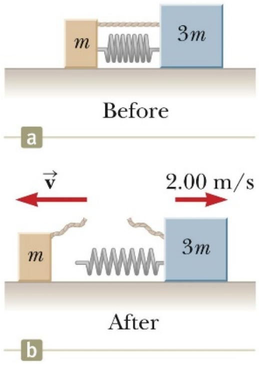
University Physics I

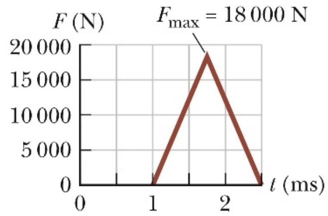
Homework Set 11

1. ** Rank the following objects from greatest to least in terms of momentum and from greatest to least in terms of kinetic energy.
    a. [*Asteroid*] An Asteroid with mass 10^6 *kg* and speed 500 *m/s*
    b. [*Train*] A high-speed train of mass 180,000 *kg* and speed 300 *km/h*
    c. [*Linebacker*] A 120 *kg* linebacker with a speed of 10 *m/s*
    d. [*Cannonball*] A 10 *kg* cannonball with a speed of 120 *m/s*
    e. [*Proton*] A proton with a mass of 1.66×10^{-27} *kg* and speed 2×10^{8} *m/s*

2. Two blocks of masses *m* and 3*m* are placed on a frictionless, horizontal surface. A light spring is attached to the more massive block and the blocks are pushed together with the spring between them as shown in the figure at right. A cord initially holding them together is broken. The block of mass 3*m* moves to the right with a speed of 2.00 *m/s*.
    a. What is the velocity of mass *m*?
    b. Find the systems initial elastic potential energy if *m* = 0.350 *kg*.
    c. Is the original energy of the system in the spring or the cord. Explain.



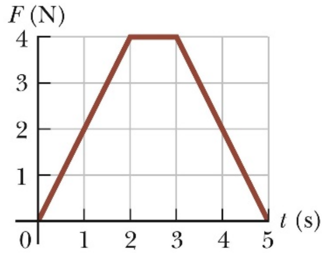
3. An estimated force-time curve for a baseball struck by a bat is shown in the figure at right. From this curve, determine:
    a. The magnitude of the impulse delivered to the ball
    b. The average force exerted on the ball during the impact



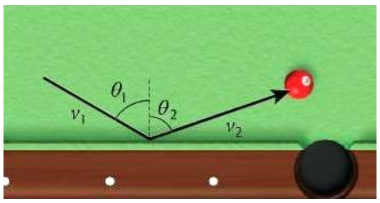
4. Experimental tests have shown that bone will rupture if it is subjected to a force density (*Pressure*) of 1.03×10^{8} N/m^2. Suppose a 70.0 *kg* person carelessly roller-skates into an overhead metal beam that hits his forehead and completely stops his forward motion. If the area of contact with the person's forehead is 1.5 cm^2, what is the maximum speed with which he can hit the beam without fracturing his skull if his head is in contact with the beam for 10.0 *ms*?

    Note: Pressure is Force/Area

5. The magnitude of the net force exerted in the *x*-direction on a 2.50 *kg* particle varies in time as shown in the figure at right. Find:
    a. The impulse of the force over the 5.00 sec time interval
    b. The final velocity of the particle if it is initially at rest
    c. The final velocity of the particle if $\boldsymbol{v_o} = -2.00$ *m/s* $\hat{\boldsymbol{x}}$
    d. The average force exerted on the particle over the 5 sec time interval



6. A billiard ball of mass *m* = 0.250 *kg* hits the cushion of a billiard table at an angle of $\theta_1 = 60.0^o$ and a speed of v_1 = 27.0 *m/s*. If it bounces off at an angle of $\theta_2 = 71.0^o$ and a speed of v_2 = 10.0 *m/s*, find the magnitude of the change in momentum of the billiard ball.



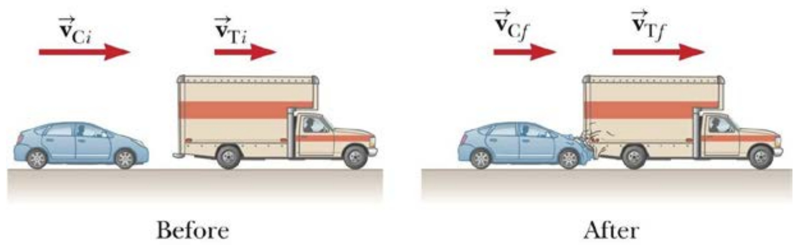
7. In the 1978 movie *Superman*, Lois Lane falls from a building and is caught by the superhero mid-air. Assuming Lois (m = 50.0 *kg*) is falling at a terminal (constant) velocity of 60.0 *m*/*s*,
    - *a.* Find the average force that is exerted on her if it takes 0.100 *s* to slow her to a stop.
    - *b.* If Lois can withstand a maximum acceleration of 7*g*'s, what is the minimum time superman should take in bringing her to a complete stop after he catches up to her?
8. Although they don't have mass, photons – traveling at the speed of light – have momentum. Space travel experts have thought of capitalizing on this fact by constructing *solar sails* – large sheets of material that would work by reflecting photons. Since the momentum of the photon would be reversed, it would experience an impulse being exerted on it, and by Newton's Third Law, the same impulse would be exerted on the solar sail, providing a force to move it forward. In space near the earth, about 3.84×10^{21} photons are incident per square meter per second. On average, the momentum of a single photon is 1.30×10^{-27} *kg m*/*s*. Assuming a 1000 *kg* space craft started at rest and has attached to it a 20.0 *m* wide square sail, how fast could the ship be moving after
    - *a.* 1 hour
    - *b.* 1 week
    - *c.* 1 month (30 *days*)
    - *d.* How long would it take the ship to attain a speed of 8000 m/s (*in years*).

    Note: In reality, the number of photons would decrease as you get further away from the sun. In this problem, we have assumed the number of photons hitting the sail is fixed throughout the journey, which isn't realistic.
9. NASA has taken an increased interest in near-Earth asteroids. These objects, popularized in certain blockbuster movies, can pass very close to Earth. Most are small (*less than 500 m across*) and while an impact with one of the smaller ones would be dangerous, experts believe that it may not be catastrophic to the human race. One possible defense system against near-Earth asteroids involves hitting an incoming asteroid with a rocket to divert its course. Assume a relatively small asteroid with a mass of 2.10×10^{10} *kg* is traveling toward the Earth at a modest speed of 12.0 *km*/*s*:
    - *a.* How fast would a large rocket with a mass 8.00×10^{4} *kg* have to be moving when it hit the asteroid head on in order to stop the asteroid? (*Assume the rocket and asteroid stick together after the collision*)
    - *b.* An alternate approach would be to divert the asteroid from its current path by a small amount and thus cause it to miss the Earth. How fast would the rocket of part (*a*) have to be traveling at impact to divert the asteroid's path by 1.00^{o}? (*Assume the rocket hits the asteroid at a right angle relative to the asteroids path*)
10. In July 2005, NASA's "Deep Impact" mission crashed a 372 *kg* probe directly onto the surface of the comet Tempel 1, hitting the surface head-on with a relative speed of 37,000 *km*/*h*. The mass of the comet was estimated to be in the range $(0.10 – 2.5) \times 10^{14}$ *kg*. Using the smallest value of the estimated mass for the comet, what was the change in the comets velocity after the impact (*in km*/*h*)? Would this be noticeable?

    Note: You can use either impulse or conservation of momentum to solve this problem.
11. Four objects are situated along the y axis as follows: a 2.00 *kg* object is at + 3.00 *m*, a 3.00 *kg* object is at +2.50 *m*, a 2.50 *kg* object is at the origin, and a 4.00 *kg* object is at -0.500 *m*. Where is the center of mass of this system?

12. The mass of the Earth is 5.97×10^{24} *kg*, and the mass of the Moon is 7.35×10^{22} *kg*. The distance of separation between their centers is measured to be 3.84×10^{8} *m*. Locate the center of mass of the Earth-Moon system as measured from the center of the Earth.

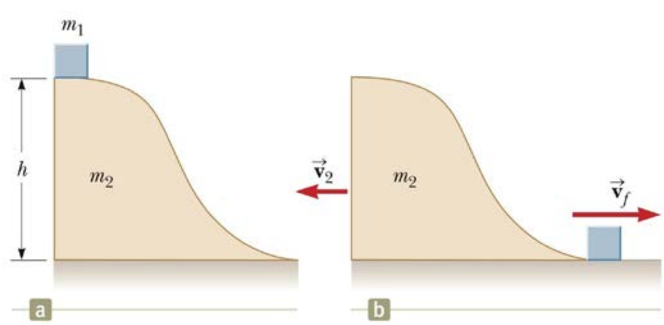
13. A 1200 *kg* car traveling initially at v_{Ci} = 25.0 *m*/s in an easterly direction collides elasticly into the back of a 9000 *kg* truck moving in the same direction at v_{Ti} = 20.0 *m/s* as shown in the figure below.



The velocity of the car immediately after the collision is v_{Cf} = 18.0 *m/s* to the east. What is the velocity of the truck immediately after the collision?

14. Two blocks of masses m_1 = 2.00 *kg* and m_2 = 4.00 *kg* are released from rest at a height *h* = 5.00 *m* on a frictionless track as shown in the figure below. When they meet on the level portion of the track, they undergo a head-on, elastic collision. Determine the maximum heights to which each mass will rise on their respective curved surface after the collision.

15. A small block of mass m_1 = 0.500 *kg* is released from rest at the top of a frictionless, curve-shaped wedge of mass m_2 = 3.00 *kg*, which sits on a frictionless, horizontal surface as shown in the figure below.

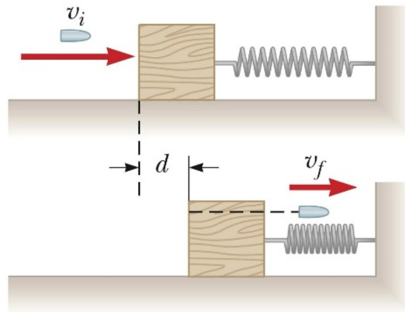


When the small block leaves the wedge, its velocity is measured to be 4.00 *m/s* to the right.

a. What is the recoiling velocity of the large wedge after the small block reaches the horizontal surface?

b. What is the height of the wedge?

16. A 5.00 *g* bullet moving with an initial speed of v_i = 400 *m*/*s* is fired into and passes through a 1.00 *kg* block as shown in the figure at right. The block, initially at rest on a frictionless, horizontal surface, is connected to a spring with a force constant 900 N/*m*. The block moves *d* = 5.00 *cm* to the right after impact before being brought to rest by the spring. Find
    a. The speed of the bullet as it emerges from the block.
    b. The amount of initial Kinetic Energy of the bullet that was lost during the collision.



17. In your job in the police lab, you must design an apparatus to measure the muzzle velocities of bullets fired from handguns. Your solution is to attach a 2.00 *kg* wood block that rests on a horizontal surface to a light horizontal spring. The other end of the spring is attached to a wall. Initially the spring is at equilibrium length. A bullet is fired horizontally into the block and remains embedded in it. After the bullet strikes the block, the block compresses the spring a maximum distance *d*. You have measured that the coefficient of kinetic friction between the block and the horizontal surface is 0.38. The table below lists some of the firearms that you will be testing.

Bullet ID	**Type**	**Bullet Mass** (*grains*)	**Muzzle Velocity** (*ft*/*s*)
A	.38 Spec Glaser Blue	80	1667
B	.38 Federal	125	945
C	.44 Remington	240	851
D	.44 Winchester	200	819
E	0.45ACP Glaser Blue	140	1355

(A grain is a unit of mass equal to 64.8 *mg*)

a. If the momentum of a bullet is directly related to the compression distance of the block, which of the bullets, (A through E), will produce the maximum compression of the spring? The minimum compression of the spring?

Note: For convenience, use momentum units of *grain*·*ft*/*s*.

Suppose you want the maximum compression of the spring to be 0.25 *m*. Use conservation principles to determine:

b. The force constant *k* of the spring

c. For the bullet that produces the minimum spring compression, what is the compression distance *d* if the spring has the force constant calculated in part (*b*)?

Note: For these calculations, be sure to convert *grains* and *ft*/*s* to *kg* and *m*/*s*.