29 (a) The speed v of both balls just before the basketball reaches the ground may be found from $v_{yf}^2 = v_{yi}^2 + 2a_y\Delta y$ as

$$v = \sqrt{v_{yi}^2 + 2a_y\Delta y} = \sqrt{0 + 2(-g)(-h)} = \sqrt{2gh}$$
$$= \sqrt{2(9.80\text{ m/s}^2)(1.20\text{ m})} = \boxed{4.85\text{ m/s}}$$

(b) Immediately after the basketball rebounds from the floor, it and the tennis ball meet in an elastic collision. The velocities of the two balls just before collision are

for the tennis ball (subscript t): $\quad v_{ti} = -v$

and for the basketball (subscript b): $\quad v_{bi} = +v$

We determine the velocity of the tennis ball immediately after this elastic collision as follows:

Momentum conservation gives

$$m_t v_{tf} + m_b v_{bf} = m_t v_{ti} + m_b v_{bi}$$

or $\quad m_t v_{tf} + m_b v_{bf} = (m_b - m_t)v \qquad$ **[1]**

From the criteria for a perfectly elastic collision:

$$v_{ti} - v_{bi} = -(v_{tf} - v_{bf})$$

or $\quad v_{bf} = v_{tf} + v_{ti} - v_{bi} = v_{tf} - 2v \qquad$ **[2]**

Substituting equation [2] into [1] gives

$$m_t v_{tf} + m_b(v_{tf} - 2v) = (m_b - m_t)v$$

or the upward speed of the tennis ball immediately after the collision is

$$v_{tf} = \left(\frac{3m_b - m_t}{m_t + m_b}\right)v = \left(\frac{3m_b - m_t}{m_t + m_b}\right)\sqrt{2gh}$$

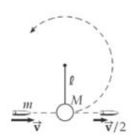
The vertical displacement of the tennis ball during its rebound following the collision is given by $v_{yf}^2 = v_{yi}^2 + 2a_y\Delta y$ as

$$\Delta y = \frac{v_{yf}^2 - v_{yi}^2}{2a_y} = \frac{0 - v_{tf}^2}{2(-g)} = \left(\frac{1}{\cancel{2g}}\right)\left(\frac{3m_b - m_t}{m_t + m_b}\right)^2(\cancel{2g}h)$$
$$= \left(\frac{3m_b - m_t}{m_t + m_b}\right)^2 h$$

Substituting,

$$\Delta y = \left[\frac{3(590\text{ g}) - (57.0\text{ g})}{57.0\text{ g} + 590\text{ g}}\right]^2(1.20\text{ m}) = \boxed{8.41\text{ m}}$$

30 Energy is conserved for the bob-Earth system between bottom and top of the swing. At the top the stiff rod is in compression and the bob nearly at rest.



ANS. FIG. P9.30

$$K_i + U_i = K_f + U_f: \quad \frac{1}{2}Mv_b^2 + 0 = 0 + Mg2\ell$$

$$v_b^2 = 4g\ell \qquad \text{so} \qquad v_b = 2\sqrt{g\ell}$$

Momentum of the bob-bullet system is conserved in the collision:

$$mv = m\frac{v}{2} + M\left(2\sqrt{g\ell}\right) \quad \rightarrow \quad \boxed{v = \frac{4M}{m}\sqrt{g\ell}}$$

31 The collision between the clay and the wooden block is completely inelastic. Momentum is conserved by the collision. Find the relation between the speed of the clay (C) just before impact and the speed of the clay+block (CB) just after impact:

$$\vec{\mathbf{p}}_{Bi} + \vec{\mathbf{p}}_{Ci} = \vec{\mathbf{p}}_{Bf} + \vec{\mathbf{p}}_{Cf} \rightarrow m_B v_{Bi} + m_C v_{Ci} = m_B v_{Bf} + m_C v_{Cf}$$
$$M(0) + mv_C = mv_{CB} + Mv_{CB} = (m+M)v_{CB}$$
$$v_C = \frac{(m+M)}{m}v_{CB}$$

Now use conservation of energy in the presence of friction forces to find the relation between the speed v_{CB} just after impact and the distance the block slides before stopping:

$$\Delta K + \Delta E_{\text{int}} = 0: \quad 0 - \frac{1}{2}(m+M)v_{CB}^2 - fd = 0$$

and $\quad -fd = -\mu nd = -\mu(m+M)gd$

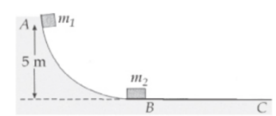
$$\rightarrow \frac{1}{2}(m+M)v_{CB}^2 = \mu(m+M)gd \rightarrow v_{CB} = \sqrt{2\mu gd}$$

Combining our results, we have

$$v_C = \frac{(m+M)}{m}\sqrt{2\mu gd}$$
$$= \frac{(12.0\text{ g} + 100\text{ g})}{12.0\text{ g}}\sqrt{2(0.650)(9.80\text{ m/s}^2)(7.50\text{ m})}$$

$$\boxed{v_C = 91.2\text{ m/s}}$$

33 The mechanical energy of the isolated block-Earth system is conserved as the block of mass m_1 slides down the track. First we find v_1, the speed of m_1 at B before collision:



ANS. FIG. P9.33

$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2}m_1 v_1^2 + 0 = 0 + m_1 gh$$

$$v_1 = \sqrt{2(9.80\text{ m/s}^2)(5.00\text{ m})} = 9.90\text{ m/s}$$

Now we use the text's analysis of one-dimensional elastic collisions to find v_{1f}, the speed of m_1 at B just after collision.

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2}v_1 = -\frac{1}{3}(9.90)\text{ m/s} = -3.30\text{ m/s}$$

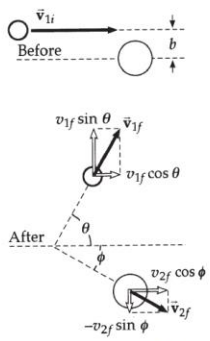
Now the 5-kg block bounces back up to its highest point after collision according to

$$m_1 g h_{\max} = \frac{1}{2}m_1 v_{1f}^2$$

which gives

$$h_{\max} = \frac{v_{1f}^2}{2g} = \frac{(-3.30\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = \boxed{0.556\text{ m}}$$

35 (a) We write equations expressing conservation of the x and y components of momentum, with reference to the figures on the right. Let the puck initially at rest be m_2. In the x direction,



ANS. FIG. P9.35

$$m_1 v_{1i} = m_1 v_{1f}\cos\theta + m_2 v_{2f}\cos\phi$$

which gives

$$v_{2f}\cos\phi = \frac{m_1 v_{1i} - m_1 v_{1f}\cos\theta}{m_2}$$

or

$$v_{2f}\cos\phi = \left(\frac{1}{0.300\text{ kg}}\right)[(0.200\text{ kg})(2.00\text{ m/s}) - (0.200\text{ kg})(1.00\text{ m/s})\cos 53.0°]$$

In the y direction,

$$0 = m_1 v_{1f}\sin\theta - m_2 v_{2f}\sin\phi$$

which gives

$$v_{2f}\sin\phi = \frac{m_1 v_{1f}\sin\theta}{m_2}$$

or

$$0 = (0.200\text{ kg})(1.00\text{ m/s})\sin 53.0° - (0.300\text{ kg})(v_{2f}\sin\phi)$$

From these equations, we find

$$\tan\phi = \frac{\sin\phi}{\cos\phi} = \frac{0.532}{0.932} = 0.571 \quad\text{or}\quad \boxed{\phi = 29.7°}$$

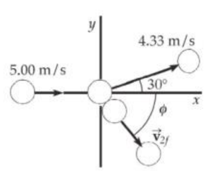
Then $v_{2f} = \dfrac{0.160\text{ kg}\cdot\text{m/s}}{(0.300\text{ kg})(\sin 29.7°)} = \boxed{1.07\text{ m/s}}$

(b) $K_i = \dfrac{1}{2}(0.200\text{ kg})(2.00\text{ m/s})^2 = 0.400\text{ J}$ and

$$K_f = \frac{1}{2}(0.200\text{ kg})(1.00\text{ m/s})^2 + \frac{1}{2}(0.300\text{ kg})(1.07\text{ m/s})^2 = 0.273\text{ J}$$

$$f_{\text{lost}} = \frac{\Delta K}{K_i} = \frac{K_f - K_i}{K_i} = \frac{0.273\text{ J} - 0.400\text{ J}}{0.400\text{ J}} = \boxed{-0.318}$$

.41 By conservation of momentum for the system of the two billiard balls (with all masses equal), in the x and y directions separately,



ANS. FIG. P9.41

$$5.00\text{ m/s} + 0 = (4.33\text{ m/s})\cos 30.0° + v_{2fx}$$

$$v_{2fx} = 1.25\text{ m/s}$$

$$0 = (4.33\text{ m/s})\sin 30.0° + v_{2fy}$$

$$v_{2fy} = -2.16\text{ m/s}$$

$$\vec{v}_{2f} = \boxed{2.50\text{ m/s at } -60.0°}$$

Note that we did not need to explicitly use the fact that the collision is perfectly elastic.