Physics 2002L, Fall 2017
Problem Set 3½
6 problems; 46 points; estimated time: 1 hr.

1.(7) A box with a mass of 5.0 kilograms is lifted (without acceleration) from the floor to a height of 2.0 meters, in order to place it on a shelf. (a) What is the increase in potential energy of the box? (b) How much work was required to lift the box to this position?

1. (Answer, 7 points)
(a)
$$PE_g = m \times g \times h$$
$$PE_g = (5.0\ kg) \times (9.8\ m/s^2) \times (2.0\ m)$$
$$PE_g = 98\ J$$
(b)
$$W = F \times d \rightarrow W = F_g \times d$$
$$W = (m \times g) \times d$$
$$W = (5.0\ kg) \times (-9.8\ m/s^2) \times (-2.0\ m)$$
$$PE_g = 98\ J$$

2. (2) Jaqen H'Ghar pushes really hard on a huge rock that the citizens of Braavos have named 'The Arya Stone,' but, like its namesake, the rock does not budge. Has the assassin-priest done any work on the rock? Explain.

2. (Answer, 2 points) Work requires changing the rock's energy; when the rock moves no distance, Jaqen has not done any work.

3. (15) A crate is pulled a distance of 4 meters across the floor by a 50-newton force from a rope attached to the crate. How much work is done on the crate by the force (a) if the rope is pulled horizontally, parallel to the floor; and (b) if the rope is pulled at an angle of 30 degrees above the floor? For the case of the angled force, how much power was applied, if the force is applied for 20 seconds, (c) in watts, and (d) in horsepower?

3. (Answer, 15 points)
(a)
$$W = F \times d$$
$$W = (50\ N) \times (4\ m)$$
$$W = 200\ J$$
(b)
Only the horizontal component of the force does any work, so —
$$F_x = F\ \sin\theta$$
$$F_x = (50\ N) \times\ \sin(30°)$$
$$F_x = (50\ N) \times (0.500)$$
$$F_x = 25\ N$$

$$W = F_x \times d$$
$$W = (25\ N) \times (4\ m)$$
$$W = 100\ J$$
(c)
$$P = W \times t$$
$$P = (100\ J) \times (20\ s)$$
$$P = 2{,}000\ W$$
(d)
$$1\ hp = 746\ W$$
$$P = (2{,}000\ W) \times \left(\frac{1\ hp}{746\ W}\right)$$
$$P = 2.68\ hp$$

4. (6) To stretch a spring a distance of 0.20 meters, 40 joules of work is done. (a) What is the increase in potential energy of the spring? (b) What is the value of the spring constant, *k*, of the spring?

4. (Answer, 6 points)
(a)
$$W_{in} = E_{out}$$
$$E_{out} = 40\ J$$
(b)
$$PE_s = kx^2$$
$$(40\ J) = k\ (0.20\ m)^2$$
$$k = \frac{(40\ J)}{(0.20\ m)^2}$$
$$k = 1{,}000\ N/m$$

5. (10) A sled and rider with a combined mass of 50 kg are at the top of a hill, 15 meters above the level ground below. The sled is given a push, providing an initial kinetic energy at the top of the hill of 1,600 joules. (a) Choosing a reference level at the bottom of the hill, what is the potential energy of the sled and rider at the top of the hill? (b) After the push, what is the total energy of the sled and rider at the top of the hill? (c) What is the sled's initial velocity at the top of

the hill? (d) If friction can be ignored, what will be the kinetic energy of the sled and rider at the bottom of the hill, and what will be the total energy at the bottom of the hill? (e) What is the sled's final velocity at the bottom of the hill?

5. (Answer, 10 points)

(a)

$$PE_g = m \times g \times h$$
$$PE_g = (50\ kg) \times (9.8\ m/s^2) \times (15\ m)$$
$$PE_g = 7{,}350\ J$$

(b)

$$E_{total} = KE + PE \ \rightarrow \ E_{total} = KE_{initial} + PE_g$$
$$E_{total} = (1{,}600\ J) + (7{,}350\ J)$$
$$E_{total} = 8{,}950\ J$$

(c)

$$KE = \frac{1}{2} \times m \times v^2$$
$$(1{,}600\ J) = \frac{1}{2} \times (50\ kg) \times {v_{initial}}^2$$
$$v_{init} = \sqrt{\frac{2 \times (1{,}600\ J)}{(50\ kg)}}$$
$$v_{init} = 8\ m/s$$

(d)

$$E_{total,\ top} = E_{total,\ bottom} = const.$$
$$KE_{top} + PE_{bottom} = E_{total}$$
$$= KE_{bottom} + PE_{bottom}$$
$$8{,}950\ J = KE_{bottom} + (m \times g \times h)$$
$$8{,}950\ J = KE_{bottom} + ((50\ kg) \times (9.8\ m/s^2) \times (0\ m)$$
$$KE_{bottom} = 8{,}950\ J$$
$$E_{total,\ bottom} = 8{,}950\ J$$

(e)

$$KE = \frac{1}{2} \times m \times v^2$$
$$(8{,}950\ J) = \frac{1}{2} \times (50\ kg) \times {v_{final}}^2$$
$$v_{final} = \sqrt{\frac{2 \times (8{,}950\ J)}{(50\ kg)}}$$
$$v_{final} = 18.9\ m/s$$

6. (6) A car with a mass of 1,200 kg is moving around a curve with a radius of 40 m at a constant speed of 20 m/s (approximately 45 mph). (a) What is the centripetal acceleration of the car? (b) what is the magnitude of the force required to produce this centripetal acceleration?

6. (Answer, 6 points)

(a)

$$a_c = \frac{v^2}{r}$$
$$a_c = \frac{(20 \frac{m}{s})^2}{40\ m}$$
$$a_c = 10\ m/s^2$$

(b)

$$F_c = m \times a_c$$
$$F_c = (1{,}200\ kg) \times (10 \frac{m}{s^2})$$
$$F_c = 12{,}000\ N\ towards\ center$$