

CHAPTER 4

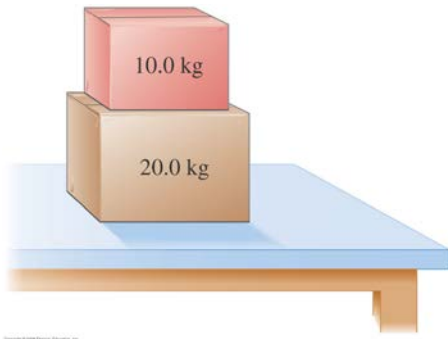
Dynamics: Newton's Laws of Motion

Windows OS

Problems

4–4 to 4–6 Newton's Laws, Gravitational Force, Normal Force

1. (I) What force is needed to accelerate a child on a sled (total mass = 55 kg) at 1.4 m/s^2 ?
2. (I) A net force of 265 N accelerates a bike and rider at 2.30 m/s^2 . What is the mass of the bike and rider together?
3. (I) What is the weight of a 68-kg astronaut (*a*) on Earth, (*b*) on the Moon ($g = 1.7 \text{ m/s}^2$), (*c*) on Mars ($g = 3.7 \text{ m/s}^2$), (*d*) in outer space traveling with constant velocity?
4. (I) How much tension must a rope withstand if it is used to accelerate a 1210-kg car horizontally along a frictionless surface at 1.20 m/s^2 ?
5. (II) Superman must stop a 120-km/h train in 150 m to keep it from hitting a stalled car on the tracks. If the train's mass is $3.63 \times 10^5 \text{ kg}$, how much force must he exert? Compare to the weight of the train (give as?). How much force does the train exert on Superman?
6. (II) What average force is required to stop a 950-kg car in 8.0 s if the car is traveling at 95 km/h?
7. (II) Estimate the average force exerted by a shot-putter on a 7.0-kg shot if the shot is moved through a distance of 2.8 m and is released with a speed of 13 m/s.
8. (II) A 0.140-kg baseball traveling 35.0 m/s strikes the catcher's mitt, which, in bringing the ball to rest, recoils backward 11.0 cm. What was the average force applied by the ball on the glove?
9. (II) A fisherman yanks a fish vertically out of the water with an acceleration of 2.5 m/s^2 using very light fishing line that has a breaking strength of 18 N ($< 4 \text{ lb}$). The fisherman unfortunately loses the fish as the line snaps. What can you say about the mass of the fish?
10. (II) A 20.0-kg box rests on a table. (*a*) What is the weight of the box and the normal force acting on it? (*b*) A 10.0-kg box is placed on top of the 20.0-kg box, as shown in Fig. 4–31. Determine the normal force that the table exerts on the 20.0-kg box and the normal force that the 20.0-kg box exerts on the 10.0-kg box.



11. (II) What average force is needed to accelerate a 9.20-gram pellet from rest to 125 m/s over a distance of 0.800 m along the barrel of a rifle?
12. (II) How much tension must a cable withstand if it is used to accelerate a 1200-kg car vertically upward at 0.70 m/s^2 ?
13. (II) A 14.0-kg bucket is lowered vertically by a rope in which there is 163 N of tension at a given instant. What is the acceleration of the bucket? Is it up or down?
14. (II) A particular race car can cover a quarter-mile track (402 m) in 6.40 s starting from a standstill. Assuming the acceleration is constant, how many “g’s” does the driver - experience? If the combined mass of the driver and race car is 535 kg, what horizontal force must the road exert on the tires?
15. (II) A 75-kg petty thief wants to escape from a third-story jail window. Unfortunately, a makeshift rope made of sheets tied together can support a mass of only 58 kg. How might the thief use this “rope” to escape? Give a quantitative answer.
16. (II) An elevator (mass 4850 kg) is to be designed so that the maximum acceleration is $0.0680g$. What are the maximum and minimum forces the motor should exert on the supporting cable?
17. (II) Can cars “stop on a dime”? Calculate the acceleration of a 1400-kg car if it can stop from 35 km/h on a dime (diameter = 1.7 cm.) How many g’s is this? What is the force felt by the 68-kg occupant of the car?
18. (II) A person stands on a bathroom scale in a motionless elevator. When the elevator begins to move, the scale briefly reads only 0.75 of the person’s regular weight. Calculate the acceleration of the elevator, and find the direction of acceleration.
19. (II) High-speed elevators function under two limitations: (1) the maximum magnitude of vertical acceleration that a typical human body can experience without discomfort is about 1.2 m/s^2 , and (2) the typical maximum speed attainable is about 9.0 m/s. You board an elevator on a skyscraper’s ground floor and are transported 180 m above the ground level

in three steps: acceleration of magnitude 1.2 m/s^2 from rest to 9.0 m/s , followed by constant upward velocity of 9.0 m/s , then deceleration of magnitude 1.2 m/s^2 from 9.0 m/s to rest. (a) Determine the elapsed time for each of these 3 stages. (b) Determine the change in the magnitude of the normal force, expressed as a % of your normal weight during each stage. (c) What fraction of the total transport time does the normal force not equal the person's weight?

20. (II) Using focused laser light, *optical tweezers* can apply a force of about 10 pN to a $1.0\text{-}\mu\text{m}$ diameter polystyrene bead, which has a density about equal to that of water: a volume of 1.0 cm^3 has a mass of about 1.0 g . Estimate the bead's acceleration in g 's.
21. (II) A rocket with a mass of $2.753 \times 10^6 \text{ kg}$ exerts a vertical force of $3.553 \times 10^7 \text{ N}$ on the gases it expels. Determine (a) the acceleration of the rocket, (b) its velocity after 8.0 s , and (c) how long it takes to reach an altitude of 9500 m . Assume g remains constant, and ignore the mass of gas expelled (not realistic).
22. (II) (a) What is the acceleration of two falling sky divers (mass = 132 kg including parachute) when the upward force of air resistance is equal to one-fourth of their weight? (b) After popping open the parachute, the divers descend leisurely to the ground at constant speed. What now is the force of air resistance on the sky divers and their parachute? See Fig. 4–32.



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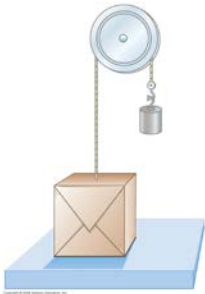
23. (II) An exceptional standing jump would raise a person 0.80 m off the ground. To do this, what force must a 68-kg person exert against the ground? Assume the person crouches a distance of 0.20 m prior to jumping, and thus the upward force has this distance to act over before he leaves the ground.
24. (II) The cable supporting a 2125-kg elevator has a maximum strength of $21,750 \text{ N}$. What maximum upward acceleration can it give the elevator without breaking?
25. (III) The 100-m dash can be run by the best sprinters in 10.0 s . A 66-kg sprinter accelerates uniformly for the first 45 m to reach top speed, which he maintains for the remaining 55 m . (a) What is the average horizontal component of force exerted on his feet by the ground

during acceleration? (b) What is the speed of the sprinter over the last 55 m of the race (i.e., his top speed)?

26. (III) A person jumps from the roof of a house 3.9-m high. When he strikes the ground below, he bends his knees so that his torso decelerates over an approximate distance of 0.70 m. If the mass of his torso (excluding legs) is 42 kg, find (a) his velocity just before his feet strike the ground, and (b) the average force exerted on his torso by his legs during deceleration.

4–7 Using Newton's Laws

27. (I) A box weighing 77.0 N rests on a table. A rope tied to the box runs vertically upward over a pulley and a weight is hung from the other end (Fig. 4–33). Determine the force that the table exerts on the box if the weight hanging on the other side of the pulley weighs (a) 30.0 N, (b) 60.0 N, and (c) 90.0 N.

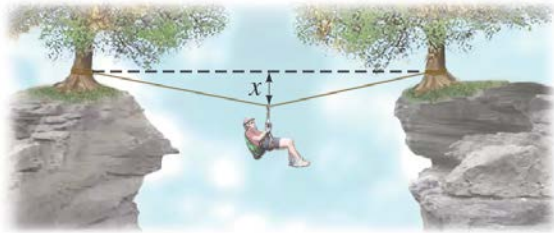


28. (I) Draw the free-body diagram for a basketball player (a) just before leaving the ground on a jump, and (b) while in the air. See Fig. 4–34.



29. (I) Sketch the free-body diagram of a baseball (a) at the moment it is hit by the bat, and again (b) after it has left the bat and is flying toward the outfield.
30. (I) A 650-N force acts in a northwesterly direction. A second 650-N force must be exerted in what direction so that the resultant of the two forces points westward? Illustrate your answer with a vector diagram.

31. (II) Christian is making a Tyrolean traverse as shown in Fig. 4–35. That is, he traverses a chasm by stringing a rope between a tree on one side of the chasm and a tree on the opposite side, 25 m away. The rope must sag sufficiently so it won't break. Assume the rope can provide a tension force of up to 29 kN before breaking, and use a “safety factor” of 10 (that is, the rope should only be required to undergo a tension force of 2.9 kN) at the center of the Tyrolean traverse. (a) Determine the distance x that the rope must sag if it is to be within its recommended safety range and Christian's mass is 72.0 kg. (b) If the Tyrolean traverse is incorrectly set up so that the rope sags by only one-fourth the distance found in (a), determine the tension force in the rope. Will the rope break?



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32. (II) A window washer pulls herself upward using the bucket–pulley apparatus shown in Fig. 4–36. (a) How hard must she pull downward to raise herself slowly at constant speed? (b) If she increases this force by 15%, what will her acceleration be? The mass of the person plus the bucket is 72 kg.

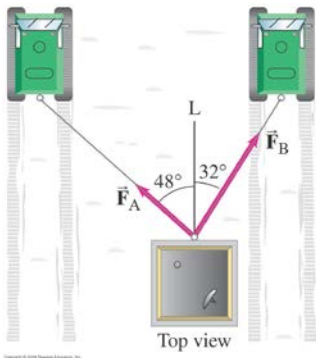


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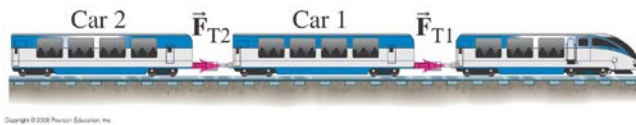
33. (II) One 3.2-kg paint bucket is hanging by a massless cord from another 3.2-kg paint bucket, also hanging by a massless cord, as shown in Fig. 4–37. (a) If the buckets are at rest, what is the tension in each cord? (b) If the two buckets are pulled upward with an acceleration of 1.25 m/s^2 by the upper cord, calculate the tension in each cord.



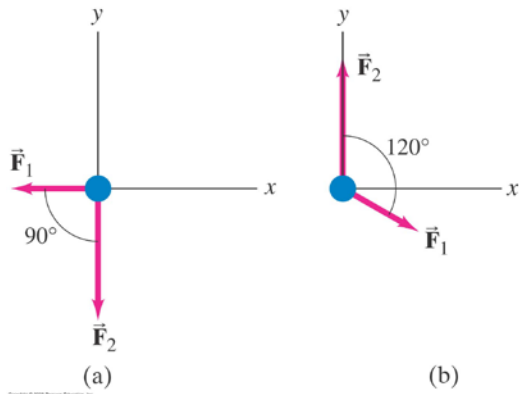
34. (II) The cords accelerating the buckets in Problem 33b, Fig. 4–37, each has a weight of 2.0 N. Determine the tension in each cord at the three points of attachment.
35. (II) Two snowcats in Antarctica are towing a housing unit to a new location, as shown in Fig. 4–38. The sum of the forces \vec{F}_A and \vec{F}_B exerted on the unit by the horizontal cables is parallel to the line L, and $F_A = 4500$ N. Determine F_B and the magnitude of $\vec{F}_A + \vec{F}_B$.



36. (II) A train locomotive is pulling two cars of the same mass behind it, Fig. 4–39. Determine the ratio of the tension in the coupling (think of it as a cord) between the locomotive and the first car (F_{T1}), to that between the first car and the second car (F_{T2}), for any nonzero acceleration of the train.



37. (II) The two forces \vec{F}_1 and \vec{F}_2 shown in Fig. 4–40a and b (looking down) act on a 18.5-kg object on a frictionless tabletop. If $F_1 = 10.2$ N and $F_2 = 16.0$ N, find the net force on the object and its acceleration for (a) and (b).



38. (II) At the instant a race began, a 65-kg sprinter exerted a force of 720 N on the starting block at a 22° angle with respect to the ground. (a) What was the horizontal acceleration of the sprinter? (b) If the force was exerted for 0.32 s, with what speed did the sprinter leave the starting block?

39. (II) A mass m is at rest on a horizontal frictionless surface at $t = 0$. Then a constant force F_0 acts on it for a time t_0 . Suddenly the force doubles to $2F_0$ and remains constant until $t = 2t_0$. Determine the total distance traveled from $t = 0$ to $t = 2t_0$ *

40. (II) A 3.0-kg object has the following two forces acting on it:

$$\vec{F}_1 = (16\hat{i} + 12\hat{j}) \text{ N}$$

$$\vec{F}_2 = (210\hat{i} + 22\hat{j}) \text{ N}$$

If the object is initially at rest, determine its velocity \vec{v} at $t = 3.0$ s.

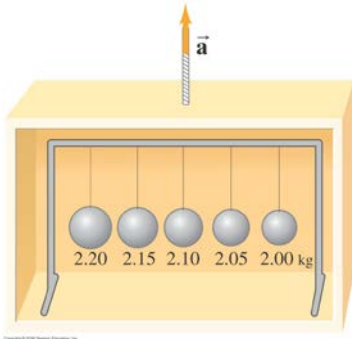
41. (II) Uphill escape ramps are sometimes provided to the side of steep downhill highways for trucks with overheated brakes. For a simple 11° upward ramp, what length would be needed for a runaway truck traveling 140 km/h? Note the large size of your calculated length. (If sand is used for the bed of the ramp, its length can be reduced by a factor of about 2.)

42. (II) A child on a sled reaches the bottom of a hill with a velocity of 10.0 m/s and travels 25.0 m along a horizontal straightaway to a stop. If the child and sled together have a mass of 60.0 kg, what is the average retarding force on the sled on the horizontal straightaway?

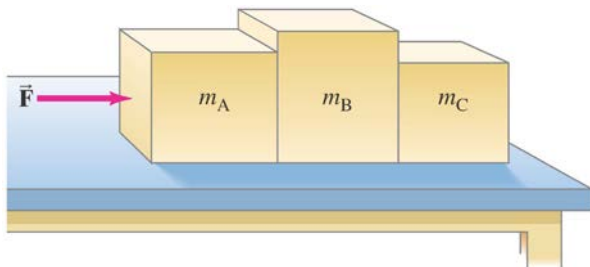
43. (II) A skateboarder, with an initial speed of 2.0 m/s, rolls virtually friction free down a straight incline of length 18 m in 3.3 s. At what angle θ is the incline oriented above the horizontal?

44. (II) As shown in Fig. 4–41, five balls (masses 2.00, 2.05, 2.10, 2.15, 2.20 kg) hang from a crossbar. Each mass is supported by “5-lb test” fishing line which will break when its

tension force exceeds 22.2 N (@ 5 lb). When this device is placed in an elevator, which accelerates upward, only the lines attached to the 2.05 and 2.00 kg masses do not break. Within what range is the elevator's acceleration?

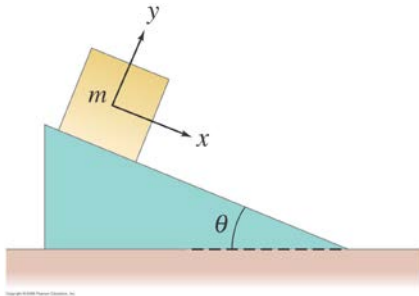


45. (II) A 27-kg chandelier hangs from a ceiling on a vertical 4.0-m-long wire. (a) What horizontal force would be necessary to displace its position 0.15 m to one side? (b) What will be the tension in the wire?
46. (II) Three blocks on a frictionless horizontal surface are in contact with each other as shown in Fig. 4–42. A force \vec{F} is applied to block A (mass m_A). (a) Draw a free-body diagram for each block. Determine (b) the acceleration of the system (in terms of m_A , m_B , and m_C), (c) the net force on each block, and (d) the force of contact that each block exerts on its neighbor. (e) If $m_A = m_B = m_C = 10.0$ kg and $F = 96.0$ N, give numerical answers to (b), (c), and (d). Explain how your answers make sense intuitively.

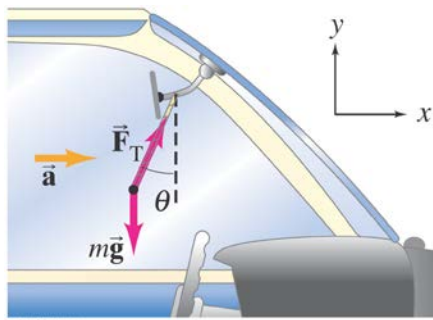


47. (II) Redo Example 4–13 but (a) set up the equations so that the direction of the acceleration \vec{a} of each object is in the direction of motion of that object. (In Example 4–13, we took \vec{a} as positive upward for both masses.) (b) Solve the equations to obtain the same answers as in Example 4 – 13.
48. (II) The block shown in Fig. 4–43 has mass $m = 7.0$ kg and lies on a fixed smooth frictionless plane tilted at an angle $\theta = 22.0^\circ$ to the horizontal. (a) Determine the acceleration of the block as it slides down the plane. (b) If the block starts from rest 12.0 m

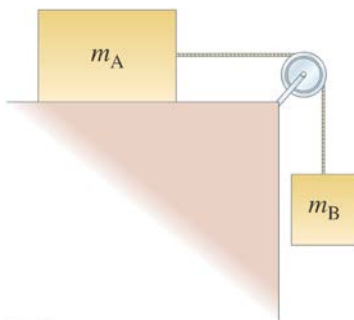
up the plane from its base, what will be the block's speed when it reaches the bottom of the incline?



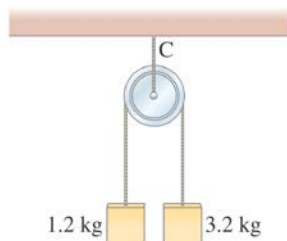
49. (II) A block is given an initial speed of 4.5 m/s up the 22° plane shown in Fig. 4-43. (a) How far up the plane will it go? (b) How much time elapses before it returns to its starting point? Ignore friction.
50. (II) An object is hanging by a string from your rearview mirror. While you are accelerating at a constant rate from rest to 28 m/s in 6.0 s, what angle θ does the string make with the vertical? See Fig. 4-44.



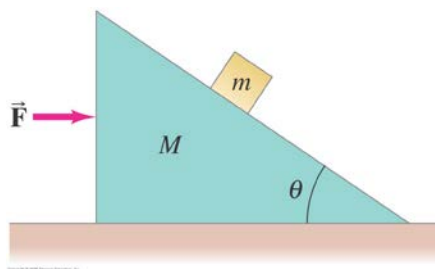
51. (II) Figure 4-45 shows a block (mass m_A) on a smooth horizontal surface, connected by a thin cord that passes over a pulley to a second block (m_B), which hangs vertically. (a) Draw a free-body diagram for each block, showing the force of gravity on each, the force (tension) exerted by the cord, and any normal force. (b) Apply Newton's second law to find formulas for the acceleration of the system and for the tension in the cord. Ignore friction and the masses of the pulley and cord.



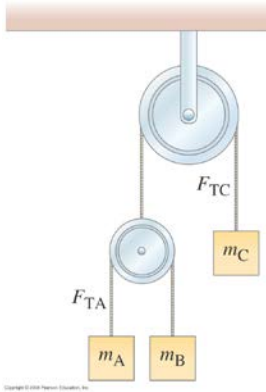
52. (II) (a) If $m_A = 13.0 \text{ kg}$ and $m_B = 5.0 \text{ kg}$ in Fig. 4–45, determine the acceleration of each block. (b) If initially m_A is at rest 1.250 m from the edge of the table, how long does it take to reach the edge of the table if the system is allowed to move freely? (c) If $m_B = 1.0 \text{ kg}$, how large must m_A be if the acceleration of the system is to be kept at $\frac{1}{100} g$?
53. (III) Determine a formula for the acceleration of the system shown in Fig. 4–45 (see Problem 51) if the cord has a non-negligible mass m_C . Specify in terms of m_A and m_B , the lengths of cord from the respective masses to the pulley. (The total cord length is $l = l_A + l_B$.)
54. (III) Suppose the pulley in Fig. 4–46 is suspended by a cord C. Determine the tension in this cord after the masses are released and before one hits the ground. Ignore the mass of the pulley and cords.



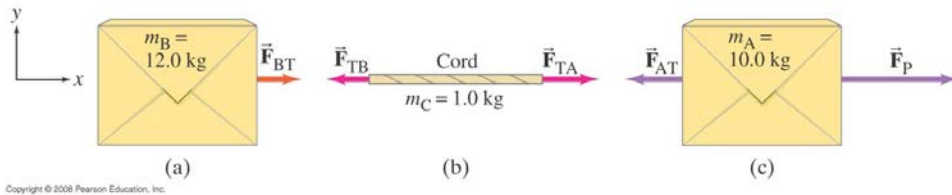
55. (III) A small block of mass m rests on the sloping side of a triangular block of mass M which itself rests on a horizontal table as shown in Fig. 4–47. Assuming all surfaces are frictionless, determine the magnitude of the force \vec{F} that must be applied to M so that m remains in a fixed position relative to M (that is, m doesn't move on the incline). [Hint: Take x and y axes horizontal and vertical.]



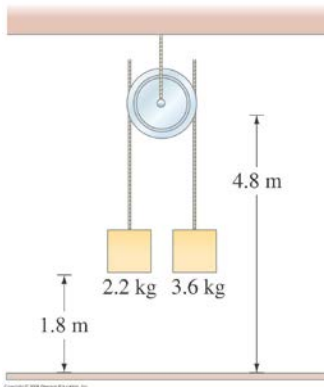
56. (III) The double Atwood machine shown in Fig. 4–48 has frictionless, massless pulleys and cords. Determine (a) the acceleration of masses m_A , m_B , and m_C , and (b) the tensions F_{TA} and F_{TC} in the cords.



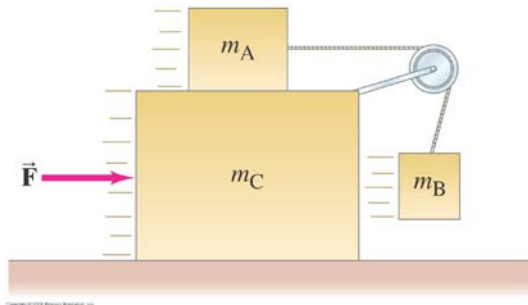
57. (III) Suppose two boxes on a frictionless table are connected by a heavy cord of mass 1.0 kg. Calculate the acceleration of each box and the tension at each end of the cord, using the free-body diagrams shown in Fig. 4–49. Assume $F_p = 35.0$ N, and ignore sagging of the cord. Compare your results to Example 4 – 12 and Fig. 4–22.



58. (III) The two masses shown in Fig. 4–50 are each initially 1.8 m above the ground, and the massless frictionless pulley is 4.8 m above the ground. What maximum height does the lighter object reach after the system is released? [Hint: First determine the acceleration of the lighter mass and then its velocity at the moment the heavier one hits the ground. This is its “launch” speed. Assume the mass doesn’t hit the pulley. Ignore the mass of the cord.]



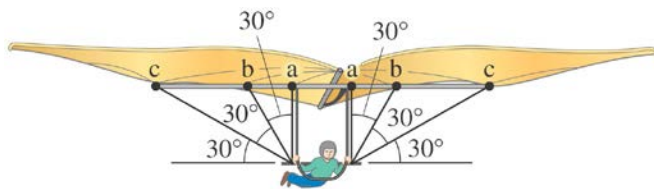
59. (III) Determine a formula for the magnitude of the force \vec{F} exerted on the large block (m_C) in Fig. 4–51 so that the mass m_A does not move relative to m_C . Ignore all friction. Assume m_B does not make contact with m_C .



60. (III) A particle of mass m , initially at rest at $x = 0$, is accelerated by a force that increases in time as $F = Ct^2$. Determine its velocity y and position x as a function of time.
61. (III) A heavy steel cable of length L and mass M passes over a small massless, frictionless pulley. (a) If a length y hangs on one side of the pulley (so $L - y$ hangs on the other side), calculate the acceleration of the cable as a function of y . (b) Assuming the cable starts from rest with length y_0 on one side of the pulley, determine the velocity y_f at the moment the whole cable has fallen from the pulley. (c) Evaluate y_f for $y_0 = \frac{2}{3}L$. [Hint: Use the chain rule, $dy/dt = (dy/dy)(dy/dt)$, and integrate.]

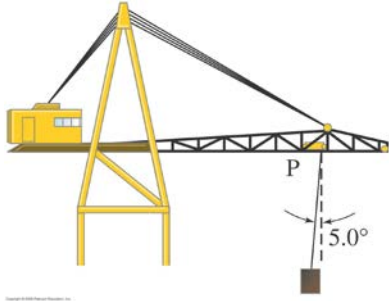
General Problems

62. A person has a reasonable chance of surviving an automobile crash if the deceleration is no more than $30g$'s. Calculate the force on a 65-kg person accelerating at this rate. What distance is traveled if brought to rest at this rate from 95 km/h ?
63. A 2.0-kg purse is dropped 58 m from the top of the Leaning Tower of Pisa and falls 55 m before reaching the ground with a speed of 27 m/s . What was the average force of air resistance?
64. Tom's hang glider supports his weight using the six ropes shown in Fig. 4-52. Each rope is designed to support an equal fraction of Tom's weight. Tom's mass is 74.0 kg. What is the tension in each of the support ropes?

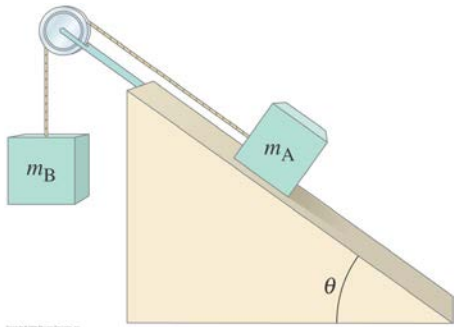


65. A wet bar of soap ($m = 150 \text{ g}$) slides freely down a ramp 3.0 m long inclined at 8.5° . How long does it take to reach the bottom? How would this change if the soap's mass were 300 g?

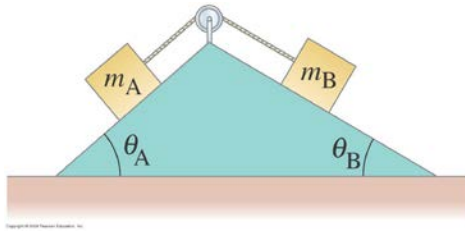
66. A crane's trolley at point P in Fig. 4-53 moves for a few seconds to the right with constant acceleration, and the 870-kg load hangs at a 5.0° angle to the vertical as shown. What is the acceleration of the trolley and load?



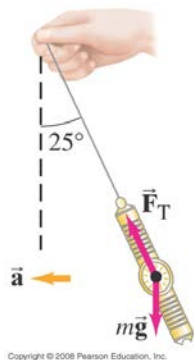
67. A block (mass m_A) lying on a fixed frictionless inclined plane is connected to a mass m_B by a cord passing over a pulley, as shown in Fig. 4-54. (a) Determine a formula for the acceleration of the system in terms of m_A , m_B , u , and g . (b) What conditions apply to masses m_A and m_B for the acceleration to be in one direction (say, m_A down the plane), or in the opposite direction? Ignore the mass of the cord and pulley.



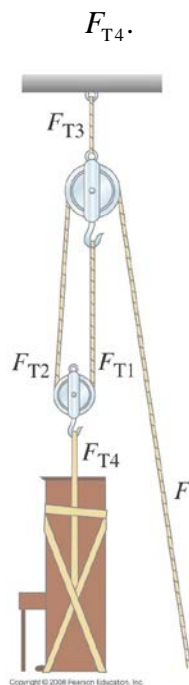
68. (a) In Fig. 4-54, if $m_A = m_B = 1.00 \text{ kg}$ and $u = 33.0\text{g}$, what will be the acceleration of the system? (b) If $m_A = 1.00 \text{ kg}$ and the system remains at rest, what must the mass m_B be? (c) Calculate the tension in the cord for (a) and (b).
69. The masses m_A and m_B slide on the smooth (frictionless) inclines fixed as shown in Fig. 4-55. (a) Determine a formula for the acceleration of the system in terms of m_A , m_B , u_A , u_B , and g . (b) If $u_A = 32\text{g}$, $u_B = 23\text{g}$ and $m_A = 5.0 \text{ kg}$, what value of m_B would keep the system at rest? What would be the tension in the cord (negligible mass) in this case? (c) What ratio, m_A/m_B , would allow the masses to move at constant speed along their ramps in either direction?



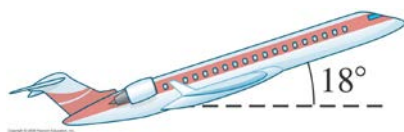
70. A 75.0-kg person stands on a scale in an elevator. What does the scale read (in N and in kg) when (a) the elevator is at rest, (b) the elevator is climbing at a constant speed of 3.0 m/s, (c) the elevator is descending at 3.0 m/s, (d) the elevator is accelerating upward at 3.0 m/s², (e) the elevator is accelerating downward at 3.0 m/s²?
71. A city planner is working on the redesign of a hilly portion of a city. An important consideration is how steep the roads can be so that even low-powered cars can get up the hills without slowing down. A particular small car, with a mass of 920 kg, can accelerate on a level road from rest to 21 m/s (75 km/h) in 12.5 s. Using these data, calculate the maximum steepness of a hill.
72. If a bicyclist of mass 65 kg (including the bicycle) can coast down a 6.5° hill at a steady speed of 6.0 km/h because of air resistance, how much force must be applied to climb the hill at the same speed (and the same air resistance)?
73. A bicyclist can coast down a 5.0° hill at a constant speed of 6.0 km/h. If the force of air resistance is proportional to the speed y so that $F_{\text{air}} = cy$, calculate (a) the value of the constant c , and (b) the average force that must be applied in order to descend the hill at 18.0 km/h. The mass of the cyclist plus bicycle is 80.0 kg.
74. Francesca dangles her watch from a thin piece of string while the jetliner she is in accelerates for takeoff, which takes about 16 s. Estimate the takeoff speed of the aircraft if the string makes an angle of 25° with respect to the vertical, Fig. 4–56.



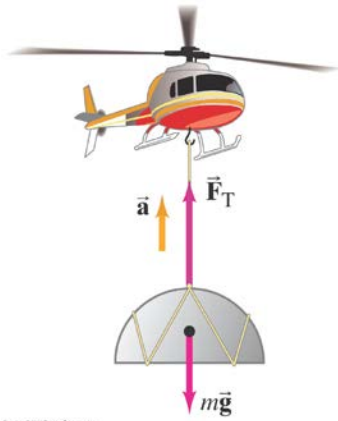
75. (a) What minimum force F is needed to lift the piano (mass M) using the pulley apparatus shown in Fig. 4–57? (b) Determine the tension in each section of rope: F_{T1} , F_{T2} , F_{T3} , and



76. In the design of a supermarket, there are to be several ramps connecting different parts of the store. Customers will have to push grocery carts up the ramps and it is obviously desirable that this not be too difficult. The engineer has done a survey and found that almost no one complains if the force required is no more than 18 N. Ignoring friction, at what maximum angle θ should the ramps be built, assuming a full 25-kg grocery cart?
77. A jet aircraft is accelerating at 3.8 m/s^2 as it climbs at an angle of 18° above the horizontal (Fig. 4–58). What is the total force that the cockpit seat exerts on the 75-kg pilot?



78. A 7650-kg helicopter accelerates upward at 0.80 m/s^2 while lifting a 1250-kg frame at a construction site, Fig. 4–59. (a) What is the lift force exerted by the air on the helicopter rotors? (b) What is the tension in the cable (ignore its mass) that connects the frame to the helicopter? (c) What force does the cable exert on the helicopter?



79. A super high-speed 14-car Italian train has a mass of 640 metric tons (640,000 kg). It can exert a maximum force of 400 kN horizontally against the tracks, whereas at maximum constant velocity (300 km/h), it exerts a force of about 150 kN. Calculate (a) its maximum acceleration, and (b) estimate the force of friction and air resistance at top speed.
80. A fisherman in a boat is using a “10-lb test” fishing line. This means that the line can exert a force of 45 N without breaking (1 lb = 4.45 N). (a) How heavy a fish can the fisherman land if he pulls the fish up vertically at constant speed? (b) If he accelerates the fish upward at 2.0 m/s^2 , what maximum weight fish can he land? (c) Is it possible to land a 15-lb trout on 10-lb test line? Why or why not?
81. An elevator in a tall building is allowed to reach a maximum speed of 3.5 m/s going down. What must the tension be in the cable to stop this elevator over a distance of 2.6 m if the elevator has a mass of 1450 kg including occupants?
82. Two rock climbers, Bill and Karen, use safety ropes of similar length. Karen’s rope is more elastic, called a *dynamic rope* by climbers. Bill has a *static rope*, not recommended for safety purposes in pro climbing. (a) Karen falls freely about 2.0 m and then the rope stops her over a distance of 1.0 m (Fig. 4–60). Estimate how large a force (assume constant) she will feel from the rope. (Express the result in multiples of her weight.) (b) In a similar fall, Bill’s rope stretches by only 30 cm. How many times his weight will the rope pull on him? Which climber is more likely to be hurt?

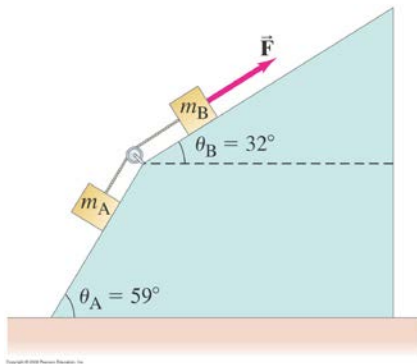


83. Three mountain climbers who are roped together in a line are ascending an icefield inclined at 31.0° to the horizontal (Fig. 4–61). The last climber slips, pulling the second climber off his feet. The first climber is able to hold them both. If each climber has a mass of 75 kg, calculate the tension in each of the two sections of rope between the three climbers. Ignore friction between the ice and the fallen climbers.

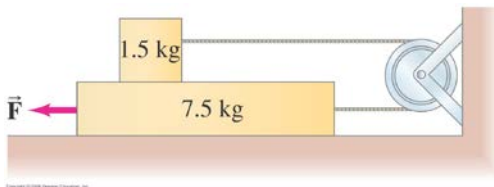


84. A “doomsday” asteroid with a mass of 1.03×10^{10} kg is hurtling through space. Unless the asteroid’s speed is changed by about 0.20 cm/s, it will collide with Earth and cause tremendous damage. Researchers suggest that a small “space tug” sent to the asteroid’s surface could exert a gentle constant force of 2.5 N. For how long must this force act?
85. A 450-kg piano is being unloaded from a truck by rolling it down a ramp inclined at 22° . There is negligible friction and the ramp is 11.5 m long. Two workers slow the rate at which the piano moves by pushing with a combined force of 1420 N parallel to the ramp. If the piano starts from rest, how fast is it moving at the bottom?
86. Consider the system shown in Fig. 4–62 with $m_A = 9.5$ kg and $m_B = 11.5$ kg. The angles $\alpha_A = 59.8^\circ$ and $\alpha_B = 32.8^\circ$ (a) In the absence of friction, what force \vec{F} would be required to pull the masses at a constant velocity up the fixed inclines? (b) The force \vec{F} is now

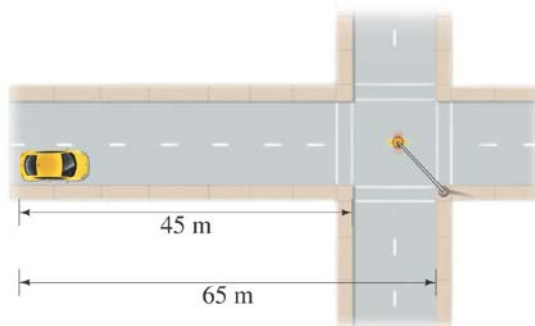
removed. What is the magnitude and direction of the acceleration of the two blocks? (c) In the absence of \vec{F} , what is the tension in the string?



87. A 1.5-kg block rests on top of a 7.5-kg block (Fig. 4–63). The cord and pulley have negligible mass, and there is no significant friction anywhere. (a) What force F must be applied to the bottom block so the top block accelerates to the right at 2.5 m/s^2 ? (b) What is the tension in the connecting cord?



88. You are driving home in your 750-kg car at 15 m/s . At a point 45 m from the beginning of an intersection, you see a green traffic light change to yellow, which you expect will last 4.0 s , and the distance to the far side of the intersection is 65 m (Fig. 4–64). (a) If you choose to accelerate, your car's engine will furnish a forward force of 1200 N . Will you make it completely through the intersection before the light turns red? (b) If you decide to panic stop, your brakes will provide a force of 1800 N . Will you stop before entering the intersection?



***Numerical/Computer**

- *89.** (II) A large crate of mass 1500 kg starts sliding from rest along a frictionless ramp, whose length is L , and whose inclination with the horizontal is θ . (a) Determine as a function of θ : (i) the acceleration a of the crate as it goes downhill, (ii) the time t to reach the bottom of the incline, (iii) the final velocity v of the crate when it reaches the bottom of the ramp, and (iv) the normal force F_N on the crate. (b) Now assume $L = 100$ m. Use a spreadsheet to calculate and graph a , t , v , and F_N as functions of θ from $\theta = 0^\circ$ to 90° in 18 steps. Are your results consistent with the known result for the limiting cases $\theta = 0^\circ$ and $\theta = 90^\circ$?