1. You push with a steady force of 19 N on a 48 kg desk fitted with casters on its four feet. How long does it take you to get the desk across a room that is 5.9 m wide?

2. What is the gravitational force on a 1.0 kg brick (a) when it is in free fall and (b) when it is resting on a table?

3. All the blocks in the figure below have the same inertia. Rank the different configurations in increasing order of tension in the rope. (Hint: free-body diagrams are a good place to start.)

![Diagram of pulleys and blocks](image.png)

4. A spring hanging from the ceiling is 0.10 m long when there is no object attached to its free end. When a 4.0 kg brick is attached to the free end, the spring is 0.23 m long. What is the spring constant of the spring?

5. When a 5.0 kg box is suspended from a spring, the spring stretches to 5.0 cm beyond its equilibrium length. In an elevator accelerating upward at 2.0 m/s², how far will the spring stretch with the same box attached?
6. A 70 kg student is falling toward Earth. (a) Draw a free-body diagram for Earth and one for the student. Assume friction caused by the air can be ignored. (b) Calculate the vector sum of the forces acting on the student and the student’s acceleration. (c) Earth’s inertia is \(6.0 \times 10^{24}\) kg. What is the magnitude of the planet’s acceleration toward the student?

7. A 1500 kg truck and a 1000 kg car are parked with their rear bumpers nearly touching each other in a level parking lot. Both vehicles have their brakes off so that they are free to roll. A woman sitting on the rear bumper of the truck exerts a constant horizontal force on the rear bumper of the car with her feet, and the car accelerates at 1.2 m/s². (a) What are the magnitude and acceleration of the center of mass of the car+truck system? (b) What are the forces (magnitude and direction) exerted on each vehicle by the woman? (c) What are the magnitude and direction of the acceleration of the truck? Ignore any friction between tires and parking lot surface.

8. You tie a 1500 kg truck, a 1000 kg car, and a 500 kg trailer together in a series by individual ropes. The two ropes are identical, and each has a tensile strength of 2000 N. You attach a strong iron handle to the truck and pull it with a force of magnitude \(F\). (a) What is the acceleration of the three-vehicle system? (b) What is the maximum pulling force you can exert on the truck before a rope breaks? (c) If you now attach the iron handle to the trailer and pull the system backwards, what is the maximum force with which you can pull it without snapping a rope?

9. A train engine is pulling four boxcars, each of inertia \(M\). The engine can exert a force of magnitude \(F\) on what it is pulling. Assuming that friction can be ignored, what is the tension in each of the four couplers as the train starts off?

10. A 60 kg student is in an elevator moving downward with constant velocity. She uses a bathroom scale to measure the force exerted on her by the floor of the elevator. (a) What force does the scale read when the elevator is traveling at constant velocity? (b) What force does it read when the elevator slows to a stop with an acceleration of magnitude 2.0 m/s²? (c) What force does it read when the elevator starts downward again with an acceleration of magnitude 2.0 m/s²?

11. A 10 kg cart is connected to a 20 kg cart by a relaxed spring of spring constant 1000 N/m, and both carts are sitting on an air track. You push the 10 kg cart in the direction of the 20 kg cart with a constant force of 10 N. (a) What is the acceleration of the center of mass of the two-cart system at any instant? (b) What is the acceleration of each cart the moment you begin to push? (c) What is the acceleration of each cart when the spring has its maximum compression?
12. An object is said to be in stable equilibrium if a displacement in either direction requires positive work to be done on the object by an external force. What is the shape of the potential energy curve (as a function of position) in the region of stable equilibrium? (Hint: think of a spring at its relaxed length.)

13. The velocity of an object as a function of time is shown in the figure below. Over what intervals is the work done on the object (a) positive, (b) negative, (c) zero?

![Velocity vs. Time Graph]

14. You are lifting a ball at constant velocity. (a) When the system is the ball, is work done on the system? If so, by what agent? (b) Describe the potential energy of this system during the lift. (c) When the system is ball+earth, is work done on the system? If so, by what agent? (d) Describe the potential energy of this system during the lift.

15. You push one 0.20 kg billiard ball for a distance of 0.10 m, exerting a constant force of 5.0 N. The ball then rolls 0.90 m across the table and hits an identical ball. (a) What is the total work done by you on the two-ball system? (b) What is the kinetic energy of the first ball right before it strikes the second one? (c) By what amount does your force change the kinetic energy of the center of mass of the system?

16. One day I get the foolish idea to jump off a bridge with an elastic bungee cord tied to my waist. The bridge deck is 150 m above the water, and the spring constant of the bungee cord is 40 N/m. Since I must fall the length of the unstretched cord before it begins to stretch, I realize that the unstretched length, which is adjustable, has to be adjusted based on my inertia. What must the maximum unstretched length of the cord be if I am to stop falling just above the water surface? Take my inertia to be 70 kg and treat my body like a particle (i.e. a mass that is concentrated at a single point).
17. A jackhammer has a motor that exerts a force of 5000 N to compress a spring 0.20 m. (See figure below.) After the spring is released from this compressed position, it drives a 2.5 kg bit into the ground. (a) What is the kinetic energy of the bit as it hits the ground? (Ignore the force of gravity acting on the bit.) (b) What is the bit’s velocity in kilometers per hour as it hits the ground? (c) Calculate the work done by Earth on the bit for a vertical jackhammer to show why the gravitational force can be neglected.

18. A 35 kg girl climbs a 10 m rope in 25 s. What is her average power output?

19. A motor must lift a 1000 kg elevator cab. The cab’s maximum occupant capacity is 400 kg, and its constant “cruising” speed is 21.5 m/s. The design criterion is that the cab must achieve this speed within 2.0 s at constant acceleration beginning from rest. (a) When the cab is carrying its maximum capacity, what power must the motor deliver to get the cab up to cruising speed? (b) What constant power must the motor supply as the fully loaded cab rises after attaining cruising speed?

20. A 1000 kg car starting at the bottom of a 20 m hill at 5.0 m/s almost comes to a complete stop as it crests the hill, barely making it over the top. (See figure below.) The power rating of the engine is 67 kW. (a) Assuming the engine’s delivery of power just accounts for the change in the car’s potential and kinetic energies as it moves from the bottom of the hill to the top, how long does it take the car to make it up the hill under full power? (b) Does your answer to (a) seem reasonable? (c) If not, what do you think is going on?