5.7 EXERCISES

Balancing Forces

Ex 5.7.1. Find $\vec{F}_{\text{net}}$ in situation give in Fig. 5.48.

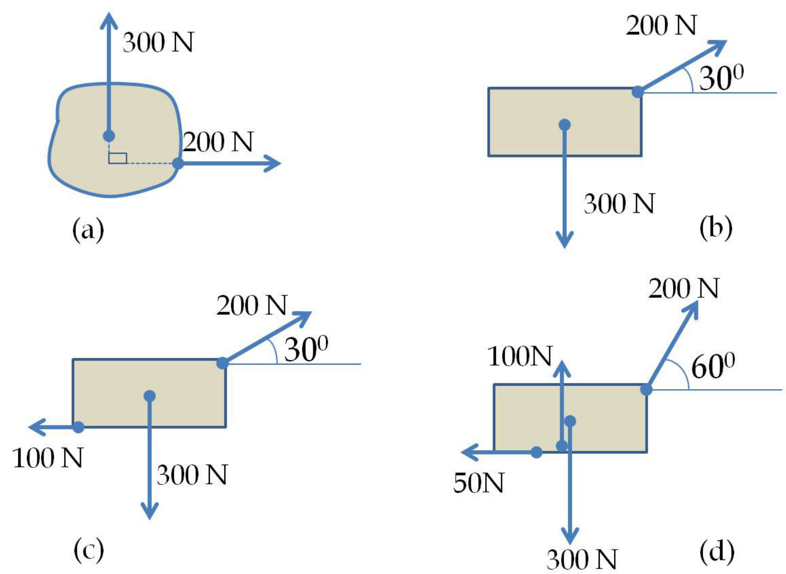


Figure 5.48: Exercise 5.7.1.

Ex 5.7.2. The net force in each situation in Fig. 5.49 is zero. Find the magnitude and direction of the force labeled F in each case.

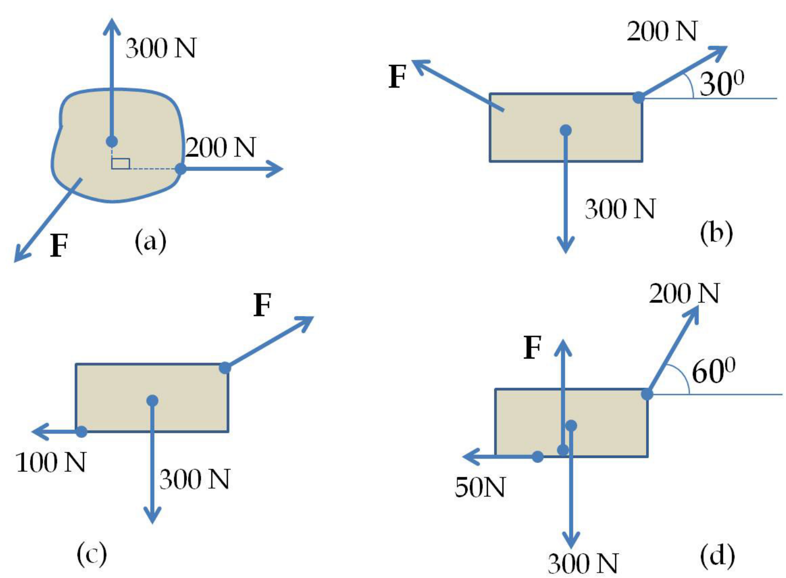


Figure 5.49: Exercise 5.7.2.

Gravitational Force

Ex 5.7.3. Find the gravitational force between two 10-kg lead spheres separated by 20 cm center-to-center distance. Provide both the magnitude of the force between the lead spheres and the directions of the forces on each sphere.

Ex 5.7.4. Look up the necessary masses and distances and find the force on the Earth by the Sun and the force on Sun by the Earth. Indicate the directions of the two forces by sketching a drawing.

Ex 5.7.5. Look up the necessary masses and distances, and find the magnitude of gravitational forces on the Earth by the Moon and by the Sun, and compare the two.

Ex 5.7.6. A 50-kg man is standing still on the surface of earth. (a) Find the force on the man exerted by the Earth. (b) Find the force on the Earth exerted by the man. Give directions of the two forces also.

Ex 5.7.7. Assuming the orbit of the Earth around the Sun to be circular and that of the Moon about the Earth be also circular, find the sum of the forces of the Moon and the Sun on the Earth in the two instances: (a) the solar eclipse, and (b) the lunar eclipse. Note: the solar eclipse happens when the Moon is in the line of sight between the Earth and the Sun, and the lunar eclipse when the Earth is between the Sun and the Moon.

Ex 5.7.8. Find the sum of the forces of the Earth and the Sun on the Moon when the Moon is in the position indicated in the Fig. 5.50.

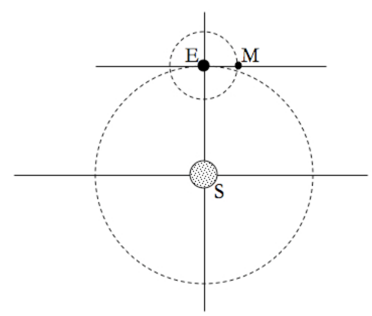


Figure 5.50: Exercise 5.7.8.

Weight

Ex 5.7.9. Using the mass and the radius of the Moon find the weight of a 1-kg brass block on the Moon.

Ex 5.7.10. What would be the weight of a 1-kg brass block on the Jupiter?

Ex 5.7.11. (a) Find the force of gravity of the Earth on a climber of mass 45-kg atop Mount Everest which is 8850 m above the sea level. Assume that the distance of the top of mount Everest from the center of the earth is 8850 m more than the average radius of the earth, which is approximately $6,370,000$ m. (b) Compare your answer to the weight of the climber at the sea level. You can compare the two by taking their ratios or by calculating the percentage difference.

Ex 5.7.12. A box of mass 3 kg is placed on a plane inclined at a 30° angle with the horizontal direction. (a) Find the weight of the box.

(b) Find the component of the weight along the incline. (c) Find the component of the weight perpendicular to the incline.

Ex 5.7.13. A box of mass 10 kg is placed on a plane inclined at a $60°$ angle with the horizontal direction. (a) Find the weight of the box. (b) Find the component of the weight along the incline. (c) Find the component of the weight perpendicular to the incline.

Normal Force and Balancing Forces

Ex 5.7.14. A book of mass 1.5 kg is resting on a table which is fixed to the ground. (a) Draw a diagram showing with symbols and arrows all the forces acting on the book. (b) What is the weight of the book. Note: give both magnitude and direction. (c) What is the net force on the book? State how you can draw your conclusion about the net force on the book. (d) Find the magnitude and direction of the force on the book by the table. (e) Find the magnitude and direction of the force on the table by the book.

Ex 5.7.15. Two books A and B of masses m_1 and m_2 respectively are stacked on a table as shown in the Fig. 5.51. (a) Draw a diagram showing with symbols and arrows all the forces acting on the book A. (b) Assuming the net force on A to be zero what would be the vector equation relating all forces on A? (c) Find the magnitude of all forces on A in terms of the masses and g. (d) Repeat steps in (a)-(c) for the book B. (Note: the weight of A acts on A not on B. The force from A acting on B may or may not be the weight of A and depends on the situation. Think!)

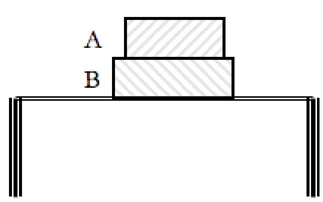
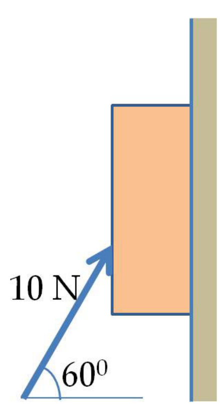


Figure 5.51: Exercise 5.7.15.

Ex 5.7.16. A 50-kg box is pushed against a wall by a force that acts horizontally and has a magnitude 200 N. Ignore any friction forces for this problem. (a) Draw a diagram showing with symbols and arrows all the forces acting on the book. (b) Choose a Cartesian coordinate system and compute the components of all forces on the box. (c) What are the magnitudes and directions of all forces on the box?



Ex 5.7.17. A book of unknown mass m can be supported against a vertical frictionless wall by applying a force 10 N at an angle $60°$ with the horizontal. (a) Draw a diagram showing with symbols and arrows all the forces acting on the book. (b) Choose a Cartesian coordinate system and compute the components of all forces on the book. (c) What are the magnitudes and directions of all forces on the book?

Static Frictional Force and Balancing Forces

Ex 5.7.18. A box of mass 1.5 kg is resting on a table which is fixed to the ground. Find the following forces: (a) the net force on the box, (b) the normal force on the box by the table, (c) frictional force on the box by the table (d) the normal force on the table by the box, and (e) the frictional force on the table by the box.

Ex 5.7.19. A book of mass 1.5 kg is at rest on a table which is fixed to the ground. The book is then pushed horizontally with a constant force of 10 N. Even with the 10 N horizontal force the book does not move. Draw a free-body diagram of forces on the book and find the following forces using the diagram. (a) the net force on the book, (b) the normal force on the book by the table, (c) the static frictional force on the book by the table, (d) the normal force on the table by the book, (e) the static frictional force on the table by the book, (f) the minimum value of coefficient of static friction between the table and the book that is consistent with the given data, and (g) the total force applied by the book on the table. Just a reminder that you need to provide both the magnitude and direction of each force.

Ex 5.7.20. A book of mass 1.5 kg at rest on a table is pushed horizontally with a force of magnitude F_A, which can be varied on demand. (a) If the coefficient of static friction between the book's bottom surface and the table is 0.3, at what value of the applied force would the book start to move? (b) Find the magnitude of the force applied by the book on the table when the static friction has its maximum value.

Ex 5.7.21. A box of mass m is at rest on a table inclined at an angle θ as shown in Fig. 5.53. The static friction between the box and the table surface has a coefficient equal to μ_s. It turns out that there is not enough static friction and an additional force of magnitude F_A acting up the incline is required to stop the box from sliding. Find the magnitude of the force F_A in terms of m, θ, g and μ_s by balancing all forces acting on the box. Use a free-body diagram to help set-up the problem.

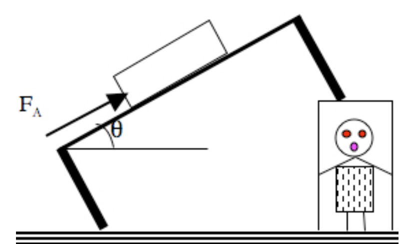


Figure 5.53: Exercise 5.7.21.

Kinetic Frictional Force and Balancing Forces

Note that forces on an object are balanced when the object moves with constant velocity. Therefore, if an object slides with a constant velocity, the net force will be zero. In the next chapter you will study problems where the net force in not zero; in that case, velocity would not be constant.

Ex 5.7.22. Consider a 1.5-kg book resting on a table. The coefficient of static friction between the book's bottom surface and the table is known to be 0.3. The book is pushed horizontally with a force of 5 N. (a) Show that there is not enough static friction to prevent the book from sliding. (b) When the book is sliding, a horizontal force of magnitude 2 N is enough to keep the book moving on the table at a constant velocity. Therefore, only 2 N force is now applied. By balancing forces on the book, using the help of a free-body diagram and a Cartesian axis system, determine the value of kinetic frictional coefficient.

Ex 5.7.23. A box of mass 5 kg is sliding at a constant velocity down an inclined plank with an angle of incline of 10°. Making use of a free-body diagram and a Cartesian axis system answer the following questions. (a) What must be the coefficient of kinetic friction between the bottom of the box and the surface of the plank? (b) What is the total force applied by the inclined plank on the box? (c) What is the total force applied by the box on the inclined plank? When providing answer for a force, give both the magnitude and direction of each force.

Ex 5.7.24. A heavy equipment of mass 1000 kg in a lab needs to be moved from one side of the room to the other. You find that it takes 300 N horizontal force to get it to budge from its place, and then only 230 N is enough to keep it moving at a constant velocity. Making use of a free-body diagram and a Cartesian axis system determine the values of the coefficients of static and kinetic frictions. Assume flat horizontal floor.

Tension and Balancing Forces

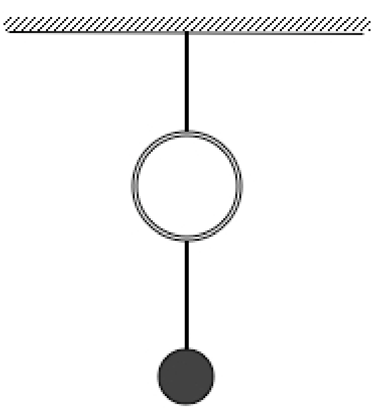


Figure 5.54: Exercise 5.7.25.

Ex 5.7.25. A 250-gram copper ring is hung from the ceiling using a light string. Then a 500-gram steel ball is hung from the ring using another light string (Fig. 5.54). (a) Draw a diagram showing with symbols and arrows all the forces acting on the ring. Label forces in your diagram with standard notation. (b) Draw a diagram showing with symbols and arrows all the forces acting on the ball. Label forces in your diagram with standard notation. (c) Choose a Cartesian coordinate system, and determine the relations between components of forces on the ring. (d) Choose a Cartesian coordinate system, and determine the relations between components of forces on the ball. (e) Find the magnitude of all the forces on the ring and on the ball in terms of the masses of the ring and the ball and the acceleration due to gravity, g.

Ex 5.7.26. Two 1-kg blocks, A and B, are hung on the two sides of a pulley by using a light string. The pulley is then hung from a support in the ceiling. Once hung, the blocks remain motionless. (a) Draw a diagram showing with symbols and arrows all the forces acting on the block A. (b) Draw a diagram showing with symbols and arrows all the forces acting on the block B. (c) Draw a diagram showing with symbols and arrows all the forces acting on the pulley. (d) Find magnitudes and directions of all forces on the blocks and the pulley.

Assumptions: The pulley is considerably lighter than 1 kg and can be assumed to be massless. The pulley can also freely rotate about an axle so that the you can assume no friction when pulley rotates. This type of pulley is often referred to as a "massless and frictionless" or and an "ideal" pulley. The tensions in the strings on the two sides of a "massless and frictionless" pulley are equal.

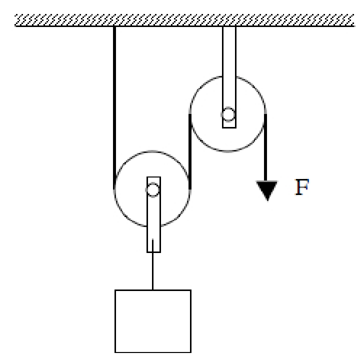


Figure 5.55: Exercise 5.7.27.

Ex 5.7.27. A large crate of mass M is lifted by pulling with a force F on a string that goes over two "massless frictionless" pulleys as shown in Fig. 5.55. You can read more about "massless and frictionless" pulley in Exercise 5.7.26. Label the pulleys as 1 and 2, where 1 is the one with the crate attached to it. (a) Draw a diagram showing with symbols and arrows all the forces acting on the pulley # 1. (b) Draw a diagram showing with symbols and arrows all the forces acting on the pulley # 2. (c) Draw a diagram showing with symbols and arrows all the forces acting on the crate. (d) Find the magnitude of the force F in terms of M and g if the crate moves up with a constant velocity using the fact that forces on an object are balanced if the velocity of the object is constant.

Explore further:

(e) Suppose, you were using only one pulley to pull the crate up. Show the arrangement, and prove that it would require more force than the two pulley system shown in this problem. (f) How many pulleys will you need and how would you arrange them so that you would need to apply only $\frac{1}{4}Mg$ for pulling the crate up at constant velocity? (g) Can you generalize the arrangement so that you would need only $\frac{1}{n}Mg$ for any n? Does your arrangement depend upon n being even or odd?

Ex 5.7.28. A porter is pulling a 50-kg box on a flat surface by tying the box with a rope (Fig. 5.56). The box is sliding on a relatively smooth floor at a constant velocity. Note that forces are balanced when an object is moving with a constant velocity. The coefficient of kinetic friction between the contact surface of the box and the floor

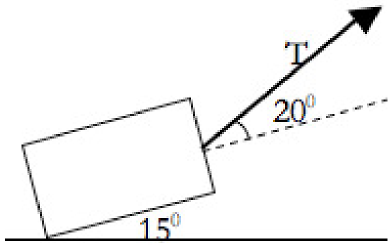


Figure 5.56: Exercise 5.7.28.

is 0.1. (a)Draw a free-body diagram of the forces on the box, and choose a coordinate system to help with balancing forces on the box to answer the following questions. (b) What is the magnitude of the tension force in the rope? (c) What is the direction of the tension force when it acts on the box? (d) What is the direction of the tension force when it acts on the porter? (e) What should be the magnitude of the least static friction force on the porter from the floor so that he does not slide? What would be the direction of this static friction force?

Spring Force and Balancing Forces

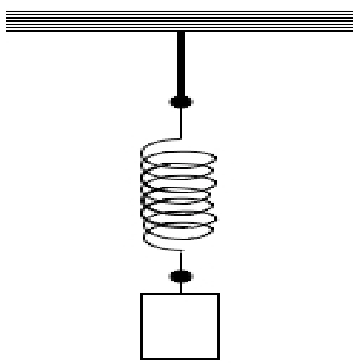


Figure 5.57: Exercise 5.7.29.

Ex 5.7.29. A 2-kg brass block is attached at the end of a spring of length 30 cm and spring constant 1000 N/m. The end of the spring is attached to an "unstretchable" string of length 25 cm. The string is then tied to a support in the ceiling so that the brass block hangs at rest (Fig, 5.57). (a) Draw a free-body diagram of forces on the brass block. (b) Draw a free-body diagram of the forces on the spring. (c) Draw a free-body diagram of forces on the string. (d) Find the magnitude and direction of all the forces you have included in (a), (b) and (c). (e) By how much does the spring stretch?

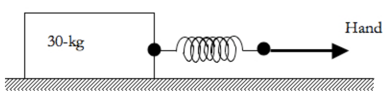


Figure 5.58: Exercise 5.7.30.

Ex 5.7.30. A 30-kg box on a smooth floor is attached to a spring and pulled horizontally (Fig. 5.58) by increasing force until the point when the box starts to slide. The length of the spring when unstretched is 20 cm. The spring constant has a value of 100 N/cm. The coefficient of static friction between the bottom of the box and the floor surface has been determined to be 0.2. (a) Draw a free-body diagram of the forces on the box. (b) Draw a free-body diagram of the forces on the spring. (c) Choose a coordinate system and work with components of forces to find out the magnitude of the maximum force that can be applied to the spring so that the box before the box starts to slide. (d) At the instant when the static friction is maximum, what is the length of the spring?

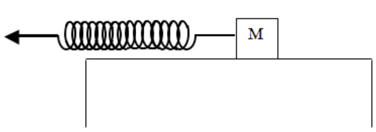
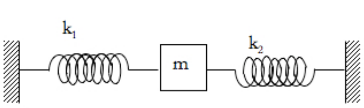


Figure 5.59: Exercise 5.7.31.

Ex 5.7.31. A block of mass m is attached to a stiff spring of spring constant k. The block is put on a rough surface so that the coefficient of static friction between the block and surface is μ_s (Fig. 5.59). The other end of the spring is then pulled with increasing force. Find the stretch of the spring in terms of m, k, μ_s, and g when the block just starts to slide.



Ex 5.7.32. A block of mass m is attached to two springs of spring constants k_1 and k_2 (Fig. 5.60). The other ends of the springs are attached to fixed walls. The mass is in the middle when neither of

the springs are stretched or compressed. The block is pulled to the right by a distance Δx and held there by a person. (a) Draw free-body diagram of the block. Do not forget to include the force by the person. (b) Use a coordinate system to write out the balanced force condition for the block. (c) Determine the magnitude and direction of the force on the block by the person.

Calculating Torque

Ex 5.7.33. Find the torque vectors on a rod from the forces shown in the figure about pivot points (a) O_1 and (b) O_2. All forces have magnitude 100 N and $L = 1$ m.

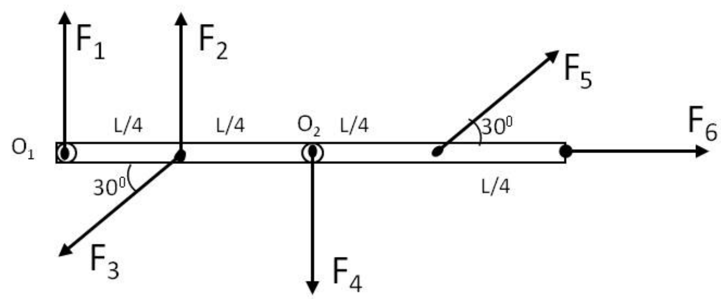


Figure 5.61: Exercise 5.7.33.

Ex 5.7.34. Find the torque vector on a wheel of radius R rolling down an incline about the pivot points (a) O_1 and (b) O_2. Give your answer in terms of the forces shown, the radius of the wheel, and the angle of inclination. Note your answer will be a vector.

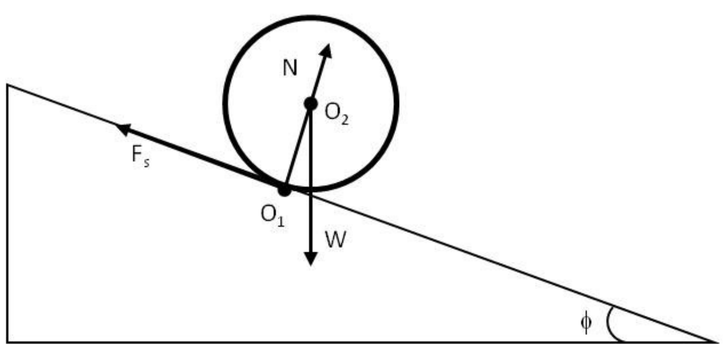


Figure 5.62: Exercise 5.7.34.

Ex 5.7.35. A wheel of radius R is rotated by applying two force that are applied at two different points at the rim of the wheel as shown in the figure. The two forces are pointed in the opposite direction but have equal magnitude. The two forces are said to form a **couple**.

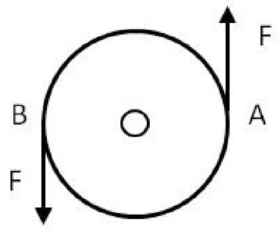


Figure 5.63: Exercise 5.7.35.

Evaluate the net torque on the wheel about (a) the center, (b) A, and (c) B.

Static Equilibrium: Balancing Forces and Torques

Ex 5.7.36. A beam of mass M is placed on a support. When the support is in the middle of the beam, the beam remains in a horizontal position without any motion. What are the forces on the beam and where do the forces act on the beam?

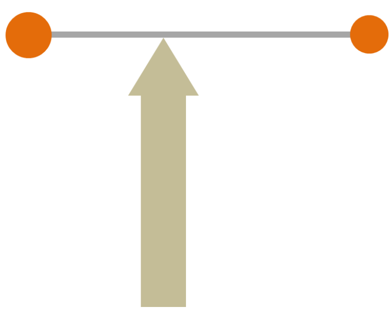


Figure 5.64: Exercise 5.7.37.

Ex 5.7.37. A baton of length L has two different blocks attached on the two ends. Assume the masses of the blocks to be m_1 and m_2. When the baton is placed on a pointed support, it rests horizontally without tipping over. (a) What are the forces on the beam and where do the forces act on the beam? (b) Where is the location of the special point relative to the end with mass m_1 where baton should be placed on the support?

Ex 5.7.38. A diving board of mass 100 kg and length 4 m is bolted at one end and resting on another support at a distance one meter from the bolted end. A diver of mass 50 kg is standing at the other end of the board. (a) Draw a diagram showing all the forces (in symbols) acting on the board, their directions and where they act on the board. For the force from the bolt, use two forces, a horizontal force and a vertical force from the bolt. (b) Use a coordinate system and generate the equations of equilibrium for forces and torques. (c) Determine the force on the board by the bolt. (d) Determine the force on the board from the other support.

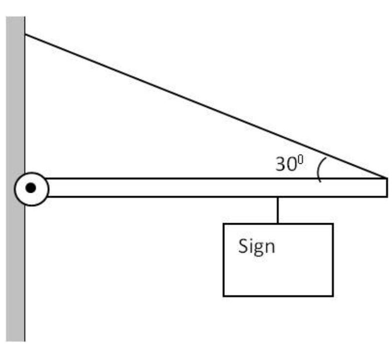


Figure 5.65: Exercise 5.7.39.

Ex 5.7.39. A sign of mass 300 kg is hanging 1 m from the end of a horizontal beam of mass 50 kg and length 3 m held in place by a pin and a cable as shown in the Fig. 5.65. The cable makes an angle of 30° with the beam. (a) Draw a diagram showing all the forces on the beam (using symbols), their directions and where they act on the beam. (b) Choose a Cartesian coordinate system and find the relations among the components for a balanced force condition on the beam. (c) Find the relation between the lever arms and the forces for a balanced torque condition. (d) Use your results to determine the magnitude of the tension in the cable. (e) Find the magnitude and direction of the total force applied by the pin on the beam.

Ex 5.7.40. A board of mass M and length L is supported by two vertical cables on the two ends. A painter of mass m is at the distance L_1 from the left end of the board. (a) Draw a diagram showing (in symbols) all the forces on the board, their directions and where on the board they act. Note: the tensions in the cables may be different. (b) Use the equations for the balanced forces and the balanced torques to determine the magnitudes of all forces in terms of M, m, L, L_1 and g.

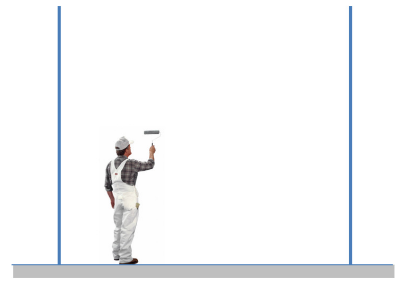
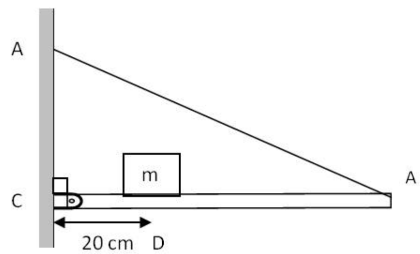


Figure 5.66: Exercise 5.7.40.

Ex 5.7.41. A steel cable AB of of length 90 cm supports a beam CB of mass 2 kg and length 60 cm hinged at C as shown in the Fig. **??**. Assuming the length of the cable to be 65 cm, find the tension in the cable and the force on the pin if mass $m = 200$ kg.



Ex 5.7.42. A rod AB of mass 30-kg and length 1 meter is supported by a pin at A and rests on a frictionless peg at C at a distance of 70 cm from A. A force of 1000 N is applied at B as shown. Find the forces on the rod at A and C.

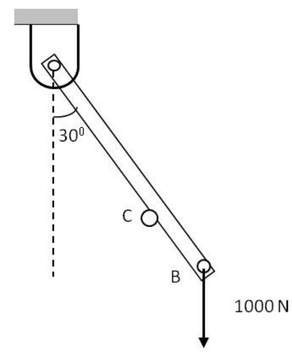


Figure 5.67: Problem 5.7.42.