



## AP<sup>®</sup> Physics C: Mechanics 2002 Sample Student Responses

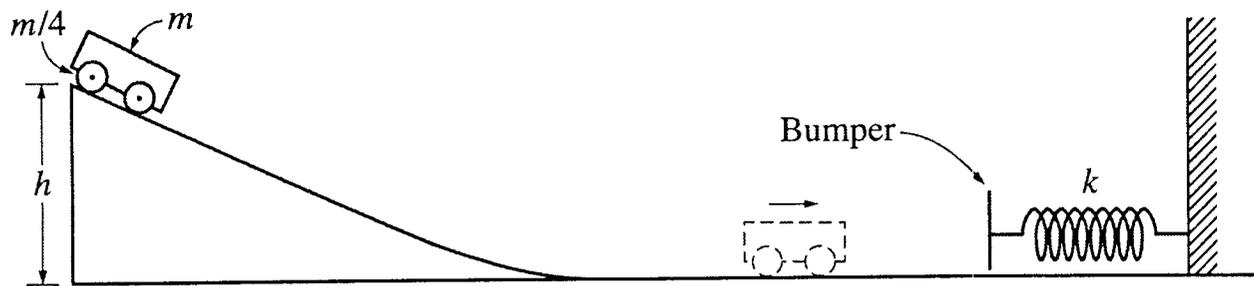
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Mech 2.

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.

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

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

$$\boxed{= \frac{1}{2} m r^2}$$

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

$$E_i = E_f$$

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

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

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

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

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

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

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

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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.

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

$$4mgh = kx^2$$

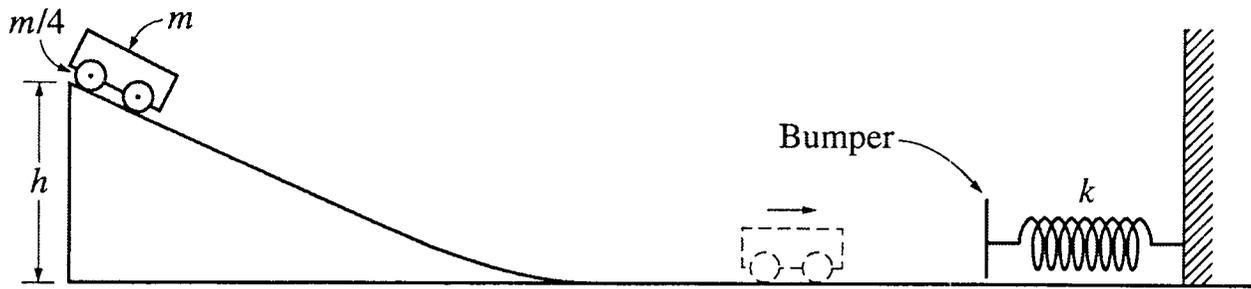
$$\frac{4mgh}{k} = x^2$$

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

- (d) Now assume that the bumper has a non-negligible 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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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.

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

$$I = \frac{1}{2} m r^2$$

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

$$\Delta U_g = \Delta K_{\text{rot}} + \Delta K_{\text{trans}}$$

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

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

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

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

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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.

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

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

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

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

- (d) Now assume that the bumper has a non-negligible 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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