	$[M^0LT^{-1}]$
Acceleration= dv/dt	$[M^0LT^{-2}]$
Force=mdv=ma	$[MLT^{-2}]$

3. Vector calculation

3.1. The scalar product

Let v =(v1,v2,v3) and w=(w1,w2,w3) be vectors in R*R*R. The dot product of v and w, denoted by v.w, is given by:

$$v \cdot w = v_1 w_1 + v_2 w_2 + v_3 w_1$$

Similarly, for the vectors* v=(v1,v2) and w=(w1,w2) in R*R ,the dot product is:

$$v \,.\, w = v_1 w_1 + v_2 w_2$$

Définition

Let v,w be nonzero vectors, and let θ be the angle between them, then:

$$\cos(\theta) = \frac{v \cdot w}{\|v\| \|w\|}$$

If θ is the angle between nonzero vectors v and w then:

$$v \cdot w = \{ \begin{array}{c} 0 \ for \ 0^{\circ} \leq \theta < 90^{\circ} \\ 0 \ for \ \theta = 90^{\circ} \\ 0 \ for \ 0^{\circ} \leq \theta < 90^{\circ} \end{array} \}$$

For any vectors u, v, w, and scalar k, we have :

- v.w=w.v Commutative Law
- (kv).w=v.(kw)=k(v.w) Associative Law
- v.0=0=0.v
- u.(v+w)=u.v+u.w Distributive Law
- (u+v).w=u.w+v.w Distributive Law
- |v.w|=‖v‖‖w‖ Cauchy-Schwarz Inequality

3.2. The vector product

Let v=(v1,v2,v3) and w=(w1,w2,w3) be vectors in R*R*R.The dot product of v and w , denoted by v×w, is the vector in R*R*R given by:

$$v \times w = \left| \begin{array}{ccc} i & j & k \\ v1 & v2 & v3 \\ w1 & w2 & w3 \end{array} \right|$$

$$v \times w = (v1\, w3 - v3\, w3)\, i - (v2\, w1 - v1\, w2)\, j + (v1\, w2 - v2\, w1)\, k$$

Theorem

1. If the cross product v×w of two nonzero vectors v and w is also nonzero vector, then it is perpendicular to both v and w.

2. If θ is the angle between nonzero vectors v and w in R*R*R, then: v×w=‖v‖ ‖w‖ sin(θ)

3.3. Gradient , divergence and curl

Gradient, divergence and curl are frequently used when dealing with variations of vectors using a vector operator designated by ∇(Pronounced del)defined as follows:

$$\nabla=\frac{\delta}{\delta x}i+\frac{\delta}{\delta y}j+\frac{\delta}{\delta z}k$$

3.3.1. Gradient

$$grand\ \Phi=\nabla\Phi=(\frac{i\delta}{\delta x}+\frac{j\delta}{\delta y}+\frac{k\delta}{\delta z})\Phi=i\frac{\delta\Phi}{\delta x}+j\frac{\delta\Phi}{\delta y}+k\frac{\delta\Phi}{\delta z}$$

3.3.2. Divergence

$$divA=\nabla\ A=(\frac{i\delta}{\delta x}+\frac{j\delta}{\delta y}+\frac{k\delta}{\delta z})=(A_x i+A_y j+A_z k)$$

3.3.3. Curl

$$curlA=\nabla * A=(\frac{i\delta}{\delta x}+\frac{j\delta}{\delta y}+\frac{k\delta}{\delta z})*(A_x i+A_y j+A_z k)$$

3.4. Tutorials

3.4.1. Exercise 1

Two physical quantities, X and Y, have the same dimensional formula, which is ML-1 T^2. Then, the dimensional formula of the quantity 5X + 2Y is:

A. M-1 LT-2

B. ML-1 T2

C. M2 L-2 T4

D. of no physical meaning

3.4.2. Exercise 2

If the velocity V (in cm/s) of a particale is given in term of time (in sec) by the equation V=at b/(t+c)

- Give the dimensions of a, b and c.

3.4.3. Exercise 3

For the equation F = Aa vb dc where F is force, A is area, v dimentional analysis give the following values for the exponents. is velocity and d is density, using the dimentional analysis

- Give the following values for the exponents

3.5. Models Answer

3.5.1. Exercise 1

If $A = \sqrt{BC}$.

Then

C= A*A/B

Therefore, the dimensional formula of C is :

$[C] = (M*M*L*L)/(MT^{-1}) = ML^{2}T$.

3.5.2. Exercise 2

V=at b/(t+c)

[V] = [at] = [b] [t+c]-1 / [t+c]=[t]=[C]

[v] = [a][t]= [a]=[v][t]-1 / [V] = LT-1

[a] =LT-1 T-1 = LT-2 (a is acceleration)

[a]=LT-2

[t] = [C]=[C]=T

[V] = [b][t]-1 = [b][c]-1

[b]=[V][t]= LT-1 T = L

[a]=LT-2 [b] = L [c] = T

3.5.3. Exercise 3

F = Aa vb dc ①

F is force [F] = MLT-2

V is velocity = [v] = LT-1

d is density = [d] = ([m])/([v]) = ML-3

A is Area = [A]= L3

① = [F] = [A]a [v]b [d]c

MLT-2 = L3a LbT-b McL-3c =L3a+b-3c T-b Mc

3a+b-3c = 1

-b = -2 => b= 2

c =1

3a+2-3=1 => 3a=1-2+3=2

a = 2/3

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: $\vec{B} = (x\vec{i}) + y\vec{j} + z\vec{k}$ 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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Index