# Problem Set # 4   Friction
Basic motion

1. You are lowering two boxes, one on top of the other, down the ramp shown in the sketch included below, by pulling on a rope parallel to the surface of the ramp. Both boxes move together at a constant speed of 15 cm/s. The coefficient of *kinetic friction* between the ramp and the lower box is 0.444, and the coefficient of *static friction* between the two boxes is 0.8.
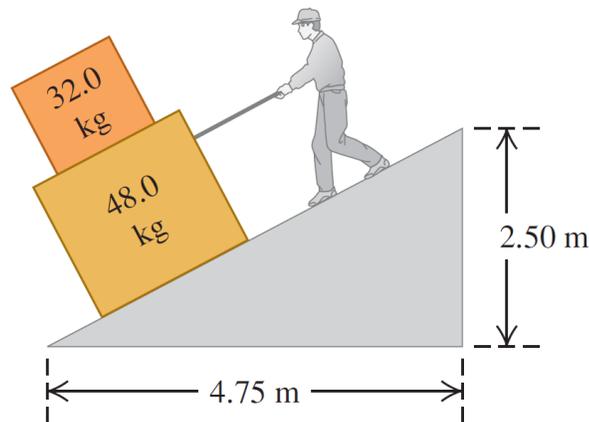

(a) What force do you need to exert to accomplish this?

(b) What are the magnitude and direction of the friction force on the upper box?

2. Two crates connected by a rope lie on a horizontal surface (see the sketch below). Crate A has mass m_A and crate B has mass m_B. The coefficient of kinetic friction between each crate and the surface is μ_k. The crates are pulled to the right at constant velocity by a horizontal force $\boldsymbol{F}$.


In terms of m_A, m_B, and μ_k calculate:

(a) the magnitude of the force $\boldsymbol{F}$;

(b) the tension in the rope connecting the blocks.

3. Block A in the sketch below weighs 60 N. The coefficient of static friction between the block and the surface on which it rests is 0.25. The weight w is 12 N and the system is in equilibrium. Find the friction force exerted on the block A. What is the maximum weight w for which the system will remain in equilibrium?
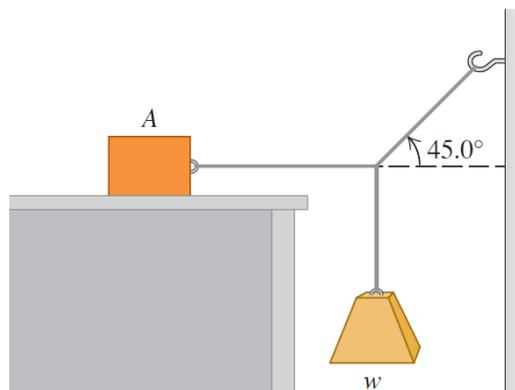

4. Blocks A, B, and C are placed as indicated below and connected by ropes of negligible mass. Both A and B weigh 25 N each, and the coefficient of kinetic friction between each block and the surface is 0.35. Block C descends with constant velocity.
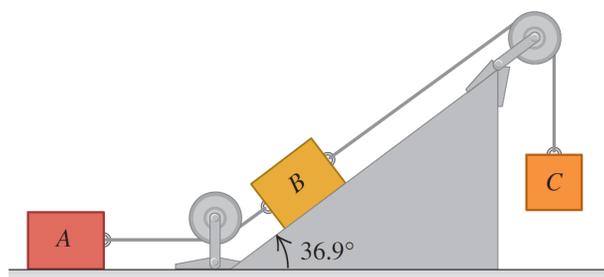
   (a) Show on a diagram all the forces acting on A and B.

   (b) Find the tension in the rope connecting A and B.

   (c) What is the weight of C?

   (d) If the rope connecting A and B were cut, what would be the acceleration of C?

5. A parcel of mass 1 Kg is placed on a rough plane which is inclined at $30°$ to the horizontal. The coefficients of static and kinetic friction are equal to each other and their common value is 0.25. Find the force that must be applied to the parcel in a *direction parallel to the plane* so that:

   (a) the parcel is just prevented from sliding down the plane;

   (b) the parcel is just on the point of moving up the plane;

   (c) the parcel moves up the plane with an acceleration of $1.5\ m/s^2$.

6. A box of mass 6 Kg is placed on a rough plane which is inclined at $45°$ to the horizontal. The coefficients of static and kinetic friction are equal to each other and their common value is 0.5. Find the *horizontal force* that must be applied to the box so that:

   (a) the box is just prevented from sliding down the plane;

   (b) the box is just on the point of moving up the plane;

   (c) the box moves up the plane with an acceleration of $2\sqrt{2}\ m/s^2$.

7. For all questions in this exercise: all strings are light and inextensible, all pulleys are light and smooth, all surfaces are frictionless. Find the acceleration of A and the tension in the strings.
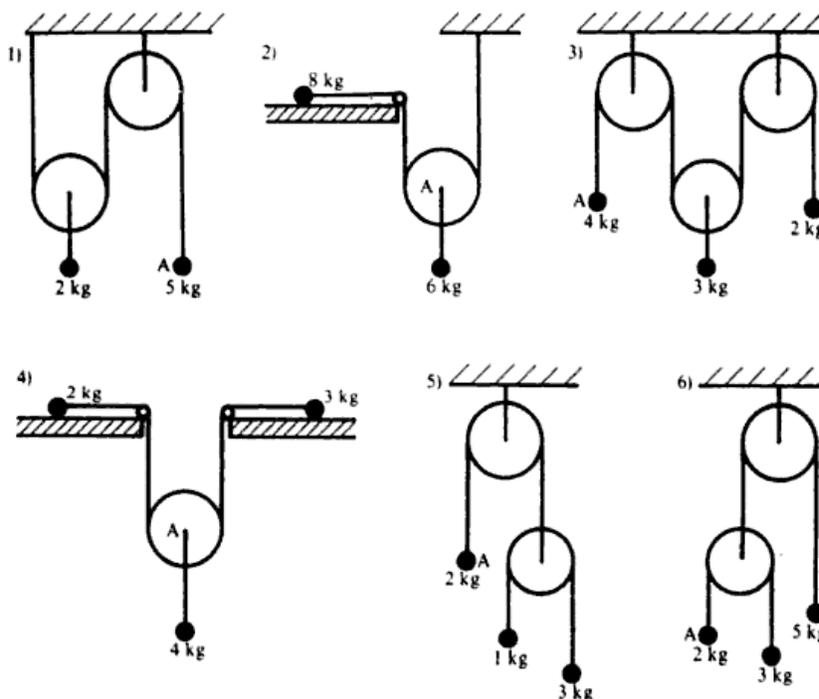
8. The diagram (on the next page) shows the cross-section of a wedge fixed to the horizontal ground. Its smooth faces PA and PB are inclined at $60°$ and $30°$ to the ground. A string passes over the small smooth pulley P, with particles of mass m and λm attached at its ends.

   (a) Show that the particle of mass m will accelerate towards P provided that $\lambda > \sqrt{3}$.

   (b) If $\lambda = 2$, find the tension in the string.

   (c) If $\lambda = 2$, and the planes PA and PB are rough, μ being the common value of the coefficients of static and kinetic friction between each particle and the plane, show that the particle of mass m will move towards P if

   $$\mu < \frac{2 - \sqrt{3}}{1 + 2\sqrt{3}}.$$

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