Lecture 1

first stage

Force, work and power

By

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1. Measurement

Physics is a science based upon exact measurement of physical quantities. Therefore it is essential that student first becomes familiar with the various methods of measurement and the units in which these measurements are expressed.

A **unit** is a value quantity or magnitude in terms of which other values, quantities or magnitudes are expressed.

2. Fundamental Quantities And Units

A **fundamental quantity** also known as **base quantity** is a quantity which cannot be expressed in terms of any other physical quantity. The units in which the fundamental quantities are measured are called fundamental units. In mechanics (study of the effects of external forces on bodies at rest or in motion), the quantities **length**, **mass** and **time** are chosen as fundamental quantities.

Fundamental Quantity	Fundamental Unit	Unit Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s

3. Dynamics

Dynamics is a branch of mechanics which deals with the forces that give rise to motion. Just as kinematics describes how objects move without describing the force that caused the motion, Newton's laws of

motion are the foundation of dynamics which describes the motion and force responsible for the motion.

4. Force

Force is that which changes the velocity of an object. Force is a vector quantity. An external force is one which lies outside of the system being considered.

4.1 Types Of Forces

Contact Force is that in which one object has to be in contact with another to exert a force on it. A push or pull on an object are examples of contact force.

Tension $\vec{T}$ is the force on a string or chain tending to stretch it.

Normal force $\vec{F_N}$ is the force which acts perpendicular to a surface which supports an object.

Weight $\vec{W}$ of an object is the force with which gravity pulls downward upon it.

It is given as $\vec{W} = m\vec{g}$. It is equal to the gravitational force on the body.

Frictional force $\vec{f}$ is the force on a body when the body when the body slides or attempts to slide along a surface and is always parallel to the surface and directed so as to oppose the motion of the body.

Other important forces include **gravitational force** or simply gravity, **electromagnetic force**, **nuclear force**.

4. 2 Net Force

The net force is the vector sum of all force vectors that act on an object. It is expressed as:

$$\vec{F}_{net} = \sum_{i=1}^{n} \vec{F}_i = \vec{F}_1 + \vec{F}_2 + \cdots + \vec{F}_n \quad \ldots \quad 4.1$$

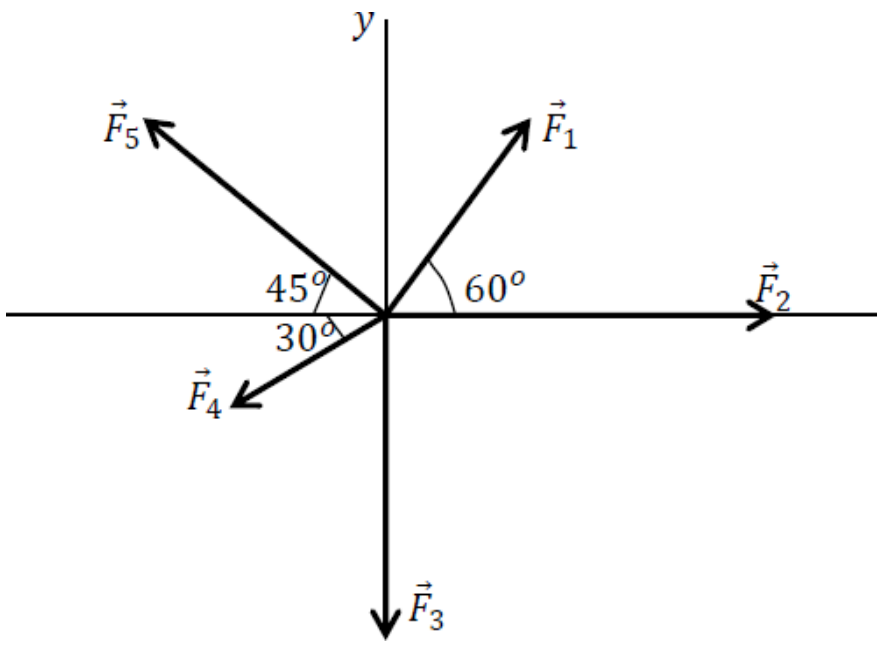
In Cartesian components, the net force are given by

$$\vec{F}_{net,x} = \sum_{i=1}^{n} F_{i,x} = \vec{F}_{1,x} + \vec{F}_{2,x} + \cdots + \vec{F}_{n,x}$$

$$\vec{F}_{net,y} = \sum_{i=1}^{n} F_{i,y} = \vec{F}_{1,y} + \vec{F}_{2,y} + \cdots + \vec{F}_{n,y} \quad \ldots \quad 4.2$$

$$\vec{F}_{net,z} = \sum_{i=1}^{n} F_{i,z} = \vec{F}_{1,z} + \vec{F}_{2,z} + \cdots + \vec{F}_{n,z}$$

Example 15:
Five coplanar forces act on an object as shown in the figure below. Find the resultant of the forces. The magnitude of the forces are: $F_1 = 15N$, $F_2 = 19N$, $F_3 = 22N$, $F_4 = 11N$, $F_5 = 16N$.



Solution:

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 + \vec{F}_5$$

$$\vec{F}_1 = \vec{F}_{1,x} + \vec{F}_{1,y} = F_1 \cos 60^o \hat{i} + F_1 \sin 60^o \hat{j}$$

$$\vec{F}_2 = \vec{F}_{2,x}\hat{i} = F_2\hat{i}$$

$$\vec{F}_3 = -\vec{F}_{3,y}\hat{j} = -F_3\hat{j}$$

$$\vec{F}_4 = -\vec{F}_{4,x}\hat{i} - \vec{F}_{4,y}\hat{j} = -F_4 \cos 30^o \hat{i} - F_4 \sin 30^o \hat{j}$$

$$\vec{F}_5 = -\vec{F}_{5,x} + \vec{F}_{5,y} = -F_5 \cos 45^o + F_5 \sin 45^o$$

$$\vec{F}_1 = 15 \cos 60^o \hat{i} + 15 \sin 60^o \hat{j} = 7.5\hat{i} + 12.99\hat{j}$$

$$\vec{F}_2 = 19\hat{i}$$

$$\vec{F}_3 = -22\hat{j}$$

$$\vec{F}_4 = -11 \cos 30^o \hat{i} - 11 \sin 30^o \hat{j} = -9.53\hat{i} - 5.5\hat{j}$$

$$\vec{F}_5 = -16 \cos 45^o + 16 \sin 45^o = -11.31\hat{i} + 11.31\hat{j}$$

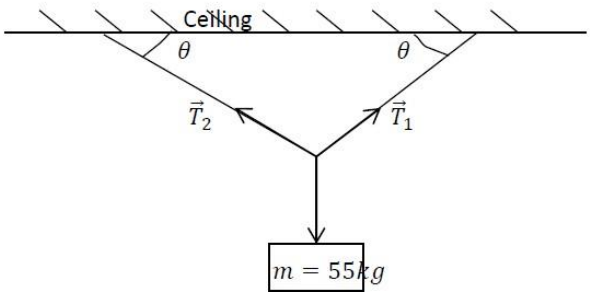
$$\vec{F}_{net,x} = (7.5 + 19 - 9.53 - 11.31)\hat{i}\ N = 5.66\hat{i}\ N$$

$$\vec{F}_{net,y} = (12.99 - 22 - 5.5 + 11.31)\hat{j}\ N = -3.2\hat{j}\ N$$

$$\vec{F}_{net} = \sqrt{(5.66)^2 + (-3.2)^2} = 6.5N$$

H.W

A mass of $55kg$ was suspended with two ropes as shown in the figure below. What is the tension in each rope if $\theta = 45^o$?



5. work

Work is defined as the product of *force* and *displacement*.

Work = Force × displacement*

$$W = F \times s$$

The unit of work is the Joule (J).

Energy is the ability to do work.

The amount of energy something has is also the amount of work it can do.
Because work is a form of energy it follows that **the unit of energy is also the Joule.**

6. Work-Energy Principle

The change in the energy of an object is equal to the work done on the object

Different Forms of Energy

Kinetic energy is energy an object has due to its motion.

Formula for kinetic energy:

$$E_K = \tfrac{1}{2} mv^2 *$$

Potential energy is the energy an object has due to its position in a force field.

The formula for potential energy:

$$E_P = mgh$$

Any time work is done energy is transferred*

7. The Principle of Conservation of Energy*

states that energy cannot be created or destroyed but can only be converted from one form to another.

Loss in Potential Energy = Gain in Kinetic Energy for a freely falling object*

8. Collisions: Kinetic Energy and Momentum

When two objects collide, momentum is conserved provided no external forces act on the system.

Kinetic energy however is not conserved.

This is because some of the kinetic energy gets converted to sound and heat energy.

9.Power

Power is the rate at which work is done.
Or
Power is the rate at which energy is converted from one form to another.

The unit of power is **the Watt (W).**

$$\text{Power} = \frac{\text{Work\_Done}}{\text{Time\_Taken}}$$