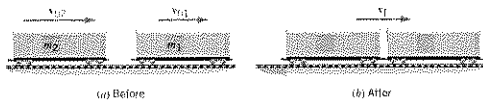


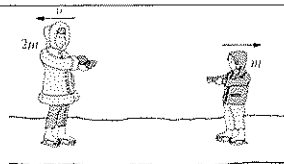
Review Slides

Post-Energy, Momentum, CM,
Angular Momentum, Torque,
Rotational Inertia

What is the type of collision pictured?



Inelastic
(because they stick together,
it is totally, or
completely, inelastic)



8. A boy of mass m and a girl of mass $2m$ are initially at rest at the center of a frozen pond. They push each other so that she slides to the left at speed v across the frictionless ice surface and he slides to the right as shown above. What is the total work done by the children?

- (A) Zero
- (B) mv
- (C) mv^2
- (D) $2mv^2$
- (E) $3mv^2$

$$W_{\text{girl}} = \Delta KE_{\text{girl}} = \frac{1}{2} (2m) v_{\text{girl}}^2$$

$$W_{\text{boy}} = \Delta KE_{\text{boy}} = \frac{1}{2} m v_{\text{boy}}^2$$

- to get v_{boy} , need momentum cons.

$$\phi = -2mv_{\text{girl}} + mv_{\text{boy}} \rightarrow v_{\text{boy}} = 2v_{\text{girl}}$$

$$W_{\text{TOT}} = W_{\text{girl}} + W_{\text{boy}} = \frac{1}{2} (2m) v^2 + \frac{1}{2} (m) (2v)^2$$

$$= mv^2 + 2mv^2 = 3mv^2$$

10. A toy spacecraft is launched directly upward. When the toy reaches its highest point, a spring is released and the toy splits into two parts with masses of 0.02 kg and 0.08 kg, respectively. Immediately after the separation, the 0.02 kg part moves horizontally due east. Air resistance is negligible. True statements about the 0.08 kg part include which of the following?

- I. It could move north immediately after the spring is released.
 - II. It takes longer to reach the ground than does the 0.02 kg part.
 - III. It strikes the ground farther from the launch point than does the 0.02 kg part.
- (A) None
 (B) I only
 (C) III only
 (D) I and II only
 (E) II and III only

- 0.08 kg part MUST move West to conserve horizontal momentum
- Both will fall at same rate since g same for both and $v_{yi} = 0$.
- By cons. of momentum, the 0.08 kg part will have slower horizontal speed than 0.02 kg part, so must strike closer to launch pt.

11. A student initially stands on a circular platform that is free to rotate without friction about its center. The student jumps off tangentially, setting the platform spinning. Quantities that are conserved for the student-platform system as the student jumps include which of the following?

- I. Angular momentum
 - II. Linear momentum
 - III. Kinetic energy
- (A) I only
 (B) II only
 (C) I and II only
 (D) II and III only
 (E) I, II, and III

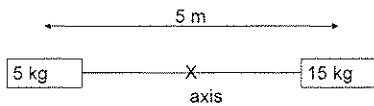
(A) as discussed in class

13. A comet moves in the Sun's gravitational field, following the path shown above. What happens to its angular momentum as it moves from point X to point Y?

- (A) It increases steadily.
- (B) It remains constant.
- (C) It decreases steadily.
- (D) It increases as it approaches the Sun and decreases as it moves away from the Sun.
- (E) It decreases as it approaches the Sun and increases as it moves away from the Sun.

(B) gravity from the Sun is a center-directed force and center-directed forces have no \perp components to \vec{r} , so no torque. If no torque, then L constant.
 $AL = r \times t$
 (just like $\Delta p = Ft$)

What is the rotational inertia for this object?



$$I = m_1 x_1^2 + m_2 x_2^2$$

$$I = 15(2.5^2) + 5(-2.5)^2$$

$$I = 125 \text{ kg} \cdot \text{m}^2$$

A block of mass M_1 on a horizontal table is connected to a hanging block of mass M_2 by a string that passes over a pulley, as shown above. The acceleration of the blocks is $0.6g$. Assume that friction and the mass of the string are negligible.

18. The tension T in the string is

(A) zero
 (B) $0.4 M_2 g$
 (C) $0.6 M_2 g$
 (D) $1.0 M_2 g$
 (E) $1.6 M_2 g$

$$M_2 g - F_T = M_2 a$$

$$M_2 g - F_T = M_2 (0.6g)$$

$$F_T = 1.6 M_2 g$$

A block of mass M_1 on a horizontal table is connected to a hanging block of mass M_2 by a string that passes over a pulley, as shown above. The acceleration of the blocks is $0.6g$. Assume that friction and the mass of the string are negligible.

19. The ratio of masses M_2/M_1 is

(A) 0.67
 (B) 1.0
 (C) 1.4
 (D) 1.5
 (E) 1.6

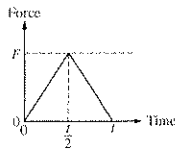
$$M_2 g = (M_1 + M_2) a$$

$$M_2 g = (M_1 + M_2) 0.6g$$

$$M_2 = 0.6 M_1 + 0.6 M_2$$

$$0.4 M_2 = 0.6 M_1$$

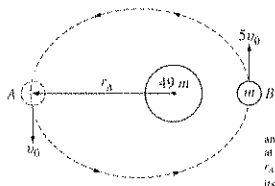
$$M_2/M_1 = 0.6/0.4 = 3/2$$



22. The graph above shows the force acting on an object as a function of time. The change in momentum of the object from time 0 to t is

- (A) $2Ft$
- (B) Ft
- (C) $\frac{1}{2}Ft$
- (D) $\frac{1}{4}Ft$
- (E) zero

$$\begin{aligned} \text{area} &= \text{impulse} \\ &= \frac{1}{2}bh \\ &= \frac{1}{2}t(F) = \frac{Ft}{2} \end{aligned}$$



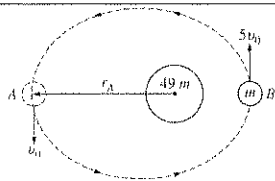
A moon of mass m orbits a planet of mass $49m$ in an elliptical orbit as shown above. When the moon is at point A , its distance from the center of the planet is r_A and its speed is v_0 . When the moon is at point B , its speed is $5v_0$.

Note: Figure not drawn to scale.

23. When the moon is at point A , the distance from the moon to the center of mass of the planet-moon system is most nearly

- (A) $\frac{1}{50}r_A$
- (B) $\frac{1}{2}r_A$
- (C) $\frac{1}{2}r_A$
- (D) $\frac{6}{7}r_A$
- (E) $\frac{49}{50}r_A$

$$\begin{aligned} 49m(\emptyset) + m(r_A) &= 50m \times x_{cm} \\ x_{cm} &= \frac{1}{50}r_A \text{ from planet} \\ \text{so distance of moon to} \\ \text{cm is } r_A - \frac{1}{50}r_A &= \frac{49}{50}r_A \end{aligned}$$



Note: Figure not drawn to scale.

24. When the moon is at point B , the distance from the moon to the center of the planet is most nearly

- (A) $\frac{1}{25}r_A$
- (B) $\frac{1}{5}r_A$
- (C) $\frac{1}{25}r_A$
- (D) r_A
- (E) $\sqrt{5}r_A$

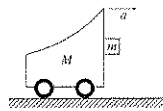
$$\begin{aligned} \text{ang. momentum is constant} \\ L_A &= L_B \\ m \cdot v_0 \cdot r_A &= m \cdot (5v_0) \cdot r_B \end{aligned}$$

$$r_B = \frac{1}{5}r_A$$

9. An object of mass M travels along a horizontal air track at a constant speed v and collides elastically with an object of identical mass that is initially at rest on the track. Which of the following statements is true for the two objects after the impact?

- (A) The total momentum is Mv and the total kinetic energy is $\frac{1}{2}Mv^2$.
 (B) The total momentum is Mv and the total kinetic energy is less than $\frac{1}{2}Mv^2$.
 (C) The total momentum is less than Mv and the total kinetic energy is $\frac{1}{2}Mv^2$.
 (D) The momentum of each object is $\frac{1}{2}Mv$.
 (E) The kinetic energy of each object is $\frac{1}{4}Mv^2$.

- total momentum is Mv
 • total energy is $\frac{1}{2}Mv^2$
 so (A) is correct



59. The figure above shows a cart of mass M accelerating to the right with a block of mass m held to the front surface only by friction. The coefficient of friction between the surfaces is μ . What is the minimum acceleration a of the cart such that the block will not fall?

- (A) μg
 (B) $\frac{g}{\mu}$
 (C) $\frac{gM}{\mu(M+m)}$
 (D) $\frac{gM}{\mu(M+m)}$
 (E) $\frac{\mu g M}{M + m}$

Normal force of push M on m

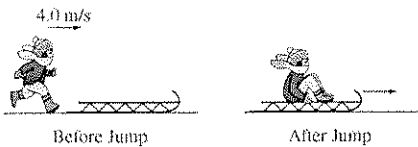
$$\sum F_y = ma_y^0 = f - mg = \mu F_{\text{norm}} - mg$$

$$\mu F_{\text{norm}} = mg$$

$$\sum F_x = ma_x = F_{\text{norm}}$$

$$\mu (ma_x) = mg$$

$$a_x = g/\mu$$



9. As shown in the figure above, a child of mass 20 kg who is running at a speed of 4.0 m/s jumps onto a stationary sled of mass 5.0 kg on a frozen lake. The speed at which the child and sled begin to slide across the ice is most nearly

- (A) 0.20 m/s
 (B) 0.80 m/s
 (C) 1.2 m/s
 (D) 3.2 m/s
 (E) 16 m/s

momentum conserved

$$20(4) + 0 = 25v$$

$$v = \frac{80}{25} = 3.2 \text{ m/s}$$



61. The acceleration of a satellite of mass m in a circular orbit of radius R around a planet of mass M is equal to which of the following?

(A) $G \frac{M}{R^2}$
 (B) $G \frac{m}{R^2}$
 (C) $G \frac{mM}{R^2}$
 (D) $G \frac{mM}{R}$
 (E) $GmMR$

$$F_g = ma_c$$

$$\frac{GmM}{R^2} = \frac{mv^2}{R} = ma_c$$

$$a_c = \frac{GM}{R^2}$$

66. A ball of mass m with speed u strikes a wall at an angle θ with the normal, as shown above. It then rebounds with the same speed and at the same angle. The impulse delivered by the ball to the wall is

(A) zero
 (B) $mu \sin \theta$
 (C) $mu \cos \theta$
 (D) $2mu \sin \theta$
 (E) $2mu \cos \theta$

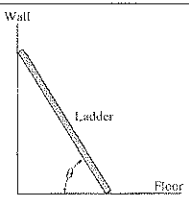


$$\Delta p = mu \cos \theta - (-mu \cos \theta) = 2mu \cos \theta$$

A uniform ladder of weight W leans without slipping against a wall making an angle θ with a floor as shown above. There is friction between the ladder and the floor, but the friction between the ladder and the wall is negligible.

31. The magnitude of the normal force exerted by the floor on the ladder is

(A) W
 (B) $W \sin \theta$
 (C) $W \cos \theta$
 (D) $\frac{W}{2} \sin \theta$
 (E) $\frac{W}{2} \cos \theta$



(A)

$$\sum F_y = ma_y = 0 = F_N - W$$

$$F_N = W$$



A uniform ladder of weight W leans without slipping against a wall making an angle θ with a floor as shown above. There is friction between the ladder and the floor, but the friction between the ladder and the wall is negligible.

32. The magnitude of the friction force exerted on the ladder by the floor is

(A) $2W \tan \theta$
 (B) W
 (C) $W \cot \theta$
 (D) $\frac{W}{2}$
 (E) $\frac{W}{2} \cot \theta$

$$\Sigma F_x = m a_x = P - f$$

use torque to find P

$$W \cos \theta \left(\frac{L}{2}\right) = P \sin \theta (L)$$

$$P = \frac{W \cos \theta}{2 \sin \theta} = \frac{W \cot \theta}{2} = f$$

What is the angular speed of the system after the man on the left grabs the stick?

$m_1 = m_2$
 Length of stick = 3 m
 $v_1 = 2.5 \text{ m/s}$
 $v_2 = 0$

ang. mom. conserved

$$m_1 v_1 r_1 + \phi = 2m v r$$

$$2.5(2r) + \phi = 2v(2r)$$

$$v = \frac{2.5}{2} = 1.25 \text{ m/s}$$

$$v = \omega r \quad \omega = \frac{v}{r} = \frac{1.25}{2.5}$$

$$\omega = 0.5 \text{ rad/s}$$

The 0.5 kg block sticks to the ball. How far from the base of the table will the two land?

Note: Figure not drawn to scale.

mom. conserved (not mechanical)

$$0.5(26) + \phi = 5.5v$$

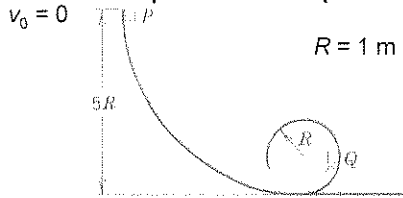
$$v = 2.36 \text{ m/s} = v_{xi}$$

projectile (cliff) prob

$$\Delta y = \frac{1}{2} a_y t^2 \rightarrow t = 0.49 \text{ s}$$

$$\Delta x = v_{xi} t = 2.36(0.49) \approx 1.16 \text{ m}$$

What is the magnitude of the normal force that the track exerts on the 2 kg cube at the top of the loop?



at top

$$F_N + mg = \frac{mv^2}{R}$$

$$F_N = \frac{mv^2}{R} - mg$$

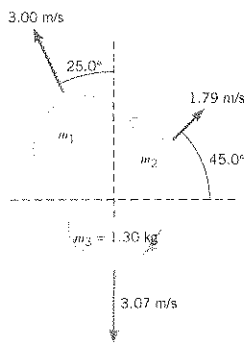
use energy to find v

$$E_{top} = E_{bot}$$

$$mg(5R) = mg(2R) + \frac{1}{2}mv^2$$

$$3mgR = \frac{1}{2}mv^2$$

$$F_N = \frac{6mgR}{R} - mg = 5mg$$



What is the total mass of the plate?

horizontal momentum before = 0

$$\sum p_x = 0 = 3m_1 \sin 25^\circ - 1.79m_2 \cos 45^\circ$$

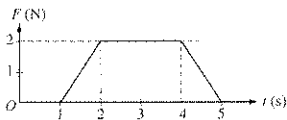
$$1.27m_1 = 1.27m_2 \rightarrow m_1 = m_2$$

$$\sum p_y = 0 = m_1(3 \cos 25^\circ) + m_2(1.79 \sin 45^\circ) - 1.3(3.07)$$

$$2.72m_1 + 1.27m_2 = 3.99 \text{ use } m_1 = m_2$$

$$3.99m = 3.99 \quad m_1 = 1 = m_2$$

$$2m_1 + 1.3m_3 = 3.3 \text{ kg}$$



10. A 2 kg object initially moving with a constant velocity is subjected to a force of magnitude F in the direction of motion. A graph of F as a function of time t is shown above. What is the increase, if any, in the velocity of the object during the time the force is applied?

- (A) 0 m/s
- (B) 2.0 m/s
- (C) 3.0 m/s
- (D) 4.0 m/s
- (E) 6.0 m/s

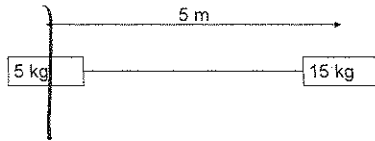
$$\Delta p = \text{area} = 2(2) + \frac{1}{2}(1)(2) + \frac{1}{2}(1)(2)$$

$$= 4 + 1 + 1 = 6 \text{ N}\cdot\text{s}$$

$$6 = m\Delta v$$

$$6 = 2\Delta v \quad \Delta v = 3 \text{ m/s}$$

Where is the CM of the system
(relative to the left end)?

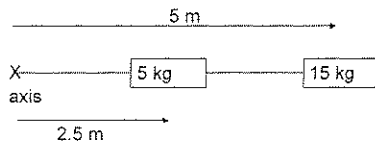


$$M x_{cm} = m_1 x_1 + m_2 x_2$$

$$20 x_{cm} = 5(0) + 15(5)$$

$$x_{cm} = 3.75 \text{ m}$$

What is the rotational inertia
for this object?



$$I = m_1 x_1^2 + m_2 x_2^2$$

$$I = 5(2.5^2) + 15(5^2)$$

$$I = 406 \text{ kg} \cdot \text{m}^2$$