UNIT 4: Newton’s Laws of Motion

Specific Objectives:

1. To understand Newton's Laws of Motion.

2. To apply Newton's Laws of motion to solve problems in dynamics.

Detailed Content	Time Ratio	Notes on Teaching
4.1 Newton's Laws of Motion	6	The Newton's Laws of Motion should be clearly stated and explained to students. Problems involving variable mass need not be taught. Students should be able to distinguish external forces and internal forces acting on a particle or a system of particles. Students are expected to apply Newton's Laws to solve problems in statics and dynamics. In dynamics, students may first study the motion of a particle. The treatment should also apply to a body whose rotational effects are negligible and its motion can be approximated by the centre of mass of the body. Students may then be guided to study the motion of a system of particles or bodies moving in a plane. The basis of analysis is Newton's Second Law which may take the form: $\vec{F} = m\vec{a}$ where *m* is the mass of the particle, $\vec{F}$ is the resultant force acting on the particle, $\vec{a}$ is the resultant acceleration of the particle. The procedure of analysis may be arranged as follows:

Detailed Content	Time Ratio	Notes on Teaching
		(1) Analyse the forces on the particle: The first step in analysing a problem in dynamics is to construct a force diagram. The force diagram for a particle should include all physically identifiable forces acting on the particle. Students should know that a force is physically identifiable if they can identify its origin, e.g. the force of gravity, the reaction of a body, a frictional force, a spring force etc. Teachers should remind students that a force should not be postulated on the basis of its supposed effect. (2) Analyse the kinematics of the particle: Students should be advised to write down the acceleration $\vec{a}$ in some coordinate system (rectangular or polar) but it should be emphasized that Newton's Laws of Motion should apply to motions relative to an inertial frame of reference. i.e. the coordinate system chosen should not be accelerating or rotating. For a simple problem the acceleration may be indicated on the force diagram, but usually it is desirable to draw another diagram for the acceleration(s). (3) The equation of motion is then given by relating (1) and (2) in $\vec{F} = m\vec{a}$: Students should try to minimize the variables in the force equation by choosing proper direction(s) for resolving the forces and accelerations and should try to set up minimum number of equations in solving the problems. Problems involving system of pulleys and motion on the surface of a wedge are worth discussing and knowledge of relative acceleration for two accelerating bodies should be revised. *Example 1* Two masses m, 2m, are connected by a light inextensible string which passes over a smooth pulley, mass m. The axle of the pulley is fastened to one end of a second string which passes over a smooth fixed pulley and has a mass 4m attached at the other end. The system is free to move in a vertical plane.

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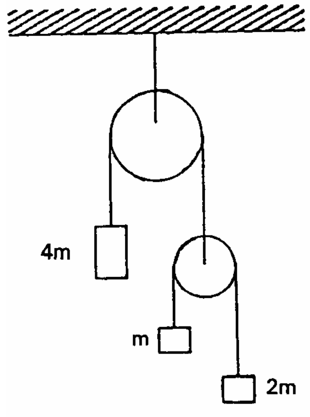

In this example, students are expected to:

(1) draw force diagrams for separated mass and the movable pulley,

(2) obtain the accelerations of the masses m and 2m relative to the fixed pulley by assigning their accelerations relative to the movable pulley first,

(3) set up force equations for individual mass and movable pulley, and (4) find the accelerations of the masses by solving the force equations.

Example 2

A particle of mass m is in contact with a smooth sloping face of a wedge which is itself standing on a smooth horizontal surface. The mass of the wedge is M and the sloping face of the wedge is inclined at an angle of 30° to the horizontal.

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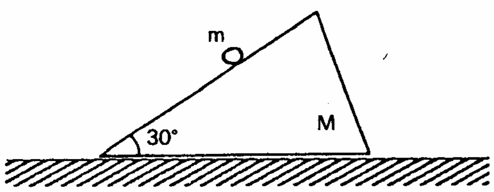

In this example, students are expected to:

(1) draw force diagrams for individual mass,

(2) choose suitable directions to set up force equations for the masses,

(3) find the accelerations of the masses.

Detailed Content	Time Ratio	Notes on Teaching
4.2 Rectilinear Motion of a Particle under Variable Forces	6	At this stage, students are expected to develop their skill in handling the motion in a straight line under a variable force. The Newton's second law ($\vec{F} = m\vec{a}$) is then reduced to

$$F = m\frac{dv}{dt}$$

where m, the mass of the particle, is constant throughout the motion.

Problems involving

(1) force as a function of time,

(2) force as a function of .velocity, and

(3) force as a function of displacement

are worth discussing, and the method of solving the problems by simple integration should be taught. Moreover, students are expected to identify the physical motion of the particle after the force equation has been solved.

Detailed Content	Time Ratio	Notes on Teaching
	12	The following are some examples: *Example 1* A stone of mass m, falls vertically from rest, the air resistance being kv where k is a constant and v is the velocity of the stone at time t. In this problem, teachers may guide students to find the velocity of the stone in time t by integration. Also, students should be able to know that the velocity will be terminated as time tends to infinity. Moreover, the terminal velocity can be determined. *Example 2* A body of mass 5 kg is moving in a straight line under the action of a force (4/s) newtons towards a fixed point 0 in that straight line, where s metres is the distance of the body from 0. The body is initially at rest and is 1 m from 0. In this problem, students are expected to find the velocity of the body for a particular distance s from 0 by simple integration. Moreover, teachers may guide students to find the time elapsed for a particular s by integrating the first result.