UNIT C: MOTION IN SIMPLE SYSTEMS

General: Material included: RH Chapters 7, 8, 9, 10; Ford Chapters 8, 10 and Section 12.6.

The systems of this unit consist of a very small number (usually two) of “particles” like those of preceding units, which interact with each other; they may, or may not, also interact with the environment. Experimental objectives may focus on the concepts of energy and momentum such as:

> verification of conservation of momentum and/or of energy, if applicable; and otherwise accounting for the gain or loss;
> use of energy and momentum principles to measure something otherwise difficult to determine.

Or, the objective may focus on the motions of the separate particles – symmetries and correlations between them; or the behavior of the system's center of mass.

Suggested Systems

STR (C-1) ***Forces in a train***. Three or four identical carts are connected by springs and accelerated over the tabletop by a cord passing over a pulley to a hanging weight. The cord represents the locomotive coupling, and the spring extensions measure car-to-car forces so the frictional forces on the individual cars can be deduced. The system can be studied under conditions of acceleration, deceleration and constant speed; with wheels locked and rolling; and with different masses in individual cars. The primary problem is devising a method to measure the lengths of the springs during the motion.

References: RH p. 93, Prob. 15
Ford p. 309, E8.25

CNV (C-2) ***One-dimensional collisions.*** Two air track gliders are the colliding objects so the system is isolated and both bodies move at CONSTANT velocity, both coming and going. Energy and momentum changes should be examined, for various mass combinations,
colliding both elastically and inelastically.

References: (L-8), (L-8/9A) “Elastic and Inelastic Collisions”
(L-9) “Conservation of Linear Momentum”
RH Chapter 10
Ford p. 442, P10.25, P10.26; p. 535, E12.56
Wall and Levine, Expt. 3 (On reserve in Science Library)

CNV (C-3) ***Ballistic pendulum***. This is a technique for measuring the speed of a fast-moving object, by letting it collide with the mass of a simple pendulum. Because of momentum conservation in the collision and energy conservation in the pendulum's subsequent motion, the object's speed is determinable from the height of the pendulum's motion.

References: (L-10), (L10A), “The Ballistic Pendulum”
RH p. 194, Ex. 3
Ford p. 314, P8.11
Wall and Levine, Expt. 5 (On reserve in Science Library)

NOV (C-4) ***Two-dimensional collisions.*** This refers to the collision between two frictionless objects which recoil along a line different from the line of approach. The objectives of C-2 are applicable, but more ingenuity is required to measure the speeds and of course directions must also be recorded. Further, the elimination of friction is harder for two-dimensional motion. You might use pucks on an air table (if available – consult instructor in advance), or
pieces of dry ice sliding on smooth metal.

References: RH Sec. 10-6
Ford Sec. 12.6

NOV (C-5) ***Impact forces***. For a single object colliding with a flat surface, the object's momentum change gives the product of the average interaction force and the contact time; for a stream of such objects, the rate of change of momentum in the stream equals the average force. If the flat surface is a horizontal pan suspended from a spring the force on it can be measured, and of course the object's momentum changes can be measured independently. Therefore it is possible to verify the assertions just made; or, alternatively, to use them to deduce the duration of the collision. (In this connection it is a fair approximation – GIVEN – that the average force during a collision is one half the maximum force.) L-21 shows a simple method of <u>measuring</u> impact time for a dropped rod. Other suitable objects are:

> a ball dropped from a known height and rebounding to a known height, measuring the maximum force from the maximum spring extension during the impact;
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> a flexible chain hung vertically above the pan with its lower end just touching, and dropped (how does the force on the pan vary with time?); water from a hose fixed at some height above the pan, running onto the pan and then off (how does the force on the pan depend on the height from which the water falls and its rate of flow)?

In any of these cases it is appropriate to investigate whether energy is conserved, and how any energy loss relates to the physical variables.

References: (L-21) “Longitudinal Impact of Rods”
RH p. 183, Prob. 22, p. 208, Probs. 1 and 4;
p. 210, Probs. 25 and 26

NOV (C-6) ***Variable mass system***. An arrangement can be devised to dribble fine shot into a pan attached to an air-track glider, which then behaves as an isolated particle of increasing mass. Objective: predict and verify how the object's deceleration from a given initial speed is related to the rate of inflow of the shot.

References: RH p. 178, Ex. 10; p. 185, Prob. 40
Ford p. 313, P8.6

NOV (C-7) ***Baton***. Masses (equal or unequal) are attached to the ends of a lightweight rod and the combination tossed upward so that it twirls in a vertical plane while rising and falling. You could concentrate on the relation between how high it rises and the number of revolutions it makes while in the air, or you could undertake a complete study of the translational motion of the center of mass and the rotational motion about the center of mass.

References: Ford, Sec. 8.3; p. 313, P8.8 and P8.9