Name:____________________________ Class:_________________ Date:_________________

Sample Problem Set I Solutions

Forces and the Laws of Motion

ADDITIONAL PRACTICE D

Givens	Solutions
1. $m = 11.0$ kg $\mu_k = 0.39$ $g = 9.81$ m/s^2	$F_k = \mu_k F_n = \mu_k mg$ $F_k = (0.39)(11.0 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{42.1 \text{ N}}$
2. $m = 2.20 \times 10^5$ kg $\mu_s = 0.220$ $g = 9.81$ m/s^2	$F_{s,max} = \mu_s F_n = \mu_s mg$ $F_{s,max} = (0.220)(2.20 \times 10^5 \text{ kg})(9.91 \text{ m/s}^2) = \boxed{4.75 \times 10^5 \text{ N}}$
3. $m = 25.0$ kg $F_{applied} = 59.0$ N $\theta = 38.0°$ $\mu_s = 0.599$ $g = 9.81$ m/s^2	$F_{s,max} = \mu_s F_m$ $F_n = mg(\cos\theta) + F_{applied}$ $F_{s,max} = \mu_s[mg(\cos\theta) = F_{applied}] = (0.599)[(25.0 \text{ kg})(9.81 \text{ m/s}^2)(\cos 38.0° + 59.0 \text{ N}]$ $F_{s,max} = (0.599)(193 \text{ N} + 59 \text{ N}) = (0.599)(252 \text{ N}) = \boxed{151 \text{ N}}$ Alternatively, $F_{net} = mg(\sin\theta) - F_{s,max} = 0$ $F_{s,max} = mg(\sin\theta) = (25.0 \text{ kg})(9.81 \text{ m/s}^2)(\sin 38.0°) = \boxed{151 \text{ N}}$
4. $\theta = 38.0°$ $g = 9.81$ m/s^2	$F_{net} = mg(\sin\theta) - F_k = 0$ $F_k = \mu_k F_n = \mu_k mg(\cos\theta)$ $\mu_k mg(\cos\theta) = mg(\sin\theta)$ $\mu_k = \frac{\sin\theta}{\cos\theta} = \tan\theta = \tan 38.0°$ $\mu_k = \boxed{0.781}$
5. $\theta = 5.2°$ $g = 9.81$ m/s^2	$F_{net} = mg(\sin\theta) - F_k = 0$ $F_k = \mu_k F_n = \mu_k mg(\cos\theta)$ $\mu_k mg(\cos\theta) = mg(\sin\theta)$ $\mu_k = \frac{\sin\theta}{\cos\theta} = \tan\theta = \tan 5.2°$ $\mu_k = \boxed{0.091}$
6. $m = 281.5$ kg $\theta = 30.0°$	$F_{net} = 3mg(\sin\theta) - \mu_s(3mg)(\cos\theta) - F_{applied} = 0$ $F_{applied} = mg$ $\mu_s = \frac{3mg(\sin\theta) - mg}{3mg(\cos\theta)} = \frac{3(\sin\theta) - 1.00}{3(\cos\theta)} = \frac{(3)(\sin 30.0°) - 1.00}{(3)(\cos 30.0°)}$

Givens	*Solutions*
	$\mu_s = \dfrac{1.50 - 1.00}{(3)(\cos 30.0°)} = \dfrac{0.50}{(3)(\cos 30.0°)}$ $\mu_s = \boxed{0.19}$
7. $m = 1.90 \times 10^5$ kg $\mu_s = 0.460$ $g = 9.81$ m/s^2	$F_{net} = F_{applied} - F_k = 0$ $F_k = \mu_k F_n = \mu_k mg$ $F_{applied} = \mu_k mg = (0.460)(1.90 \times 10^5 \text{ kg})(9.81 \text{ m/s}^2)$ $F_{applied} = \boxed{8.57 \times 10^5 \text{ N}}$
8. $F_{applied} = 6.0 \times 10^3$ N $\mu_k = 0.77$ $g = 9.81$ m/s^2	$F_{net} = F_{applied} - F_k = 0$ $F_k = \mu_k F_n$ $F_n = \dfrac{F_{applied}}{\mu_k} = \dfrac{6.0 \times 10^3 \text{ N}}{0.77} = \boxed{7.8 \times 10^3 \text{ N}}$ $F_n = mg$ $m = \dfrac{F_n}{g} = \dfrac{7.8 \times 10^3 \text{ N}}{9.81 \text{ m/s}^2} = \boxed{8.0 \times 10^2 \text{ kg}}$
9. $F_{applied} = 1.13 \times 10^8$ N $\mu_s = 0.741$	$F_{net} = F_{applied} - F_{s,max} = 0$ $F_{s,max} = \mu_s F_n = \mu_s mg$ $m = \dfrac{F_{applied}}{\mu_s g} = \dfrac{1.13 \times 10^8 \text{ N}}{(0.741)(9.81 \text{ m/s}^2} = \boxed{1.55 \times 10^2 \text{ kg}}$
10. $m = 3.00 \times 10^3$ kg $\theta = 31.0°$ $g = 9.81$ m/s^2	$F_{net} = mg(\sin \theta) - F_k = 0$ $F_k = \mu_k F_n = \mu_k mg(\cos \theta)$ $\mu_k mg(\cos \theta) = mg(\sin \theta)$ $\mu_k = \dfrac{\sin \theta}{\cos \theta} = \tan \theta = \tan 31.0°$ $\mu_k = \boxed{0.601}$ $F_k = \mu_k mg(\cos \theta) = (0.601)(3.00 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(\cos 31.0°)$ $F_k = \boxed{1.52 \times 10^4 \text{ N}}$ Alternatively, $F_k = mg(\sin \theta) = (3.00 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(\sin 31.0°) = \boxed{1.52 \times 10^4 \text{ N}}$

Forces and the Laws of Motion

Problem D

COEFFICIENTS OF FRICTION

PROBLEM

A 20.0 kg trunk is pushed across the floor of a moving van by a horizontal force. If the coefficient of kinetic friction between the trunk and the floor is 0.255, what is the magnitude of the frictional force opposing the applied force?

SOLUTION

Given: $m = 20.0$ kg

$\mu_k = 0.255$

$g = 9.81 \text{ m/s}^2$

Unknown: $F_k = ?$

Use the equation for frictional force, substituting mg for the normal force F_n.

$$F_k = \mu_k F_n = \mu_k mg$$

$$F_k = (0.255)(20.0 \text{ kg})(9.81 \text{ m/s}^2)$$

$$F_k = 50.0 \text{ N}$$

ADDITIONAL PRACTICE

1. The largest flowers in the world are the *Rafflesia arnoldii*, found in Malaysia. A single flower is almost a meter across and has a mass up to 11.0 kg. Suppose you cut off a single flower and drag it along the flat ground. If the coefficient of kinetic friction between the flower and the ground is 0.39, what is the magnitude of the frictional force that must be overcome?
2. Robert Galstyan, from Armenia, pulled two coupled railway wagons a distance of 7 m using his teeth. The total mass of the wagons was about 2.20×10^5 kg. Of course, his job was made easier by the fact that the wheels were free to roll. Suppose the wheels are blocked and the coefficient of static friction between the rails and the sliding wheels is 0.220. What would be the magnitude of the minimum force needed to move the wagons from rest? Assume that the track is horizontal.
3. The steepest street in the world is Baldwin Street in Dunedin, New Zealand. It has an inclination angle of 38.0° with respect to the horizontal. Suppose a wooden crate with a mass of 25.0 kg is placed on Baldwin Street. An additional force of 59 N must be applied to the crate perpendicular to the pavement in order to hold the crate in place. If the coefficient of static friction between the crate and the pavement is 0.599, what is the magnitude of the frictional force?

4. Now imagine that a child rides a wagon down Baldwin Street. In order to keep from moving too fast, the child has secured the wheels of the wagon so that they do not turn. The wagon and child then slide down the hill at a constant velocity. What is the coefficient of kinetic friction between the tires of the wagon and the pavement?
5. The steepest railroad track that allows trains to move using their own locomotion and the friction between their wheels and the track is located in France. The track makes an angle of 5.2° with the horizontal. Suppose the rails become greasy and the train slides down the track even though the wheels are locked and held in place with blocks. If the train slides down the tracks with a constant velocity, what is the coefficient of kinetic friction between the wheels and track?
6. Walter Arfeuille of Belgium lifted a 281.5 kg load off the ground using his teeth. Suppose Arfeuille can hold just three times that mass on a 30.0° slope using the same force. What is the coefficient of static friction between the load and the slope?
7. A blue whale with a mass of 1.90×10^5 kg was caught in 1947. What is the magnitude of the minimum force needed to move the whale along a horizontal ramp if the coefficient of static friction between the ramp's surface and the whale is 0.460?
8. Until 1979, the world's easiest driving test was administered in Egypt. To pass the test, one needed only to drive about 6 m forward, stop, and drive the same distance in reverse. Suppose that at the end of the 6 m the car's brakes are suddenly applied and the car slides to a stop. If the force required to stop the car is 6.0×10^3 N and the coefficient of kinetic friction between the tires and pavement is 0.77, what is the magnitude of the car's normal force? What is the car's mass?
9. The heaviest train ever pulled by a single engine was over 2 km long. Suppose a force of 1.13×10^8 N is needed to overcome static friction in the train's wheels. If the coefficient of static friction is 0.741, what is the train's mass?
10. In 1994, a 3.00×10^3 kg pancake was cooked and flipped in Manchester, England. If the pancake is placed on a surface that is inclined 31.0° with respect to the horizontal, what must the coefficient of kinetic friction be in order for the pancake to slide down the surface with a constant velocity? What would be the magnitude of the frictional force acting on the pancake?