AP® Physics C: Mechanics
2002 Sample Student Responses

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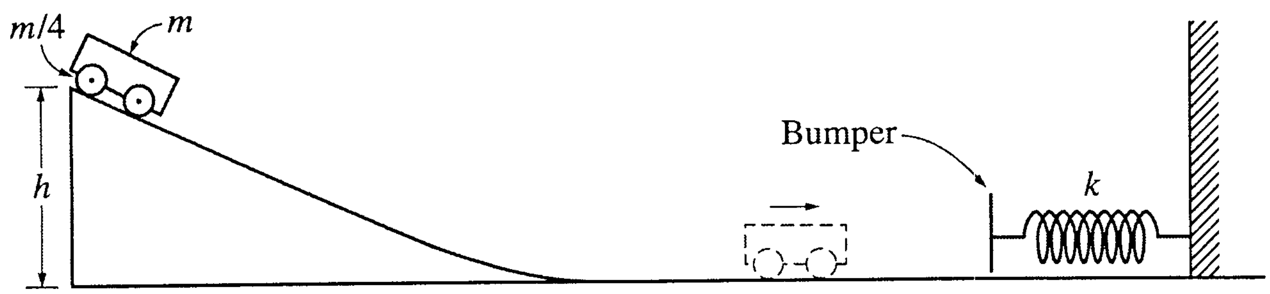

Mech 2.

The cart shown above is made of a block of mass m and four solid rubber tires each of mass $m/4$ and radius r. Each tire may be considered to be a disk. (A disk has rotational inertia $\frac{1}{2}ML^2$, where M is the mass and L is the radius of the disk.) The cart is released from rest and rolls without slipping from the top of an inclined plane of height h. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Determine the total rotational inertia of all four tires.

$4\left(\frac{1}{2}ML^2\right)$

$4\left(\frac{1}{2}\left(\frac{m}{4}\right)(r)^2\right)$

$= \frac{1}{2}mr^2$

(b) Determine the speed of the cart when it reaches the bottom of the incline.

$E_i = E_f$

$2mgh = \frac{1}{2}(2m)v^2 + \frac{1}{2}\left(\frac{1}{2}mr^2\right)\omega^2$

$2mgh = mv^2 + \frac{1}{4}mr^2\omega^2 = v^2$

$2mgh = mv^2 + \frac{1}{4}mv^2$

$2mgh = \frac{5}{4}mv^2$

$\frac{4}{5}(2mgh) = mv^2$

$\frac{8}{5}mgh = mv^2$

$\sqrt{\frac{8}{5}gh} = v$

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(c) After rolling down the incline and across the horizontal surface, the cart collides with a bumper of negligible mass attached to an ideal spring, which has a spring constant k. Determine the distance x_m the spring is compressed before the cart and bumper come to rest.

$$E_i = E_f$$

$$2mgh = \frac{1}{2}kx^2$$

$$4mgh = kx^2$$

$$\frac{4mgh}{k} = x^2$$

$$\sqrt{\frac{4mgh}{k}} = x$$

(d) Now assume that the bumper has a non-neglible mass. After the collision with the bumper, the spring is compressed to a maximum distance of about 90% of the value of x_m in part (c). Give a reasonable explanation for this decrease.

The collision between the cart and the bumper is inelastic. Therefore $mv_0 = Mv_f$ where m is the mass of the cart, v_0 is the speed of the cart before the collision, M is the mass of the cart and the bumper, and v_f is the final velocity of the cart-bumper system. If linear momentum is conserved v_f will be less than v_0. A smaller v_f will result in a smaller distance travelled so the spring will only be compressed 90% of the x_m in part c.

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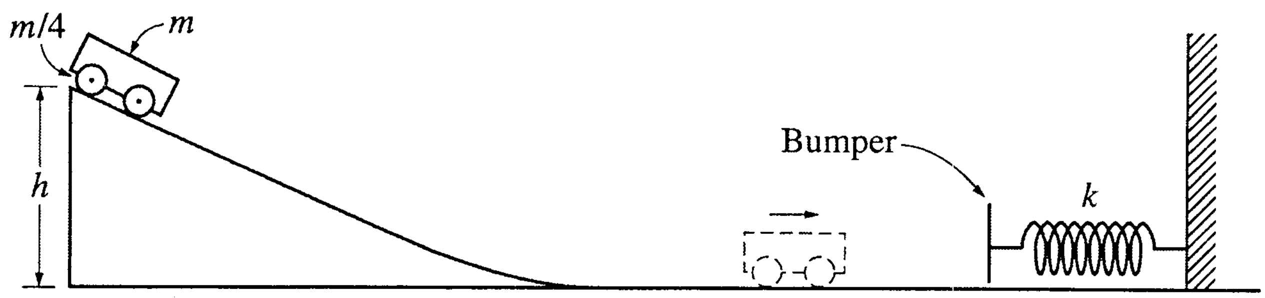

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(a) Determine the total rotational inertia of all four tires.

$$I = 4\left(\frac{1}{2}\frac{m}{4}r^2\right)$$

$$\boxed{I = \frac{1}{2}mr^2}$$

(b) Determine the speed of the cart when it reaches the bottom of the incline.

$$\Delta U_g = \Delta K_{rot} + \Delta K_{Trans}$$

$$2mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}2mV^2$$

$$2mgh = \frac{1}{2}\left(\frac{1}{2}mr^2\right)\left(\frac{V}{r}\right)^2 + \frac{1}{2}2mV^2$$

$$2gh = \frac{V^2}{4} + V^2 = \frac{5V^2}{4}$$

$$\boxed{\sqrt{\frac{8gh}{5}} = V}$$

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(c) After rolling down the incline and across the horizontal surface, the cart collides with a bumper of negligible mass attached to an ideal spring, which has a spring constant k. Determine the distance x_m the spring is compressed before the cart and bumper come to rest.

$\Delta U_{grav} = \Delta K_{rot} + \Delta K_{Trans} = \Delta U_{Elastic}$

$\Delta U_g = \Delta U_{Elastic}$

$2mgh = \frac{1}{2} k X_m^2$

$\sqrt{\frac{4mgh}{k}} = X_m$

(d) Now assume that the bumper has a non-neglible mass. After the collision with the bumper, the spring is compressed to a maximum distance of about 90% of the value of x_m in part (c). Give a reasonable explanation for this decrease.

Due to conservation of momentum, the speed (V) of the cart would be decreased as it hit the stationary bumper. This would lower the total kinetic energy of the cart-bumper system. Since the total Kinetic energy of the cart going in is equal to the final potential energy of the spring, less KE means less compression of the spring

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