7.8: Exercises

Exercise 7.8.1

In a mattress test, you drop a 7.0 kg bowling ball from a height of 1.5 m above a mattress, which as a result compresses 15 cm as the ball comes to a stop.

a. What is the kinetic energy of the ball just before it hits the mattress?
b. How much work does the gravitational force of the earth do on the ball as it falls, for the first part of the fall (from the moment you drop it to just before it hits the mattress)?
c. How much work does the gravitational force do on the ball while it is compressing the mattress?
d. How much work does the mattress do on the ball?
e. Now model the mattress as a single spring with an unknown spring constant k, and consider the whole system formed by the ball, the earth and the mattress. By how much does the potential energy of the mattress increase as it compresses?
f. What is the value of the spring constant k?

Exercise 7.8.2

A block of mass 1 kg is sitting on top of a compressed spring of spring constant k = 300 N/m and equilibrium length 20 cm. Initially the spring is compressed 10 cm, and the block is held in place by someone pushing down on it with his hand. At t = 0, the hand is removed (this involves no work), the spring expands and the block flies upwards.

a. Draw a free-body diagram for the block while the hand is still pressing down. Try to get the forces approximately to scale. The following question should help.
b. What must be the force (magnitude and direction) exerted by the hand on the block?
c. How much elastic potential energy was stored in the spring initially?
d. Taking the system formed by the block and the earth, how much total work is done on it by the spring, as it expands to its equilibrium length? (You do not need to do a new calculation here, just think of conservation of energy.)
e. How high does the block rise above its initial position?
f. Treating the block alone as the system, how much net work is done on it by the two external forces (the spring and gravity) from the time just before it starts moving to the time it reaches its maximum height? (Again, no calculation is necessary if you can justify your answer.)

Exercise 7.8.3

A crane is lifting a 500-kg object at a constant speed of 0.5 m/s. What is the power output of the crane?

Exercise 7.8.4

In a crash test, a car, initially moving at 30 m/s, hits a wall and crumples to a halt. In the process of crumpling, the center of mass of the car moves forward a distance of 1 m.

a. If the car has a mass of 1, 800 kg, what is the magnitude of the average force acting on it while it stops? What, physically, is this force?
b. Does the force you found in (a) actually do any work on the car? (Think carefully!)
c. What is the net change in the car's kinetic energy? Where does all that kinetic energy go?

Exercise 7.8.5

A block of mass 3 kg slides on a horizontal, rough surface towards a spring with k = 500 N/m. The kinetic friction coefficient between the block and the surface is μ_k = 0.6. If the block's speed is 5 m/s at the instant it first makes contact with the spring,

a. Find the maximum compression of the spring.
b. Draw work-energy bar diagrams for the process of the block coming to a halt, taking the system to be the block and the surface only.