Chapter 8 Dynamics
LECTURE OUTLINE & NOTES

DYNAMICS, p. 193

Adding the parameters of positions, velocities, and accelerations differentiates dynamics from statics.

KINEMATICS OF A PARTICLE, p. 194

The velocity vector of a point moving on a path is tangent to the path; the acceleration is the derivative of the velocity with respect to time and may have components that are tangential and normal (figures and formulas pp. 194-195).

Relating Distance, Velocity and the Tangential Component of Acceleration

Acceleration, velocity, and distance may vary with time, and acceleration and velocity may vary with distance (formulas p. 196).

Constant Tangential Acceleration

Simplified formulas for velocity and distance apply when tangential acceleration is constant (formulas p. 198).

Rectilinear Motion

During motion in a straight line, the formula for acceleration is simplified by omitting the normal component.

Rectangular Cartesian Coordinates

Mutually perpendicular fixed unit vectors can be used to express position, velocity, and acceleration of a point which is moving in more than one dimension (formulas p. 199).

Circular Cylindrical Coordinates

Another coordinate system replaces two of the perpendicular coordinates with an angle at and a distance from the origin (figure and formulas pp. 201-202).

Circular Path

Simplified formulas used in the cylindrical coordinate system to find velocity and acceleration apply when the distance to the origin is constant (formulas pp. 202-203).

RIGID BODY KINEMATICS, p. 203

Rigid bodies undergo little deformation when force is applied.

The Constraint of Rigidity

For any two points of a rigid body, the magnitude of the position vector between them is constant, and the dot products of their velocities and a unit vector in the direction of that position vector are equal (figure and formulas pp. 203-204).

The Angular Velocity Vector

For any two points of a rigid two-dimensional body moving on a plane, the change in the position vector from one point to the other during a time increment equals the cross product of the original position vector and the angular velocity vector (figures and formulas pp. 205-207).

Instantaneous Center of Zero Velocity

For a body as described above, with angular velocity not equal to zero, there exists a point at each instant such that the entire body is rotating around that point and the point itself has zero velocity (formula p. 207).

Accelerations in Rigid Bodies

For a body as described above, the dot product of the acceleration of one point and the unit vector in the direction from that point to a second point is equal to the dot product of the acceleration of the second point and the same unit vector, minus the product of the magnitude of the position vector from one point to the other and the square of the magnitude of the angular velocity of the body (formulas p. 209).

NEWTON'S LAWS OF MOTION, p. 210

For any element of a mechanical system, the resultant force on the element is equal to the product of its mass and acceleration; the force exerted by one body on a second body has equal magnitude and opposite direction compared to the force exerted by the second body on the first (formula p. 210).

Applications to a Particle

A material element, all of whose parts have the same acceleration, may be idealized as a particle whose spatial extent is disregarded.

Systems of Particles

A collection of material elements under consideration is a system; forces on an element may arise from outside the system or result from interactions between elements; because the internal forces must be equal and opposite, their sum is zero (formulas p. 213).

Linear Momentum and Center of Mass

The linear momentum of a system is the sum of the linear momentums of its elements; the sum of external forces on a system is the derivative with respect to time of the linear momentum of the system; the center of mass of the system is the point which accelerates under the resultant of the external forces exactly as would a single particle having the mass of the system (formulas pp. 213-214).

Impulse and Momentum

The change in momentum of a system over a period of time due to the resultant external force is the impulse of that force; the three coordinate components of the momentum may not all be changed by the impulse, and the unchanged components are said to be conserved (formulas pp. 215-216).

Moments of Force and Momentum

The moment with respect to a point of an external force on a system is the sum of the cross products of the position vectors from the point to each of the elements of the system and the product of each element's mass and acceleration; it is also the time rate of change of angular momentum about that point (figures and formulas pp.217-219).

WORK AND KINETIC ENERGY, p. 219

Changes in velocity and acceleration with distance have implications for calculations of work and kinetic energy.

A Single Particle

The integral of the product of the magnitude of a force on a particle and the change of position of the particle is the work done on that particle by that force over that distance; it is equal to the change in the particle's kinetic energy (formulas pp. 219-220).

Work of a Constant Force

Work is only done by a force over the component of a particle's movement that is parallel to that force (figure and formulas p. 221).

Distance-Dependent Central Force

For a force of attraction or repulsion which varies with distance from a fixed central point, work is done by the variable force over the net change of radial distance; the sum of the work done by internal forces of a rigid body or by an internal force between two particles that depends only on the distance between them is zero (figure and formulas pp. 222-225).

KINETICS OF RIGID BODIES, p. 225

For a rigid body, the principle of motion of the mass center (p. 214) is applicable to problems of kinetics, whereas the moment equation (p. 217) must be adapted to relate accelerations to angular velocity and angular acceleration.

Moment Relationships for Planar Motion

The moment of inertia about an axis through the center of mass of a rigid body, perpendicular to the plane of motion, measures the body's resistance to change in its angular velocity, and is found by taking the moment about a point of reference of a force on an element of mass and relating the acceleration of the point of reference to that of the center of mass (figure and formulas pp. 226-227).

Work and Kinetic Energy

The power transmitted to a rigid body from several forces is the dot product of the resultant force and the velocity of a selected point plus the dot product of the resultant moment about the selected point and the angular velocity vector; the kinetic energy of the body is related to the velocity of a selected point, the mass of the body, the angular velocity of the body, a position vector from the selected point to the center of mass, and the moment of inertia of the selected point (formulas pp. 231-232).