which the force is applied is about 0.4 m. At approximately what speed will they leave the ground and how high will they rise?

61. [II] Suppose that a person of mass m steps off a ladder at a height s_h and lands on the ground without bouncing. If the total compression of the body and the soil during impact is s_c, and if the deceleration is assumed constant, show that the force exerted by the ground is given by

$$F_{av} = mg\,(s_h/s_c)$$

Notice that bending the knees extends s_c considerably, decreasing F_{av} accordingly.

62. [II] When a person jumps and lands stiff-legged on the heels of the feet, a considerable force can be exerted on the long leg bones. The greatest stress occurs in the tibia, or shin bone, a bit above the ankle where the bone has its smallest cross section. If a force in excess of about 50 000 N is applied upward on the heel, the tibia will probably fracture. Keeping in mind the results of Problem 61, what is the minimum height of a fall above which a 60-kg person is likely to suffer a tibial fracture? Assume the body decelerates uniformly through a distance of 1.0 cm and the landing occurs squarely on both feet.

63. [II] In Problem 36, how much force must the driver's neck exert to keep her head in line with her body during the collision if her head weighs 44.5 N (10 lb)? Think about "whiplash."

64. [III] Navy jets are hurled off the deck of a modern carrier by a combination of catapult and engine thrust. The catapult (e.g., the C-7) has a 250-ft stroke (that is, runway) and will yank a 70 000-lb F-14A jet, with its engines developing a net average thrust of 16 000 lb, from rest to a speed of 200 ft/s in just 2.4 s. (a) Compute the average force exerted by the catapult. (b) Is the acceleration of the plane uniform? [*Hint: Try several of the equations for constant a.*]

SECTION 4.7: COUPLED MOTIONS

65. [I] Referring to Fig 4.22*b*, suppose m_2 equals 2.00 kg and it's on a frictionless surface. If $m_1 = 10.0$ kg, someone holds m_2 at rest, what will be the tension in the string?

66. [I] The pulley in Fig. 4.22*a* is essentially weightless and frictionless. If $m_1 = 10.0$ kg, the m_2 weighs 300 N, and someone holds on to m_2 so that the system is motionless, what is the tension in the rope and the acceleration of m_1?

67. [I] The pulley in Fig. 4.22*a* is essentially weightless and frictionless. If m_1 weighs 100 N and the m_2 weighs 300 N, and someone holds on to m_1 so that the system is motionless, what is the tension in the rope and the acceleration of m_1? How much force must the person exert and in what direction?

68. [I] Referring to Fig 4.22*b* suppose m_2, which weighs 300 N, rests on a frictionless surface. If the tension in the string is measured to be 100 N, what is the acceleration of m_1?

69. [I] The pulley in Fig. 4.22*a* is essentially weightless and frictionless. If $m_1 = 10.0$ kg and the second mass m_2 weighs 98.1 N, what is the tension in the rope and the acceleration of m_1?

70. [I] The two masses in Fig. 4.22*c* are $m_1 = 10.0$ kg and $m_2 = 20.0$ kg. What must be the tension in the rope on the right if the two blocks accelerate at 0.50 m/s^2 in a straight line over a frictionless surface?

71. [I] The pulley in Fig. 4.22*a* is essentially weightless and frictionless. Suppose that someone holds onto $m_2 = 10.0$ kg and accelerates it upward at 4.905 m/s^2. What will then be the tension in the rope given that $m_1 = 10.0$ kg?

72. [I] Suppose that the blocks in Fig 4.22*b* are $m_1 = 10.0$ kg and $m_2 = 20.0$ kg and the surfaces are frictionless. (a) If someone holds on to m_1 and pulls it down with an acceleration of 9.81 m/s^2, what is the tension in the rope? (b) What is the value of the force (F_A) applied to m_1 by the person?

SOLUTION: (a) The mass m_2 experiences a net horizontal force such that $\sum F_H = F_T = m_2 a = (20.0\text{ kg})(9.81\text{ m/s}^2) = 196$ N; that's the tension. (b) The mass m_1 experiences a net force such that $\sum F = m_1 a = (10.0\text{ kg})(9.81\text{ m/s}^2)$; moreover, taking down as positive $\sum F = F_W + F_A - F_T = m_1 a = m_1 g = 98.1$ N; hence $F_A = 98.1\text{ N} - F_W + F_T = 98.1\text{ N} - 98.1\text{ N} + F_T$ and $F_A = F_T = 196$ N.

73. [I] THIS PROBLEM WILL HELP US LEARN ABOUT FORCES AND ACCELERATION. In Fig. P73 the cylindrical roller weighs 5.0 N and each of the hanging masses weighs 1.0 N. Assume the pulley is weightless and frictionless, and the roller slides freely. (a) What is the tension in the rope when everything is at rest? (b) After the roller is released, describe the motion of the system. (c) Is the tension now the same as it was before? (d) Draw a free-body diagram of both the roller and the hanging mass. (e) When released, at what rate will the cylinder accelerate? (f) Compare your result with that of Problem 47 and make sure you understand the difference.

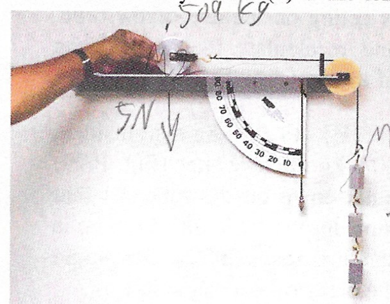

Figure P73

74. [II] THIS PROBLEM WILL HELP US LEARN ABOUT FORCES AND ACCELERATION. Figure P74 depicts four identical 20.0-kg cartons being pushed forward by a 80.0-N force on a frictionless horizontal plane. (a) What is the total mass being accelerated? (b) Determine the acceleration of each block. (c) What is the net force exerted on each block? (d) What force does the block second from the left exert on the block third from the left?

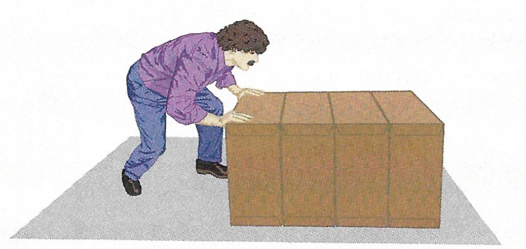

Figure P74

75. [II] A tug pulls two small barges (of mass $m_1 = 4.00 \times 10^3$ kg and $m_2 = 3.50 \times 10^3$ kg) tied together, one behind the other. The tug exerts 1.00 kN on the line to the first barge (m_1) and accelerates at 0.100 m/s^2. Compute the tension in the two ropes and, knowing that friction opposes the motion, determine the friction on each barge, assuming it's the same for both. [*Hint: There are two unknowns, the tension in the connecting rope and the friction. Take the sum of the forces on the first barge and the sum of the forces on the second barge, and solve the two equations simultaneously.*]

76. [II] Examine the air track depicted in Fig. Q3 and suppose that when let loose the hanging mass creates a tension of 0.260 N in the string that's attached to a 0.280-kg glider. Now imagine that a second glider of mass 0.200 kg is placed on the track in front of (i.e., to the right of) the first one and the two are attached by a very light spring. The hanging mass is released; determine the acceleration of the gliders and the force compressing the spring. Ignore friction.

77. [II] Two crates rest on the floor one next to the other. A man pushes with a horizontal force of 400 N on the larger (50.0 kg), which, in turn, pushes the other (25.0 kg) so that both slide as he walks along. Each crate experiences a friction force opposing the motion equal to 40% of its weight. Determine the acceleration of each crate. What is the force exerted by one crate on the other?

78. [II] Refer to Fig. P78. Compute the acceleration of the 1.3×10^3-N weight. Neglect friction and the mass of the rope and pulleys. Now remove the 1.8×10^3-N weight, replace it by a constant downward tug of 1.8×10^3 N acting on the end of the rope, and recalculate the acceleration of the first weight.

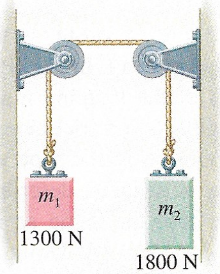

Figure P78

79. [II] An 80.0-kg man inside a 40.0-kg dumb-waiter (Fig. P.79) pulls down on the rope. At that moment the scale on which he is standing reads 200 N. Determine the elevator's acceleration.

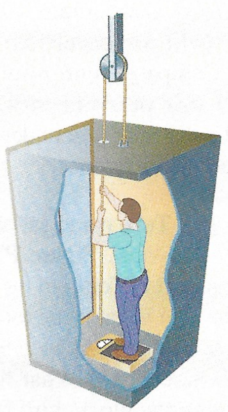

Figure P79

80. [II] In 1784, George Atwood published the description of a device for "diluting" the effect of gravity, thereby facilitating the accurate measurement of g. Figure P80 shows the apparatus: two masses tied together by a length of essentially massless rope slung over an essentially massless free-turning pulley. With $m_2 > m_1$, prove that both masses accelerate at a rate of

$$a = \frac{(m_2 - m_1)}{(m_2 + m_1)} g$$

Show that the tension in the rope is

$$F_T = \frac{2m_1 m_2}{(m_2 + m_1)} g$$

If $m_2 = 2m_1$, what is a? When is a equal to zero? When $m_2 >> m_1$, find a.

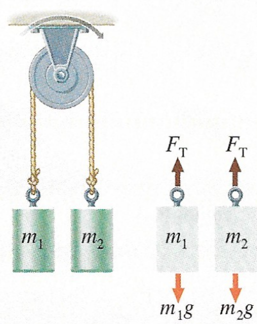

Figure P80

81. [III] Figure P81 shows three masses attached via massless ropes over weightless, frictionless pulleys on a frictionless surface. Compute (a) the tension in the ropes and (b) the acceleration of the system. Draw all appropriate free-body diagrams. (c) Discuss your results in terms of internal and external forces.

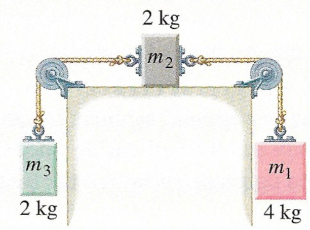

Figure P81

82. [III] A physicist on planet Mongo is using a device equivalent to Atwood's machine (Fig. P80) to measure the Mongoian gravitational acceleration g_M. He fixes one of the two 0.25-kg masses at each end of the rope. While both are at rest, he places a 0.025-kg gronch (a toadlike creature) on one of the masses. That body and its wart-covered passenger descend 0.50 m before the gronch hops off. The body continues traveling downward another 1.2 m in the next 3.0 s. Compute g_M.

SECTION 4.8: FRICTION

83. [I] A dog weighing 300 N harnessed to a sled can exert a maximum horizontal force of 160 N without slipping. What is the coefficient of static friction between the dog's foot pads and the road?

84. [I] Assume that your mass is 70.0 kg and that you are wearing leather-soled shoes on a wooden floor. Now walk over to a wall and push horizontally on it. How much force can you exert before your feet start sliding away?

85. [I] What is the maximum acceleration attainable by a four-wheel-drive vehicle with a tires-on-the-road static coefficient of μ_s?

86. [I] Mass m_1 sits on top of mass m_2, which is pulled along at a constant speed by a horizontal force F. If m_1 = 10.0 kg, m_2 = 5.0 kg, and μ_k for all surfaces is 0.30, find F.

87. [I] Someone wearing leather shoes is standing in the middle of a wooden plank. One end of the board is gradually raised until it makes an angle of 17° with the floor, at which point the person begins to slide down the incline. Compute the coefficient of static friction.

88. [I] A 30.0-kg youngster is dragged around the living room floor at a constant speed (giggling all the while) via a 60-N horizontal force. What was the appropriate pants-carpet friction coefficient?

89. [I] A wooden crate containing old $1000 bank notes has a total mass of 50.0 kg. It is transported on a flatbed truck to a facility to be burned. If the coefficient of static friction between the bed and the crate is 0.3 and the truck begins to climb a 20° incline at a constant speed, will the crate begin to slide?

SOLUTION: The maximum friction force that the crate can experience is $F_f(\text{max}) = \mu_s F_N = 0.3\, F_W \cos 20° = 0.3\,(491\text{ N}) \cos 20° = 138.4$ N. The driving force down the incline is $F_W \sin 20° = (491\text{ N}) \sin 20° = 167.9$ N so it slides.

90. [I] A garbage can partly filled with sand weighs 100 N, and it takes a force of 40 N to drag it down to the street at a uniform speed. How much force will it take to drag a full can weighing 150 N?

91. [II] A crate is being transported on a flatbed truck. The coefficient of static friction between the crate and the horizontal bed is

0.50. What is the minimum stopping distance if the truck, traveling at 50.0 km/h, is to decelerate uniformly and the crate is not to slide forward on the bed?

92. [II] What is the steepest incline that can be climbed at a constant speed by a four-wheel-drive vehicle having a tires-on-the-road coefficient of static friction of 0.90?

93. [II] Assume an even weight distribution on all four tires of a car with four-wheel antilock brakes. What is the minimum stopping time from 27 m/s if the coefficients of static and kinetic friction are 0.9 and 0.8, respectively?

94. [II] Place a book flat on a table and press down on it with your hand. Now suppose the hand-book and table-book values of μ_k are 0.50 and 0.40, respectively; the book's mass is 1.0 kg and your downward push on it is 10 N. How much horizontal force is needed to keep the book moving at a constant speed if your hand is stationary with respect to the table?

SOLUTION: The normal force between your hand and the book is 10 N; the friction force between your hand and the book is $F_{f\,HB} = \mu_k F_N = 0.50(10\text{ N}) = 5.0\text{ N}$. The normal force between the book and the table is $(10\text{ N} + g \times 1.0\text{ kg}) = (10\text{ N} + 9.81\text{ N}) = 19.81\text{ N}$; the friction force between the book and the table is $F_{f\,BT} = \mu_k F_N = 0.40(19.81\text{ N}) = 7.92\text{ N}$. The net friction force opposing the motion is 12.9 N or, to two significant figures, 13 N. This is the required force.

95. [II] THIS PROBLEM WILL HELP US LEARN ABOUT FORCES AND EQUILIBRIUM. The soda can with the wad of clay on it in Fig. P95 has a net mass of 404.2 g and rests on a surface where there is friction. The incline angle is 20.0°, and the two hanging weights are each 1.00 N. (a) What is the component of the weight acting down the incline? (b) What is the normal force acting up on the can? (c) Draw a free-body diagram of the can and clay together. (d) If the can is just on the verge of sliding up the incline, what is the value of the coefficient of static friction between it and the incline?

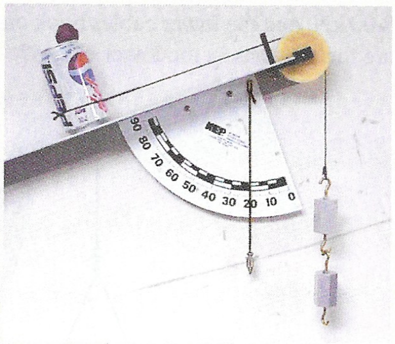

Figure P95

96. [II] THIS PROBLEM WILL HELP US LEARN MORE ABOUT FORCE AND ACCELERATION. The two blocks, each of mass m, shown in Fig. P96 are being accelerated at a rate a across a surface that has a coefficient of friction of μ_k by a horizontal force F. (a) Write an expression (in terms of m, g, μ_k, and a) for the tension in the rope that ties the blocks together. Ignore the weight of both the rope and the chain. (b) Write an expression for the force F (in terms of m, g, μ_k, and a).

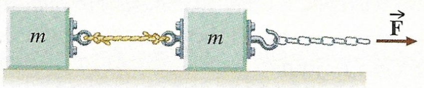

Figure P96

97. [II] THIS PROBLEM DEALS WITH FORCE AND ACCELERATION. Using Fig. P96 and with the previous problem in mind, suppose each block has a mass of 10.0 kg. If the connecting rope breaks at a tension of 20.0 N, (a) write an expression for the acceleration that will break the rope. (b) The force F applied via the chain to the first block on the right must overcome both friction and inertia. What value of F will cause that rope to break given that friction exists? (c) What is the effect of friction on the breaking of the rope?

98. [II] THIS PROBLEM WILL HELP US LEARN MORE ABOUT FORCE AND ACCELERATION. Figure P98 shows three objects on a frictionless surface. (a) Write an expression for F_{T3} given that the system accelerates as the mass m descends. (b) Write expressions for F_{T2} and F_{T1}. (c) Write an expression for the acceleration, a, of the system in terms of g and the masses. Does your answer agree with the solutions for Problem 73.

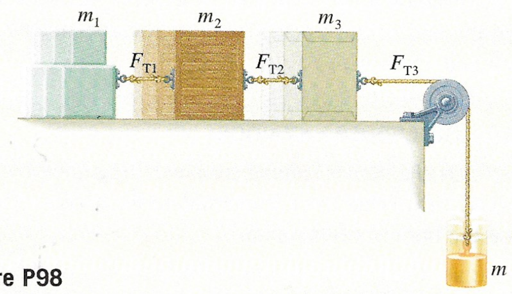

Figure P98

99. [II] A skier on a 4.0° inclined, snow-covered run skied downhill at a constant speed. Compute the coefficient of friction between the waxed skis and snow on that day when the temperature was around 0°C. Why is it that if the temperature were to drop to −10°C, μ_k would rise to around 0.22? Neglect air friction.

100. [II] A youngster shoots a bottle cap up a 20° inclined board at 2.0 m/s. The cap slides in a straight line, slowing to 1.0 m/s after traveling some distance. If $\mu_k = 0.4$, find that distance.

101. [II] A 100-kg bale of dried hay falls off a truck traveling on a level road at 88.0 km/h. It lands flat on the blacktop and skids 100 m before coming to rest. Assuming a uniform deceleration, compute the coefficient of kinetic friction between the bale and the road.

102. [II] A 100-kg trunk loaded with old books is to be slid across a floor by a young woman who exerts a force of 300 N down and forward at 30° with the horizontal. If $\mu_k = 0.4$ and $\mu_s = 0.5$, compute the resulting acceleration.

SOLUTION: The maximum static friction force that the trunk can experience is $F_f(\max) = \mu_s F_N$ where $F_N = F_W + 300\text{ N} \sin 30° = (100\text{ kg})(9.81\text{ m/s}^2) + 300\text{ N} \sin 30° = 1.131\text{ kN}$. Thus $F_f(\max) = 0.5(1.131\text{ kN}) = 566\text{ N}$. The horizontal force she exerts is $(300\text{ N}) \cos 30° = 259.8\text{ N}$ and the trunk does not move: $a = 0$.

103. [II] Suppose the woman in Problem 102 puts aside some of the books so that the mass of the load is 50 kg. (a) Pushing with the same force, what will the acceleration be now? (b) A bit annoyed, she squirts some oil under the trunk so that $\mu_s = 0.4$ and $\mu_k = 0.3$. What now?

104. [II] One of two identical 200-kg crates is dragged along the floor at a constant speed by a horizontal force of 200 N. How much force would it take to pull them both at some constant speed if (a) they are tied together one behind the other? (b) the second is stacked on top of the first?

105. [III] What is the steepest incline that can be climbed at a constant speed by a rear-wheel-drive auto having a tires-on-the-road μ_s of 0.9 and 57% of its weight on the front axle? Ignore all other forms of friction and remember that the wheels are turning.

106. [III] Determine the force (F) needed to keep the blocks depicted in Fig. P106 moving at a constant speed—m_2 to the right and m_1 to the left. Assume both the frictionless pulley and the rope to be massless: m_1 has a weight of 5.0 N; m_2 has a weight of 10 N; and $\mu_k = 0.40$ for all surfaces.

Figure P106

107. [III] A greasy flatbed truck is carrying a crate weighing 2.0 kN. The truck accelerates uniformly from rest to a speed of 30 km/h in a distance of 30.0 m. In that time, the crate slides 1.0 m back toward the end of the truck. Compute the coefficient of friction between bed and box.

SECTION 4.9: EQUILIBRIUM: STATICS

108. [I] A 200-N chandelier is hung from a ceiling hook by a chain weighing 50 N. (a) What force is exerted on the hook? (b) What force acts on the bottom of the chain?

109. [I] What are the tension forces acting on each of the weightless ropes in Fig. P109?

Figure P109

110. [I] THIS PROBLEM WILL HELP US LEARN MORE ABOUT FORCES AND EQUILIBRIUM. There are three strings tied to the small motionless ring in Fig. P110. The one on the right makes an angle θ with the horizontal, while the one on the left makes an angle ϕ. Given that each of the six hanging masses weighs 1.00 N, (a) Draw a free-body diagram of the ring. (b) Write expressions for the horizontal and vertical components of each force exerted by a string on the ring. (c) Use the sum-of-the-forces-equals-zero to determine θ and ϕ.


Figure P110

111. [I] The 10-kg block in Fig. P111 is held at rest by the four ropes shown. If the tension in the ropes on the right and top are each 98 N, what is the tension in the remaining two ropes?

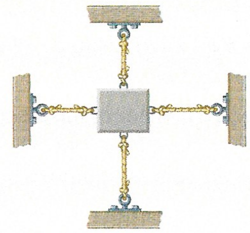
Figure P111

112. [I] The orthodontal wire brace in Fig. P112 makes an angle of 80.0° with the perpendicular to the protruding tooth. If the tension in the wire is 10.0 N, what force is exerted on the tooth by the brace?

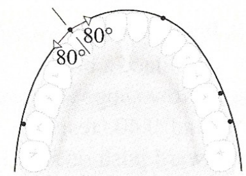

Figure P112

113. [I] Referring to Fig. P113, determine the scale reading in the right arm of the suspension and the angle θ. The scale was set to read zero with no suspended load.

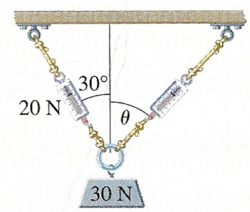

Figure P113

114. [I] The steel beam that hangs horizontally in Fig. P114 weighs 8.00 kN, and the lower cables hook on to it at angles of 70.0°. What are the tensions in the lower cables?

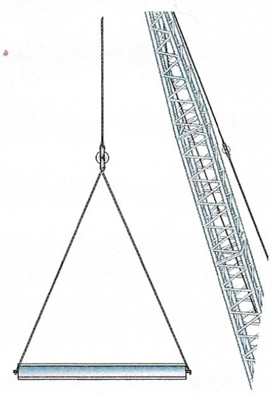
Figure P114

115. [I] In the static arrangement shown in Fig. P115, the pulleys and ropes are essentially weightless. If weight-1 is 15.0 N, weight-2 is 31.0 N, and the two angles are measured to be $\theta = 45.0°$ and $\phi = 20.0°$, determine the value of weight-3. Check that the system is in equilibrium.

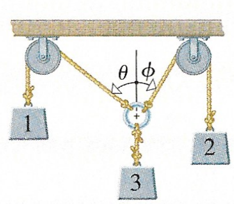

Figure P115

116. [I] The hand in Fig. P116 exerts a downward force that holds the length of pipe at rest. The pulleys are essentially weightless. (a) Compute that force. (b) What is the tension in the rope that is strung over the pulley? (c) What force supports the upper hook?

SOLUTION: (a) The load is 300 N. The bottom pulley is attached to the load and both are supported by two vertical lengths of rope. The tension in each length of rope is (300 N)/2 = 150 N. (b) There is one continuous rope and the tension everywhere within it is 150 N. (c) The hook supports the load (300 N) and the downward pull of the hand (150 N), and so the ceiling exerts an upward force of 450 N.

Figure P116

117. [I] Look at Fig. P117. If the hand pulls down so that the 100-N weight remains at rest, what is the tension in the long rope? What force is exerted down on the rightmost ceiling bracket?

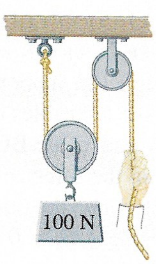

Figure P117

118. [I] What is the tension in each length of rope in Fig. P118, given that the load is at rest?

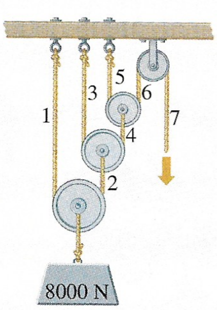

Figure P118

119. [I] The cylinder (and the several masses attached to it) photographed in Fig. P119 is at rest, although it can roll frictionlessly along the 30°-inclined plane. The scale reads 2.7 N. Compute the net weight of the cylinder and the attached masses.

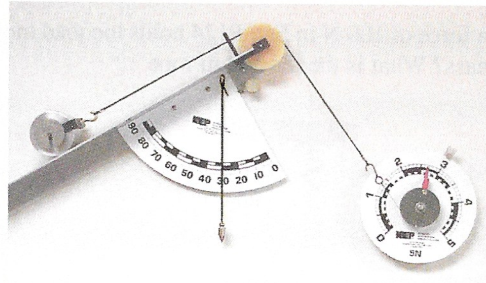

Figure P119

120. [I] What downward force on the rope in Fig. P120 will hold the 300-N block at rest assuming the pulleys are essentially weightless? Notice that there are two different ropes holding up the load.

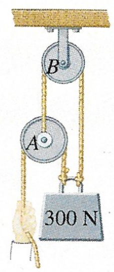

Figure P120

121. [II] Determine the weight of the motionless mass m in Fig. P121. Assume the pulleys and ropes are all essentially weightless.

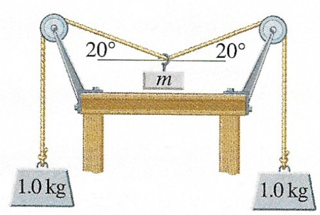

Figure P121

122. [II] An essentially weightless rope is strung nearly horizontally over a light pulley, as shown in Fig. P122. The spring balance is adjusted to read zero. A 100-N weight is then hung at the midpoint of the span and the rope sags, descending 10 cm from the horizontal. Determine the scale reading.

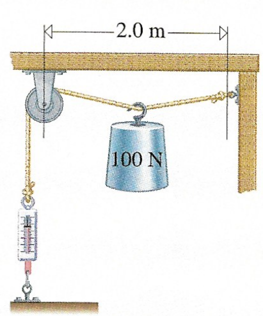

Figure P122

123. [II] A 533.8-N tightrope walker dances out to the middle of a 20-m-long wire stretched parallel to the ground between two buildings. She is wearing a pink tutu, of negligible weight; the wire sags, making a 5.0° angle on both sides of her feet with the horizontal. Find the tension.

124. [II] If a force of 100 N in Fig. P124 holds the load motionless, what is its mass? What is the tension in rope 1?

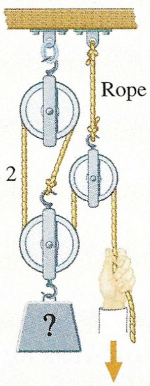

Figure P124

125. [II] Determine both the angle at which the pulley hangs and the tension in the hook supporting it in Fig. P125.

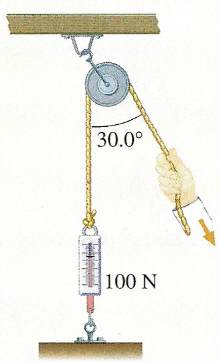

Figure P125

126. [II] THIS PROBLEM WILL HELP US LEARN MORE ABOUT FORCES AND EQUILIBRIUM. The spring in Fig. P126 exerts a horizontal force of 200 N (45.0 lb) on the ring, which is at rest. (a) Draw a free-body diagram of the ring. (b) What is the horizontal force exerted by cable-AB on the ring? (c) What is the tension in cable-AB? (d) What is the vertical force exerted by cable-AB on the ring? (e) What is the value of the load?

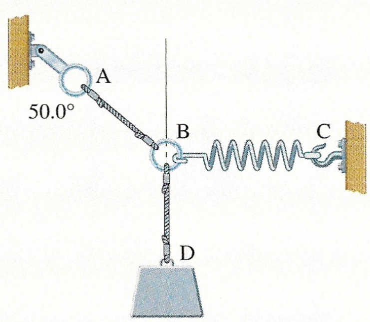

Figure P126

127. [II] THIS PROBLEM WILL HELP US LEARN ABOUT FORCES AND EQUILIBRIUM. The system shown in Fig. P127 is in equilibrium. (a) Draw a free-body diagram of the ring. (b) What is the vertical force exerted by rope-2 on the ring? (c) Determine the angle θ. (d) What is the horizontal force exerted by rope-2 on the ring? (e) What is the tension in each rope? (f) How much does the mass on the left weigh?

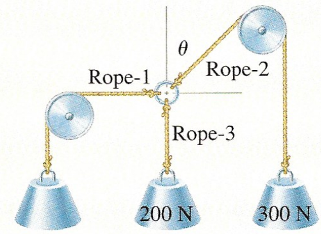

Figure P127

128. [II] THIS PROBLEM IS ABOUT FORCES AND EQUILIBRIUM. In Fig. P128 a 500-g mass sits on top of a 397-g spool of solder. The string makes an angle of 29° with the horizontal, and the two hanging masses each weigh 1.00 N. (a) What are the horizontal and vertical components of the tensile force exerted by the string on the spool? (b) Determine the normal force on the bottom of spool. (c) What is the coefficient of static friction between the spool and platform, given that the system is just on the verge of moving?

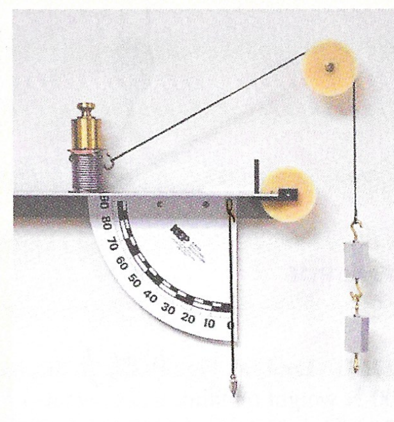

Figure P128

129. [II] THIS PROBLEM WILL HELP US LEARN MORE ABOUT FORCES AND EQUILIBRIUM. The crane in Fig P129 supports a 20.0-kN (4.5 × 10^3 lb) load. To simplify things take the cables to be represented by two separate bundles: cable-AB and cable-BC. (a) Draw a free-body diagram of point-B putting in the forces exerted by the boom, cable-AB, and cable-BC. (b) Determine the horizontal and vertical components of each force. (c) Using $\sum F_x = 0$ and $\sum F_y = 0$ determine the compressive force on the boom.

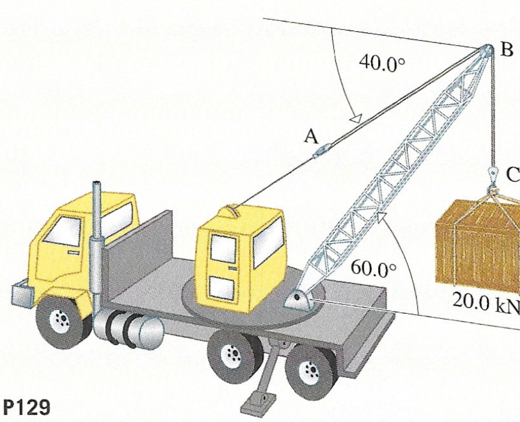

Figure P129