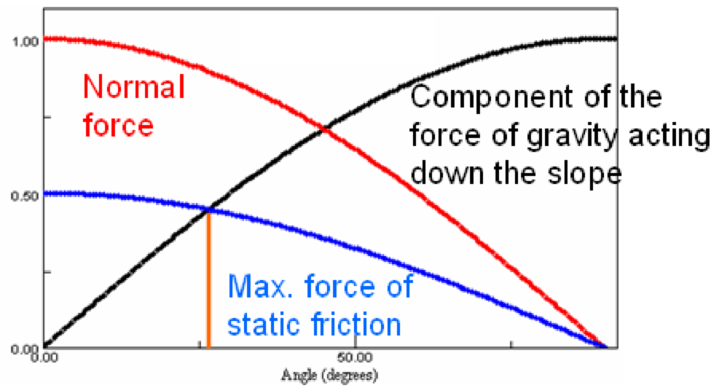
Answers to selected problems from Essential Physics, Chapter 5

1. (a) FBD 3 (b) FBD 3 (c) FBD 4 (d) FBD 1 (e) FBD 2 (f) FBD 5

3. (a) Mg is the force of gravity, applied on the box by the Earth. F_N is the normal force, which is the perpendicular component (perpendicular to the surfaces in contact) of the contact force applied on the box by the ramp. F_S is the force of static friction, the parallel component of the contact force that acts to keep the box at rest on the ramp. F_K is the force of kinetic friction, the parallel component of the contact force that opposes the motion if the box is sliding up or down the ramp. (b) (i) FBD 4 (ii) FBD 5 (iii) FBD 1.

5. (a) FBD 4 (b) FBD 4 (c) FBD 4 (d) FBD 4, although the force of static friction would have to be larger in this case than it is in cases (a) – (c), to give a net force acting up the hill. In the other three cases, the net force is zero. (e) FBD 5

7.

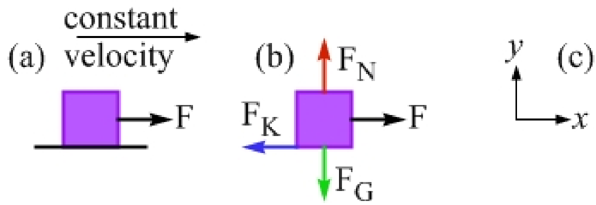


(a) See the graph in red. Note that the *y*-axis is in units of mg. (b) The graph could also represent the component of the force of gravity that acts perpendicular to the slope, and the maximum possible force of static friction if the coefficient of static friction equals 1.0. (c) See the graph in black. (d) That graph can also represent the force of static friction needed to act on the box to prevent it from slipping. (e) See the blue graph. (f) The box starts to slide when the angle of the incline is just to the right of where the blue line meets the black line (see the vertical orange line on the graph above). Beyond that angle, the force of friction needed to keep the box at rest is larger than the maximum possible force of friction.

9. (a) equal in both cases (b) equal in both cases (c) both forces have a magnitude of 8.0 N (d) We can conclude that the coefficient of static friction between the box and the surface is at least 0.4.

11. If the turntable rotates at constant angular velocity (that is, the rate at which the turntable spins is constant), then the force of static friction gives rises to the centripetal acceleration. If the turntable is speeding up or slowing down, then the component of the force of static friction that is directed toward the center of the turntable gives rise to the centripetal acceleration.

13.



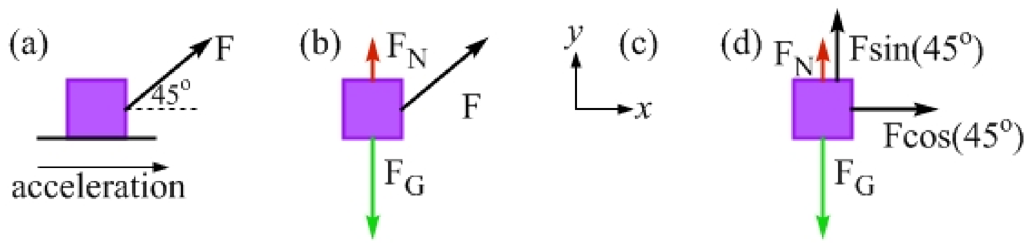
(e)

$$\sum \vec{F}_y = m\vec{a}_y = 0$$
$$+F_N - mg = 0$$
$$F_N = mg$$

$$\sum \vec{F}_x = m\vec{a}_x = 0$$
$$+F - F_K = 0$$
$$F = F_K = \mu_K F_N = \mu_K mg$$

(f) $\mu_K = \dfrac{F}{mg} = \dfrac{10 \text{ N}}{20 \text{ N}} = 0.5$

15.



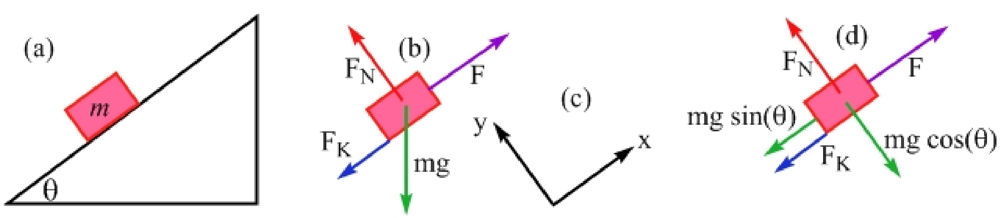
(e)

$$\sum \vec{F}_y = m\vec{a}_y = 0$$
$$+F_N + F\sin(45°) - mg = 0$$
$$F_N = mg - F\sin(45°)$$

$$\sum \vec{F}_x = m\vec{a}_x$$
$$+F\cos(45°) = ma$$
$$F = ma/\cos(45°)$$

(f) $a = 2.0 \text{ m/s}^2$ (g) 7.1 N (h) 19.5 N

17.



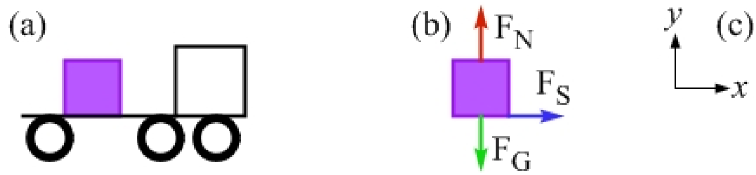
(e)

$$\sum \vec{F}_y = m\vec{a}_y = 0$$
$$+F_N - mg\cos\theta = 0$$
$$F_N = mg\cos\theta$$

$$\sum \vec{F}_x = m\vec{a}_x = 0$$
$$+F - F_K - mg\sin\theta = 0$$
$$F = F_K + mg\sin\theta$$

(f)
$$F = \mu_K mg\cos\theta + mg\sin\theta = (0.2)(20 \text{ kg})(9.8 \text{ m/s}^2)\cos 30° + (20 \text{ kg})(9.8 \text{ m/s}^2)\sin 30°$$
$$F = 132 \text{ N}$$

19.

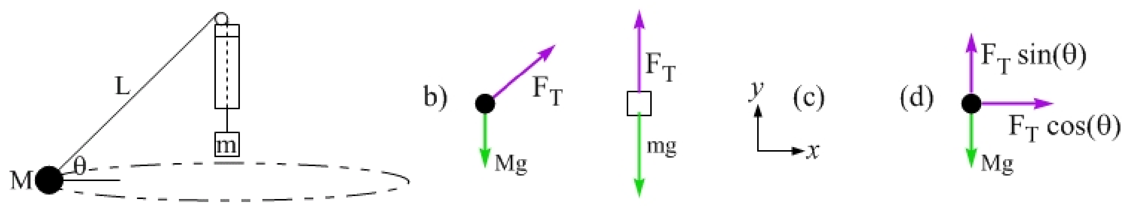


(e) $$\sum \vec{F}_y = m\vec{a}_y = 0 \qquad +F_N - mg = 0 \qquad F_N = mg$$

$$\sum \vec{F}_x = m\vec{a}_x \qquad F_S = ma$$

(f) The force is a static force of friction, acting in the direction of the truck's acceleration, with a magnitude of 6.0 N.
(g) 3.9 m/s^2 (h) We don't need to know the coefficient of kinetic friction

21. (a)



(e) $$\sum \vec{F}_y = M\vec{a}_y = 0 \qquad +F_T \sin\theta - Mg = 0 \qquad F_T \sin\theta = Mg$$

$$\sum \vec{F}_x = M\vec{a}_x \qquad F_T \cos\theta = M\frac{v^2}{r} \qquad F_T \cos\theta = M\frac{v^2}{L\cos\theta}$$

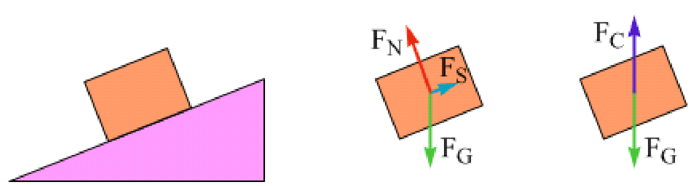
$$\sum \vec{F} = m\vec{a} = 0 \qquad F_T = mg$$

(f) $F_T = mg$ (g) $v = \sqrt{\dfrac{gL\cos^2\theta}{\sin\theta}}$ or $v = \sqrt{\dfrac{mgL\cos^2\theta}{M}}$

23. 40 N

25. (a) 47 N, at an angle of 58° with respect to the horizontal. (b) 47 N (c) 1.6 N

27.



(a) Using g = 9.8 m/s^2, the contact force exactly balances the force of gravity, and is thus 49 N directed straight up. (b) 47 N (c) 13 N.

29. (a) 6.3 N, down the slope (b) 16 N, in the direction of the normal force
(c) 5.8 N, so a component of this force is directed down the slope

31. 4.1 m

33. This is true when the force has a downward vertical component.
(b) $\tan\theta_c = \mu_S$ (c) 26.6°

35. (a) 8.5 N (b) We can say that the coefficient of static friction between the box and the surface is at least 0.35.

37. (a) 0.8 m (b) 0.4 s (c) 0.89 s

39. (a) 2.1 m/s^2 (b) 3.0 m/s^2

41. 2.9 m/s^2

43. 2.1 m/s^2

45. There is only one solution, which is $\mu_K = 0.33$

47. (a) 2.0 m/s^2 , directed down the ramp (b) 25 N
(c) The minimum value of F is 6.67 N, while the maximum value is 55.6 N.

49. (a) 60 N (b) 45 N (c) 105 N

51. (a) 295 N (b) 590 N

53. (a) 2.7 m/s^2 , directed left (b) 5.3 m/s^2 , directed left
(c) 5.3 m/s^2 , directed right (d) 2.7 m/s^2 , directed right

55. (a) 2.0 m/s^2 , directed right (b) 4.0 N, directed right (c) 32 N, directed left

57. $v = \sqrt{g\,r\tan\theta} = 26.7$ m/s

59. (a) The horizontal component of the normal force.
(b) $F_N = \dfrac{mg}{\sin\theta}$ (c) $v = \sqrt{\dfrac{gr}{\tan\theta}}$