EXPERIMENTAL PHYSICS 1

SOLUTION EXERCISE 10

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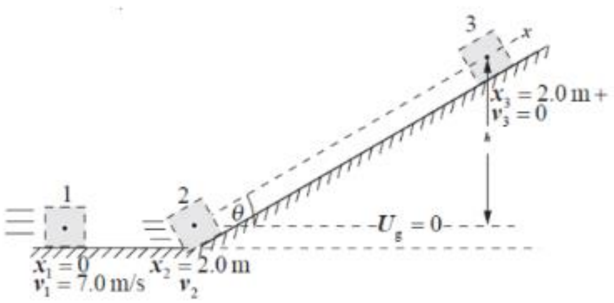
Problem 4:

38 • A 3.0-kg block slides along a frictionless horizontal surface with a speed of 7.0 m/s (Figure 7-41). After sliding a distance of 2.0 m, the block makes a smooth transition to a frictionless ramp inclined at an angle of 40° to the horizontal. What distance along the ramp does the block slide before coming momentarily to rest?

Picture the Problem The pictorial representation shows the block in its initial, intermediate, and final states. It also shows a choice for $U_g = 0$. Let the system consist of the block, ramp, and Earth. Because the surfaces are frictionless, the initial kinetic energy of the system is equal to its final gravitational potential energy when the block has come to rest on the incline.



Apply conservation of mechanical energy to the system to obtain:	$W_{ext} = \Delta K + \Delta U$ or, because $W_{ext} = 0$, $\Delta K + \Delta U = 0$
Because $K_3 = U_1 = 0$:	$-K_1 + U_3 = 0$
Substituting for K_1 and U_3 yields:	$-\frac{1}{2}mv_1^2 + mgh = 0 \Rightarrow h = \frac{v_1^2}{2g}$ where h is the change in elevation of the block as it slides to a momentary stop on the ramp.
Relate the height h to the displacement ℓ of the block along the ramp and the angle the ramp makes with the horizontal:	$h = \ell \sin\theta$
Equate the two expressions for h and solve for ℓ to obtain:	$\ell \sin\theta = \frac{v_1^2}{2g} \Rightarrow \ell = \frac{v_1^2}{2g\sin\theta}$
Substitute numerical values and evaluate ℓ:	$\ell = \frac{(7.0\text{ m/s})^2}{2(9.81\text{ m/s}^2)\sin 40°} = \boxed{3.9\text{ m}}$

Problem 5:

66 •• A bullet of mass m_1 is fired horizontally with a speed v_0 into the bob of a ballistic pendulum of mass m_2. The pendulum consists of a bob attached to one end of a very light rod of length L. The rod is free to rotate about a horizontal axis through its other end. The bullet is stopped in the bob. Find the minimum v_0 such that the bob will swing through a complete circle.

Picture the Problem Choose $U_g = 0$ at the bob's equilibrium position. Momentum is conserved in the collision of the bullet with bob and the initial kinetic energy of the bob plus bullet is transformed into gravitational potential energy as it swings up to the top of the circle. If the bullet plus bob just makes it to the top of the circle with zero speed, it will swing through a complete circle.

Use conservation of momentum to relate the speed of the bullet just before impact to the initial speed of the bob plus bullet:

$$m_1 v_0 - (m_1 + m_2)V = 0$$

Solve for the speed of the bullet to obtain:

$$v_0 = \left(1 + \frac{m_2}{m_1}\right)V \qquad (1)$$

Use conservation of mechanical energy to relate the initial kinetic energy of the bob plus bullet to their potential energy at the top of the circle:

$$\Delta K + \Delta U = 0$$

or, because $K_f = U_i = 0$,

$$-K_i + U_f = 0$$

Substitute for K_i and U_f:

$$-\tfrac{1}{2}(m_1 + m_2)V^2 + (m_1 + m_2)g(2L) = 0$$

Solving for V yields:

$$V = 2\sqrt{gL}$$

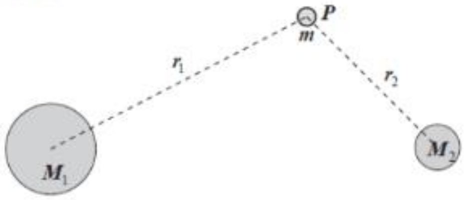
Substitute for V in equation (1) and simplify to obtain:

$$v_0 = \boxed{2\left(1 + \frac{m_2}{m_1}\right)\sqrt{gL}}$$

Problem 6:

54 ••• When we calculate escape speeds, we usually do so with the assumption that the body from which we are calculating escape speed is isolated. This is, of course, generally not true in the Solar system. Show that the escape speed at a point near a system that consists of two massive spherical bodies is equal to the square root of the sum of the squares of the escape speeds from each of the two bodies considered individually.

Picture the Problem The pictorial representation shows the two massive objects from which the object (whose mass is m), located at point P, is to escape. This object will have escaped the gravitational fields of the two massive objects provided, when its gravitational potential energy has become zero, its kinetic energy will also be zero.



Express the total energy of the system consisting of the two massive objects and the object whose mass is m:

$$E = \tfrac{1}{2}mv^2 - \frac{GM_1m}{r_1} - \frac{GM_2m}{r_2}$$

When the object whose mass is m has escaped, $E = 0$ and:

$$0 = \tfrac{1}{2}mv_e^2 - \frac{GM_1m}{r_1} - \frac{GM_2m}{r_2}$$

Solving for v_e yields:

$$v_e^2 = \frac{2GM_1}{r_1} + \frac{2GM_2}{r_2}$$

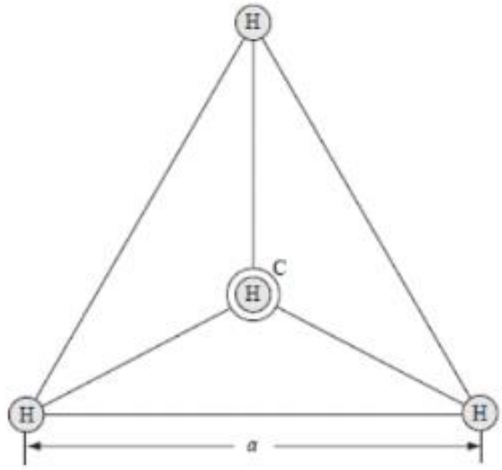
The terms on the right-hand side of the equation are the squares of the escape speeds from the objects whose masses are M_1 and M_2. Hence;

$$v_e^2 = \boxed{v_{e,1}^2 + v_{e,2}^2}$$

Problem 8:

49 •• The methane molecule (CH_4) has four hydrogen atoms located at the vertices of a regular tetrahedron of edge length 0.18 nm, with the carbon atom at the center of the tetrahedron (Figure 9-48). Find the moment of inertia of this molecule for rotation about an axis that passes through the centers of the carbon atom and one of the hydrogen atoms.

Picture the Problem The axis of rotation passes through the center of the base of the tetrahedron. The carbon atom and the hydrogen atom at the apex of the tetrahedron do not contribute to I because the distance of their nuclei from the axis of rotation is zero. From the geometry, the distance of the three H nuclei from the rotation axis is $a/\sqrt{3}$, where a is the length of a side of the tetrahedron.



Apply the definition of the moment of inertia for a system of particles to obtain:

$$I = \sum_i m_i r_i^2 = m_H r_1^2 + m_H r_2^2 + m_H r_3^2$$
$$= 3m_H\left(\frac{a}{\sqrt{3}}\right)^2 = m_H a^2$$

Substitute numerical values and evaluate I:

$$I = \left(1.67\times10^{-27}\text{ kg}\right)\left(0.18\times10^{-9}\text{ m}\right)^2$$
$$= \boxed{5.4\times10^{-47}\text{ kg}\cdot\text{m}^2}$$