Chapter 3. Momentum and Energy

Think and Solve (Mathematica Application)

50. In Chapter 1 we learned that acceleration $a = \frac{\Delta v}{\Delta t}$, and in Chapter 2 we learned that the cause of acceleration involves net force, where $a = \frac{F}{m}$. Equate these two equations for acceleration and show that, for constant mass, $F\Delta t = \Delta(mv)$.

51. A 10-kg bag of groceries is tossed onto a table at 3 m/s and slides to a stop in 2 s. Begin with the equation you derived in Problem 50, and show that the force of friction is 15 N.

52. An ostrich egg of mass m is tossed at a speed v into a sagging bed sheet and is brought to rest in a time t.

(a) Show that the force acting on the egg when it hits the sheet is $\frac{mv}{t}$

(b) Show that if the mass of the egg is 1 kg, its initial speed is 2 m/s, and the time to stop is 1 s, then the average force on the egg is 2 N.

53. A 6-kg ball rolling at 3 m/s bumps into a pillow and stops in 0.5 s.

(a) Show that the force exerted by the pillow is 36 N.

(b) How much force does the ball exert on the pillow?

54. At a baseball game, a ball of mass m= 0.15 kg moving at a speed v= 30 m/s is caught by a fan.

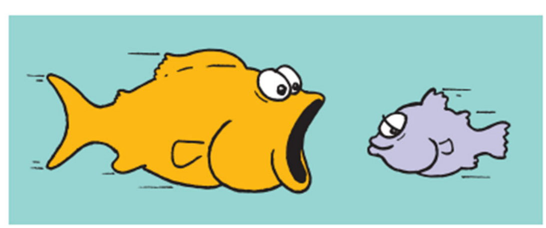
(a) Show that the impulse supplied to bring the ball to rest is 4.5 N.s.

(b) Show that if the ball is stopped in 0.02 s, then the average force of the ball on the catcher's hand is 225 N.

55. Jeannie Beanie (mass 40 kg), standing on slippery ice, catches her leaping dog, Daisy (mass 20 kg), who leapt into her arms after running across an adjacent field at 6 m/s. Use the conservation of momentum to show that the speed of Jeannie and her dog after the catch is 2 m/s.

56. A railroad diesel engine weighs four times as much as a freight car. The diesel engine coasts at 5 km/h into a freight car that is initially at rest. Use the conservation of momentum to show that after they couple together, the engine + car coast at 4 km/h.

57. A 5-kg fish swimming at 1 m/s swallows an absentminded 1-kg fish swimming toward it at a velocity that brings both fish to a halt. Show that the speed of the smaller fish before lunch was 5 m/s.



58. Little Hudson (next page) holds the 10-kg barbell 0.3 m above the floor.

(a) What is the PE of the barbell relative to the floor?

(b) How much additional work will Hudson do when he lifts the barbell to a height 1.0 m above the floor?

(c) If Hudson then drops the barbell, what will be its KE of impact with the floor?

59. If you push a crate horizontally with a force of 100 N across a 10-m factory floor, and the friction force between the crate and the floor is a steady 70 N, how much kinetic energy is gained by the crate?

60. A simple lever is used to lift a heavy load. When a 60-N force pushes one end of the lever downward 1.2 m, the load rises 0.2 m. Show that the weight of the load is 360 N.

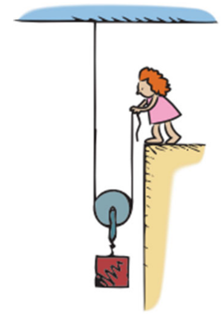
61. The following questions refer to Problem 60:

(a) How much work is done by the 60-N force?

(b) What is the gain in PE of the load?

(c) How does the work done compare with the increased PE of the load?

62. In raising a 6000-N piano with a pulley system, the movers note that for every 2 m of rope pulled down, the piano rises 0.2 m. Show that, ideally, the force required to lift the piano is 600 N.



63. The girl steadily pulls her end of the rope upward a distance of 0.4 m with a constant force of 50 N. By how much does the PE of the block increase? Show that the mass of the block is 10 kg.

64. How many watts of power do you expend when you exert a force of 6 N that moves a book 2 m in a time interval of 3 s?

65. Show that 480 W of power is expended by a weightlifter who lifts a 60-kg barbell a vertical distance of 1.2 m in a time interval of 1.5 s.

66. When an average force F is exerted over a certain distance on a shopping cart of mass m, its kinetic energy increases by $\frac{1}{2}mv^2$.

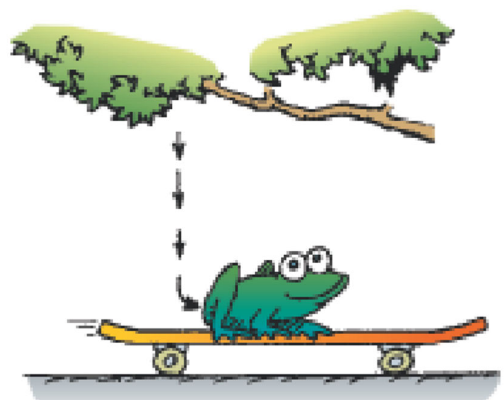
(a) Use the work–energy theorem to show that the distance over which the force acts is $\frac{mv^2}{2F}$.

(b) If twice the force is exerted over twice the distance, how does the resulting increase in kinetic energy compare with the original increase in kinetic energy?

67. Emily holds a banana of mass m over the edge of a bridge of height h. She drops the banana, and it falls to the river below. Use the conservation of energy to show that the speed of the banana just before hitting the water is v = $\sqrt{2gh}$.

68. Starting from rest, Megan zooms down a frictionless slide from an initial height of 4.0 m. Show that her speed at the bottom of the slide is $\sqrt{80}$ m/s, or 8.9 m/s.

91. Freddy Frog drops vertically from a tree onto a horizontally moving skateboard. The skateboard slows. Give two reasons for the slowing, one in terms of a horizontal friction force between Freddy's feet and the skateboard, and one in terms of momentum conservation.

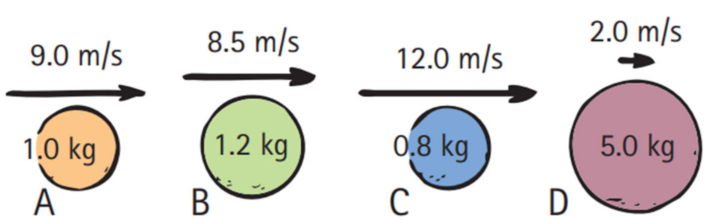


Think and rank

69. The balls have different masses and speeds. Rank the following from greatest to least:

(a) Momentum.

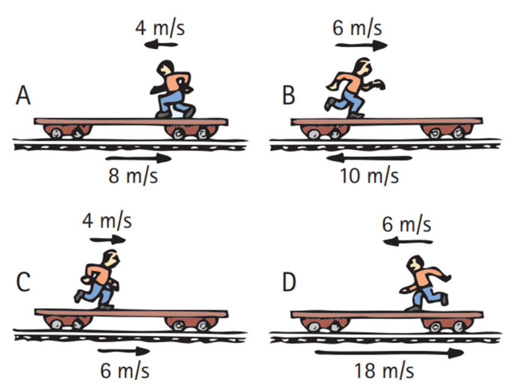
(b) The impulses needed to stop the balls.



70. Jogging Jake runs along a train flatcar that moves at the velocities shown. In each case, Jake's velocity is given relative to the car. Call direction to the right positive. Rank the following from greatest to least:

(a) The magnitude of Jake's momentum relative to the flatcar.

(b) Jake's momentum relative to an observer at rest on the ground.



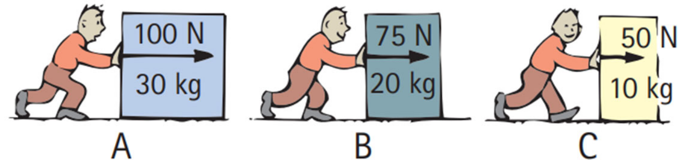
71. Starting from rest, Marshall pushes crates across the floor of his classroom for 3 seconds with a net force as shown. For each crate, rank the following from greatest to least:

(a) Impulse delivered.

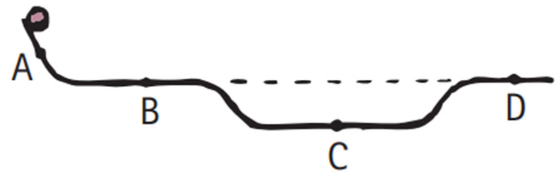
(b) Change in momentum.

(c) Final speed.

(d) Momentum at the end of 3 seconds.



72. A ball is released from rest at the left of the metal track shown. Assume it has only enough friction to roll rather than to slide, but not enough to lessen its speed. Rank, from greatest to least, the following quantities at each point:

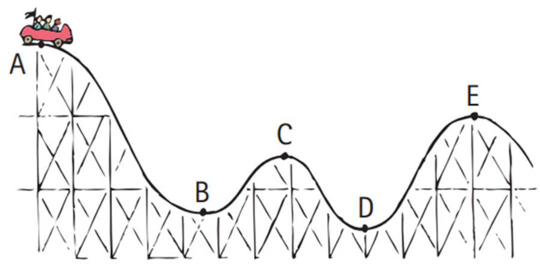


(a) Momentum.

(b) KE.

(c)PE.

73. The roller coaster ride starts from rest at point A. Rank, from greatest to least, the following quantities at each point:

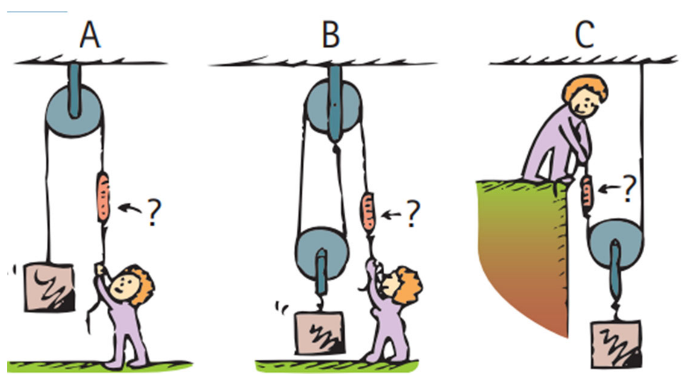


(a) Speed.

(b) KE.

(c) PE

74. Rank the scale readings from greatest to least. (Ignore friction.)



Readiness Assurance Test (RAT)

Choose the BEST answer to the question or the BEST way to complete the statement.

1. A freight train rolls along a track with considerable momentum. If it then rolls at the same speed but has twice as much mass, its momentum is now

A. zero. **B.** twice as large. **C.** four times as large. **D.** unchanged.

2. In the absence of external forces, momentum is conserved in

A. an elastic collision. **B.** an inelastic collision.

C. either an elastic or an inelastic collision. **D.** neither an elastic nor an inelastic collision.

3. If the running speed of Fast Freda doubles, what also doubles is her

A. momentum. **B.** kinetic energy. **C.** both of these **D.** neither of these

2. Which of the following equations best illustrates the usefulness of automobile airbags?

A. $F = ma$ **B.** $Ft = \Delta mv$ **C.** $KE = ½mv^2$ **D.** $Fd = \Delta ½mv^2$

5. Which of the following equations is most useful for solving a problem that asks for the distance that a fast moving box slides across a Post Office floor before coming to a stop?

A. $F = ma$ **B.** $Ft = \Delta mv$ **C.** $KE = ½mv^2$ **D.** $Fd = \Delta ½mv^2$

6. How much work is done on a 200-kg crate that is hoisted 2 m in a time of 4 s?

A. 400 J **B.** 1000 J **C.** 1600 J **D.** 4000 J

7. A circus diver drops from a high pole into water far below. When he is halfway down,

A. his potential energy is halved.

B. he has gained an amount of kinetic energy equal to half his initial potential energy.

C. his kinetic energy and potential energy are equal.

D. all of these

8. A bicycle that travels twice as fast as another when braking to a stop will skid

A. twice as far. **B.** four times as far.

C. eight times as far. **D.** depends on the bike's mass.

9. The initial source of energy for wind power, fossil fuels, and biomass is

A. nuclear. **B.** matter itself. **C.** solar. **D.** photovoltaic.

10. A machine cannot multiply

A. force. **B.** distance. **C.** energy.

D. none of these; that is, it can multiply all of them