Lecture 2 – Kinetics of a particle Part 1

What is Kinetics ?

Kinetics is the study of ____ ______________________________ they cause. Note that kinematics only deals with the motion of an object, while statics is the study of objects without any resultant force.

Figure 1. From a distance, the aeroplane's motion may be modelled as if each of them was a particle

A particle is modelled as a ____________________ whose volume is negligible in a 3D space. Hence, the rotation of its body will not be considered here, but will be dealt with in 'kinetics of a rigid body'. Only _____________________ motion of particles will be of interest here.

Overview of Kinetics of a particle

- Force and Acceleration
- Equations of motion
- Work and Energy
- Impulse and momentum

Force and Acceleration

Force and acceleration are mathematically linked together via Newton's three laws of motion, which are

First law: If no net force acts on a particle, then it is possible to select a set of reference frames, called inertial reference frames, observed from which the particle moves without any change in velocity.

Second law: Observed from an inertial reference frame, the net force on a particle is proportional to the time rate of change of its linear momentum: $F = d[mv] / dt$. Momentum is the product of mass and velocity. This law is often stated as $F = ma$ (the net force on an object is equal to the mass of the object multiplied by its acceleration).
- An example of a variable mass with respect to time is a vehicle consuming fuel.

Third law: Whenever a particle A exerts a force on another particle B, B simultaneously exerts a force on A with the same magnitude in the opposite direction. The strong form of the law further postulates that these two forces act along the same line.

Equations of motion

For a single particle, its equation of motion can be easily formed by utilising Newton's second law. The sum of forces, or the resultant force acting on the particle is proportional to the acceleration in the direction of the force. In the rectangular coordinates, this translates to a mathematical expression

The above expressions can be written in vector form as

$$\sum \mathbf{F} = m\mathbf{a}$$

where ____, which denotes the sum of forces in the direction of positive x, y- and z-axes

____, which denotes the particle's accelerations in the direction of positive x, y- and z-axes

Kinetic diagram

A kinetic diagram of a body shows the (magnitude and direction of the) ______________ of the particle. It illustrates the direction of the impending motion.

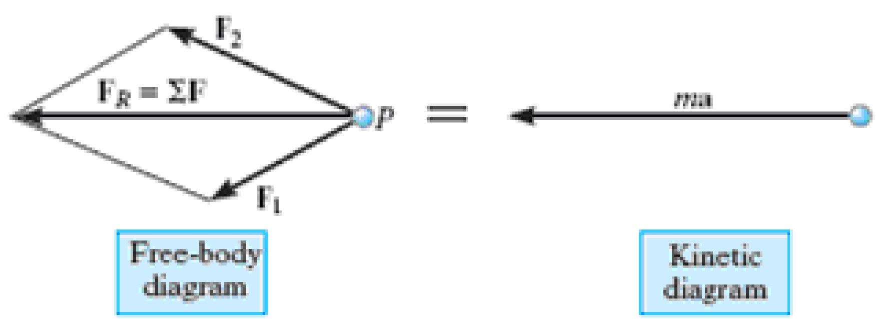

Figure 1

Normal and tangential coordinates

In the case where the ____ ____, it may be more appropriate to use the normal and tangential coordinates when analyzing its kinetics. An example of such systems is a roller coaster running along its track.

The coordinates consist of three perpendicular direction vectors which span the entire 3D space, namely normal, tangential and binormal directions.

1. The tangential component is, of course, tangent to the path of the motion.

2. The normal component is directed ____ ______________________ of the path, hence the force in this direction is also known as the centripetal force.
3. The binormal component is normal to the plane which contains the other two vectors. There cannot be any motion in the direction of this component, hence the binormal resultant force must always be zero.

We can now formulate the equations of motion in the normal and tangential coordinates.

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NOTE: The formula for the radius of curvature is given by $\rho(t) = \dfrac{|1 + f'(t)^2|^{3/2}}{|f''(t)|}$.

Cylindrical coordinates

This is similar to the 3D polar coordinates we used in the previous lecture. There are again three direction vectors which span the 3D space, namely radial, tangential (normal to radial), and vertical components. Hence, the equations of motion in cylindrical coordinates are given by

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