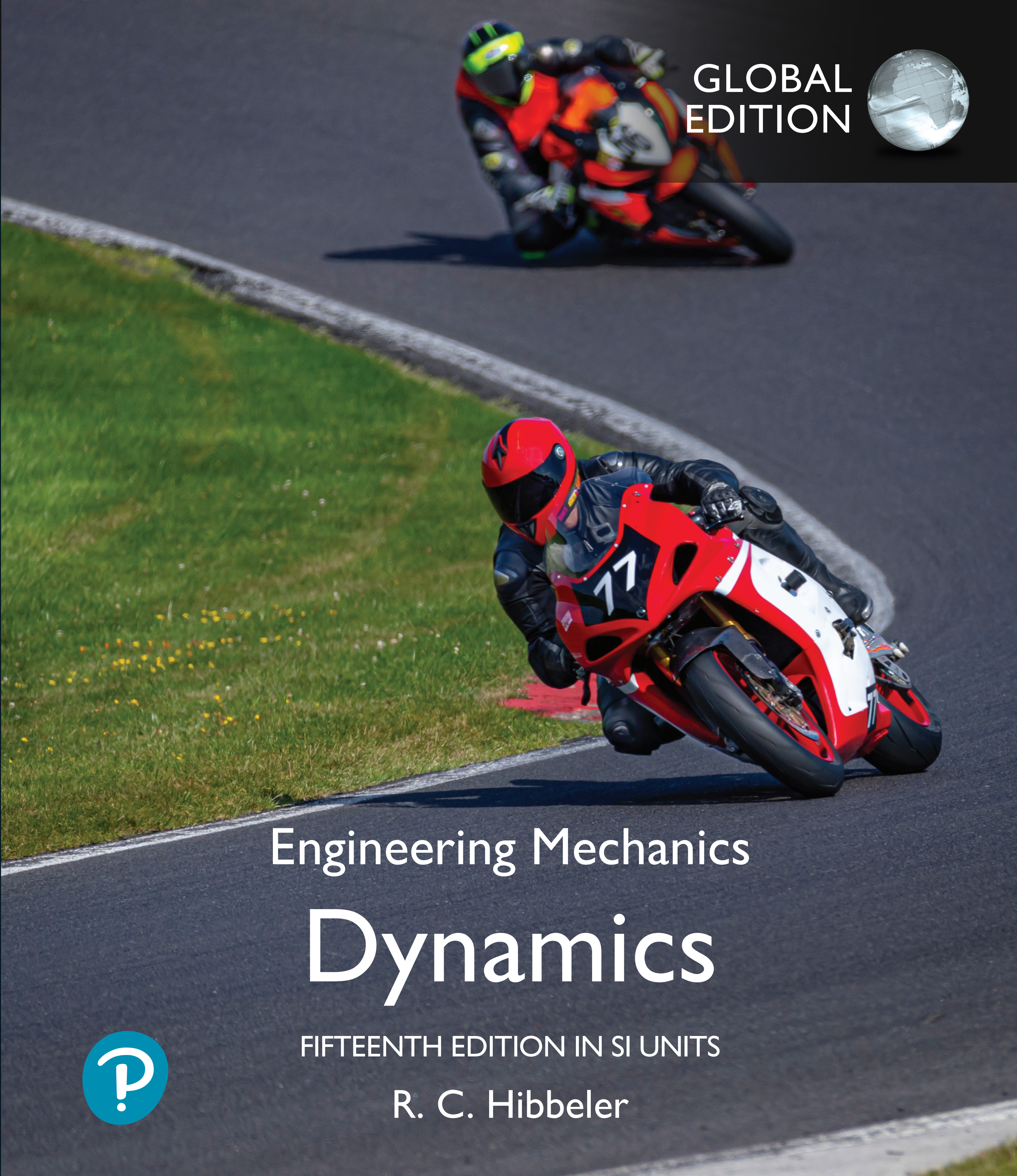


GLOBAL EDITION

Engineering Mechanics

Dynamics

FIFTEENTH EDITION IN SI UNITS

R. C. Hibbeler

ENGINEERING MECHANICS

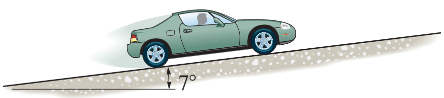
DYNAMICS

FIFTEENTH EDITION IN SI UNITS

PROBLEMS

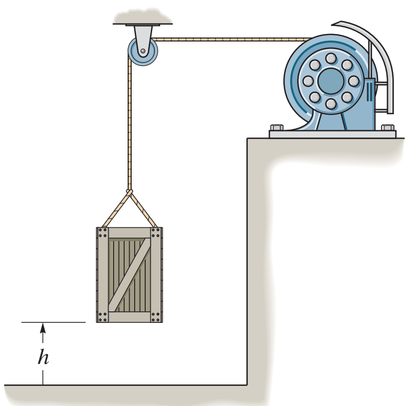
All solutions must include a free-body diagram.

14–42. An automobile having a mass of 2 Mg travels up a 7° slope at a constant speed of $v = 100$ km/h. If mechanical friction and wind resistance are neglected, determine the power developed by the engine if the automobile has an efficiency $\varepsilon = 0.65$.



Prob. 14–42

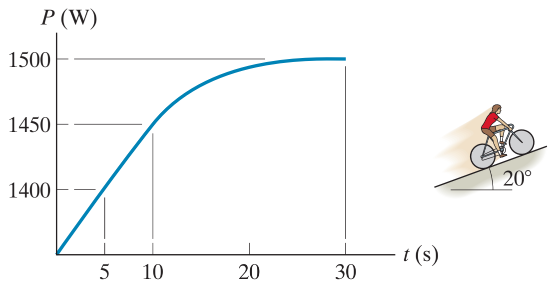
14–43. A motor hoists a 60-kg crate at a constant velocity to a height of $h = 5$ m in 2 s. If the indicated power of the motor is 3.2 kW, determine the motor's efficiency.



Prob. 14–43

***14–44.** A car has a mass m and accelerates along a horizontal straight road from rest such that the power is always a constant amount P. Determine how far it must travel to reach a speed of .

14–45. Using the biomechanical power curve shown, determine the maximum speed attained by the rider and his bicycle, which have a total mass of 92 kg, as the rider ascends the 20° slope starting from rest.



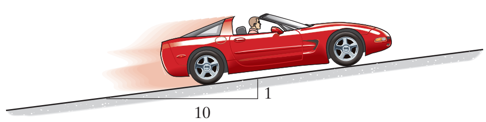
Prob. 14–45

14–46. A spring having a stiffness of 5 kN/m is compressed 400 mm. The stored energy in the spring is used to drive a machine which requires 90 W of power. Determine how long the spring can supply energy at the required rate.

14–47. To dramatize the loss of energy in an automobile, consider a car having a weight of 25 000 N that is traveling at 56 km/h. If the car is brought to a stop, determine how long a 100-W light bulb must burn to expend the same amount of energy.

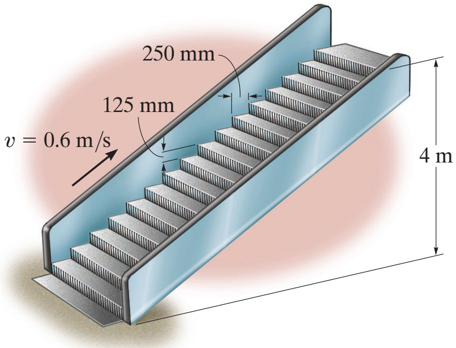
***14–48.** If the engine of a 1.5-Mg car generates a constant power of 15 kW, determine the speed of the car after it has traveled a distance of 200 m on a level road starting from rest. Neglect friction.

14–49. The 2-Mg car increases its speed uniformly from rest to 25 m/s in 30 s up the inclined road. Determine the maximum power that must be supplied by the engine, which operates with an efficiency of $\varepsilon = 0.8$. Also, find the average power supplied by the engine.



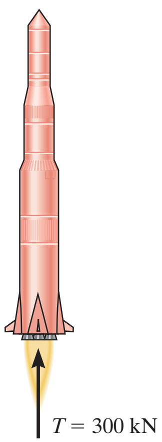
Prob. 14–49

14–50. The escalator steps move with a constant speed of 0.6 m/s. If the steps are 125 mm high and 250 mm in length, determine the power of a motor needed to lift an average mass of 150 kg per step. There are 32 steps.



Prob. 14–50

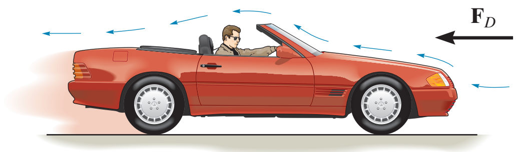
14–51. A rocket having a total mass of 8 Mg is fired vertically from rest. If the engines provide a constant thrust of $T = 300$ kN, determine the power output of the engines as a function of time. Neglect the effect of drag resistance and the loss of fuel mass and weight.



Prob. 14–51

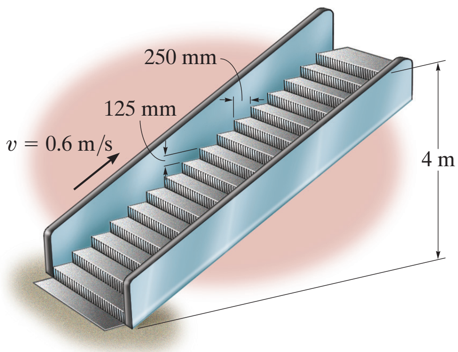
***14–52.** The sports car has a mass of 2.3 Mg, and while it is traveling at 28 m/s the driver causes it to accelerate at 5 m/s^2. If the drag resistance on the car due to the wind is $F_D = (0.3v^2)$ N, where   is the velocity in m/s, determine the power supplied to the engine at this instant. The engine has a running efficiency of $\varepsilon = 0.68$.

14–53. The sports car has a mass of 2.3 Mg and accelerates at 6 m/s^2, starting from rest. If the drag resistance on the car due to the wind is $F_D = (10v)$ N, where   is the velocity in m/s, determine the power supplied to the engine when $t = 5$ s. The engine has a running efficiency of $\varepsilon = 0.68$.



Probs. 14–52/53

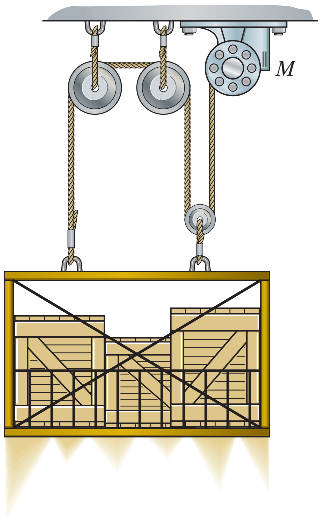
14–54. If the escalator in Prob. 14–50 is not moving, determine the constant speed at which a man having a mass of 80 kg must walk up the steps to generate 100 W of power—the same amount that is needed to power a standard light bulb.



Prob. 14–54

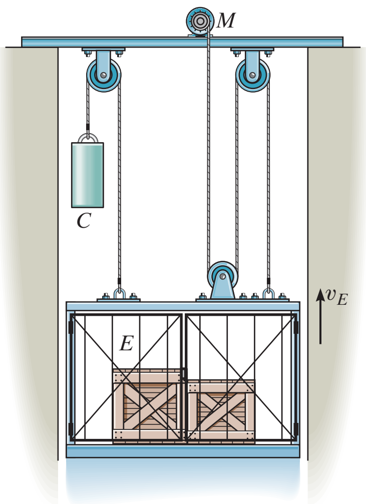
14–55. The motor is used to lift the loaded 500-kg elevator with a constant velocity $v_E = 8$ m/s. If the motor draws 60 kW of electrical power, determine the motor's efficiency. Neglect the mass of the pulleys and cable.

***14–56.** The 500-kg elevator starts from rest and moves upward with a constant acceleration $a_c = 2\text{ m/s}^2$. Determine the power output of the motor M when $t = 3$ s. Neglect the mass of the pulleys and cable.



Probs. 14–55/56

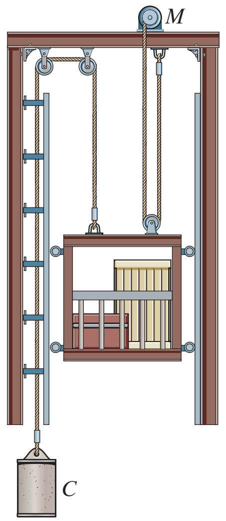
14–57. The elevator E and its freight have a total mass of 400 kg. Hoisting is provided by the motor M and the 60-kg block C. If the motor has an efficiency of $\varepsilon = 0.6$, determine the power that must be supplied to the motor when the elevator is hoisted upward at a constant speed of $v_E = 4$ m/s.



Prob. 14–57

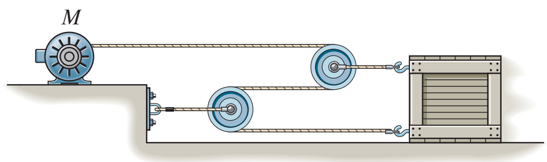
14–58. The material hoist and the load have a total mass of 800 kg and the counterweight C has a mass of 150 kg. At a given instant, the hoist has an upward velocity of 2 m/s and an acceleration of 1.5 m/s^2. Determine the power generated by the motor M at this instant if it operates with an efficiency of $\varepsilon = 0.8$.

14–59. The material hoist and the load have a total mass of 800 kg and the counterweight C has a mass of 150 kg. If the upward speed of the hoist increases uniformly from 0.5 m/s to 1.5 m/s in 1.5 s, determine the average power generated by the motor M during this time. The motor operates with an efficiency of $\varepsilon = 0.8$.



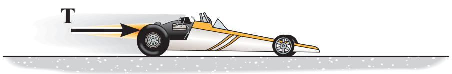
Probs. 14–58/59

***14–60.** The crate has a mass of 150 kg and rests on a surface for which the coefficients of static and kinetic friction are $\mu_s = 0.3$ and $\mu_k = 0.2$, respectively. If the motor M supplies a cable force of $F = (8t^2 + 20)$ N, where t is in seconds, determine the power output developed by the motor when $t = 5$ s.



Prob. 14–60

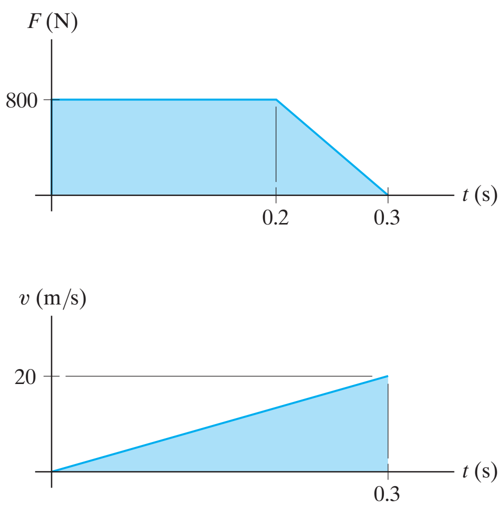
14–61. If the jet on the dragster supplies a constant thrust of $T = 20$ kN, determine the power generated by the jet as a function of time. Neglect drag and rolling resistance, and the loss of fuel. The dragster has a mass of 1 Mg and starts from rest.



Prob. 14–61

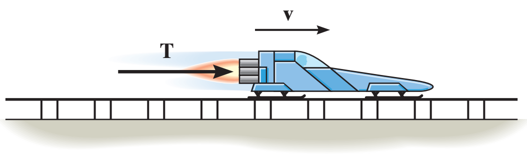
14–62. An athlete pushes against an exercise machine with a force that varies with time as shown in the first graph. Also, the velocity of the athlete's arm acting in the same direction as the force varies with time as shown in the second graph. Determine the power applied as a function of time and the work done in $t = 0.3$ s.

14–63. An athlete pushes against an exercise machine with a force that varies with time as shown in the first graph. Also, the velocity of the athlete's arm acting in the same direction as the force varies with time as shown in the second graph. Determine the maximum power developed during the 0.3-second time period.



Probs. 14–62/63

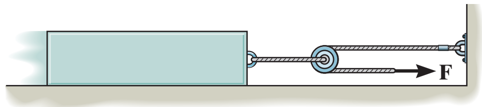
***14–64.** The rocket sled has a mass of 4 Mg and travels from rest along the horizontal track for which the coefficient of kinetic friction is $\mu_k = 0.2$. If the engine provides a constant thrust $T = 150$ kN, determine the power output of the engine as a function of time. Neglect the loss of fuel mass and air resistance.



Prob. 14–64

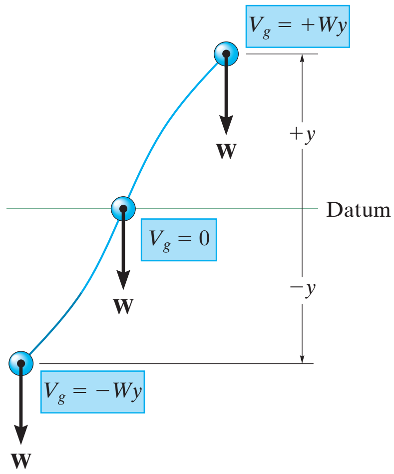
14

14–65. The block has a mass of 150 kg and rests on a surface for which the coefficients of static and kinetic friction are $\mu_s = 0.5$ and $\mu_k = 0.4$, respectively. If a force $F = (60t^2)$ N, where t is in seconds, is applied to the cable, determine the power developed by the force when $t = 5$ s. *Hint*: First determine the time needed for the force to cause motion.



Prob. 14–65

14.5 CONSERVATIVE FORCES AND POTENTIAL ENERGY



Gravitational potential energy

Fig. 14–17

Conservative Force. If the work of a force is independent of its path and depends only on the force's initial and final positions on the path, then the force is called a ***conservative force***. Examples of conservative forces are the weight of a particle and the force developed by a spring. The work done by the weight depends only on the *vertical* displacement of the weight, and the work done by a spring force depends only on the spring's elongation or compression.

In contrast to a conservative force, consider the force of friction exerted on a sliding object by a fixed surface. The work done depends on the path—the longer the path, the greater the work. Consequently, frictional forces are ***nonconservative***. The work is dissipated from the body in the form of heat.

Energy. ***Energy*** is defined as the capacity for doing work. There are essentially two types of energy, kinetic and potential. Kinetic energy is associated with the motion of the particle. For example, if a particle is originally at rest, then the principle of work and energy requires $\Sigma U_{1\rightarrow 2} = T_2$. In other words, the work done on the particle is transferred into kinetic energy, which gives the particle a speed . When the energy depends upon the position of the particle, measured from a fixed datum or reference plane, it is called ***potential energy***. Thus, potential energy is a measure of the amount of work a conservative force must do to move a particle from a given position to the datum. In mechanics, the potential energy created by gravity (weight) and an elastic spring is important.

Gravitational Potential Energy. If a particle is located a distance y above an arbitrarily selected datum, as shown in Fig. 14–17, the particle's weight **W** has positive ***gravitational potential energy***, V_g, since **W** has the capacity of doing positive work when the particle is moved back down to the datum. Likewise, if the particle is located a distance y below the datum, V_g is negative since the weight does negative work when the particle is moved back up to the datum. At the datum $V_g = 0$.*

In general then, if y is positive upward, the gravitational potential energy of the particle of weight W is

$$V_g = Wy \tag{14–13}$$

Gravitational potential energy of this weight is increased as it is hoisted upward.

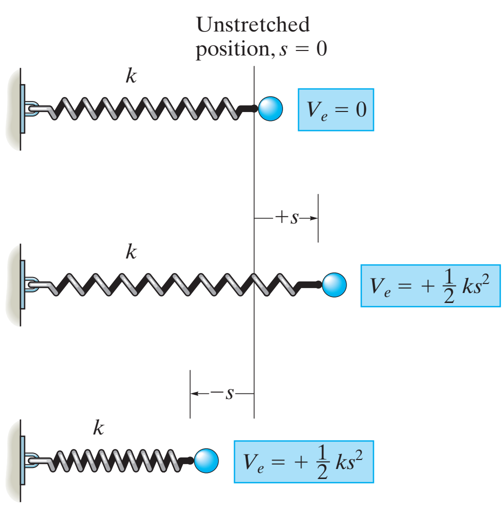
*Here the weight is assumed to be *constant*. This assumption is suitable for small differences in elevation Δy. If the elevation change is significant, however, a variation of weight with elevation must be taken into account (see Prob. 14–83).

Elastic Potential Energy. When an elastic spring is elongated or compressed a distance s from its unstretched position, the force on the spring does work and thereby stores elastic potential energy V_e in the spring. This energy is

$$V_e = +\tfrac{1}{2}ks^2 \tag{14–14}$$

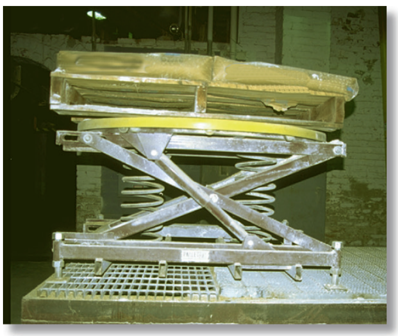
Here V_e is always positive since, in the deformed position, the force of the spring has the *capacity* or "potential" for always doing positive work on the particle when the spring is returned to its unstretched position, Fig. 14–18.

14



Elastic potential energy

Fig. 14–18



The weight of the sacks resting on this platform causes potential energy to be stored in the supporting springs. As each sack is removed, the platform will *rise* slightly since some of the potential energy within the springs will be transformed into an increase in gravitational potential energy of the remaining sacks. Such a device is useful for removing the sacks without having to bend over to pick them up as they are unloaded.