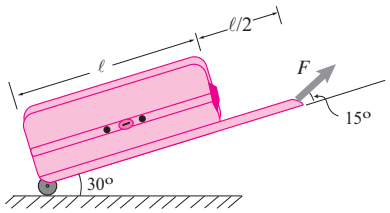
7.2 Levers, Wedges, Toggles, Gears and Pulleys

7.2.1 A suitcase with bad wheels has length $\ell = 0.5\,\text{m}$ and thickness (height) of $\ell = 0.25\,\text{m}$ is pulled along steadily with a force $F = 100\,\text{N}$ as shown in the figure.

a) Find the weight W of the suitcase.

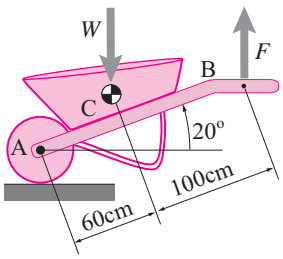
b) Find the ground force on the wheel (both magnitude and direction).

c) What is force amplification if you consider F as the input and W as the output.



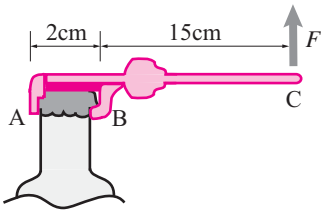
Problem 7.2.1

7.2.2 A wheelbarrow containing 100 kg of this-n-that is wheeled steadily with a force F as shown in the figure. For the given geometry and $g \approx 10\,\text{m/s}^2$, find the required force F.



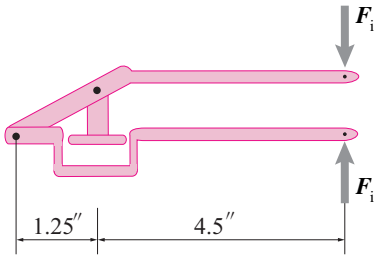
Problem 7.2.2

7.2.3 A bottle-opener ABC contains a cut-out AB of approximate diameter 2 cm that clamps on the bottle cap. The arm BC is approximately 15 cm long. If the cap is opened by applying a vertical force $F = 10\,\text{N}$ at C, find the force on the cap at B.



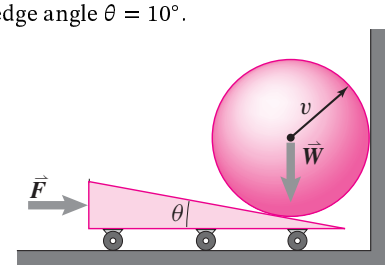
Problem 7.2.3

7.2.4 A cut-out view of a garlic press is shown in the figure. For an input force $F_i = 10\,\text{lbf}$, find the output force F_o at the site of the press. What is the force amplification?



Problem 7.2.4

7.2.5 Assuming all frictionless contacts, find the force F on the wedge required to lift the sphere weighing 500 N if the wedge angle $\theta = 10°$.

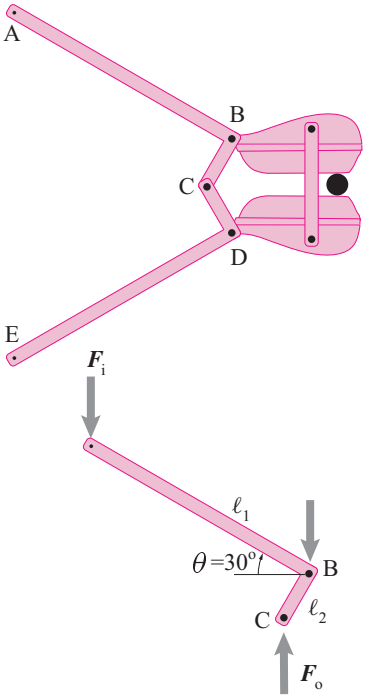


Problem 7.2.5

7.2.6 A cutter, shown in the figure, uses a toggle mechanism BCD to get a big force amplification at the cutting edge. A partial free-body diagram of one of the arms of the cutter is shown in the figure. Assuming an input force of $F_i = 20\,\text{N}$ at A, find the intermediate output force F_o at C when

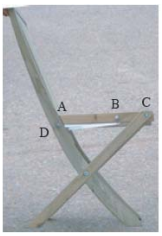
a) $\theta = 30°$,

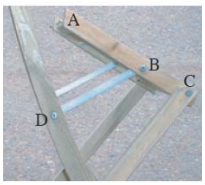
b) $\theta = 10°$.

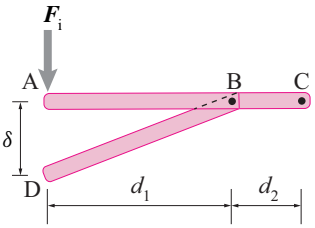


Problem 7.2.6

7.2.7 A toggle-like mechanism is used in a folding chair shown in the pictures here. The metallic link DB gets almost parallel to the seating plank AC when the chair is open. Given the dimensions $d_1 = 30\,\text{cm}, d_2 = 10\,\text{cm}, \delta = 2\,\text{cm}$ and the force at A, $F_i = 500\,\text{N}$, find the force in the link DB. Why is this force so big or small? In practice why would you never see such a large force? *



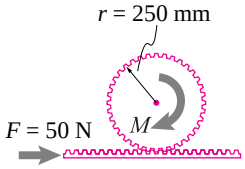




Problem 7.2.7

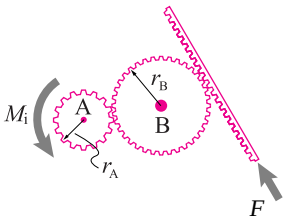
7.2.8 A gear of radius 250 mm is meshed in with a rack that carries a horizontal

load $F = 50$ N. Find the torque M on the gear that is required for equilibrium.



Problem 7.2.8

7.2.9 The input gear A of radius $r_A = 10$ cm drives gear B that is one and a half times bigger than gear A. Gear B, in turn, drives a rack. If the input torque on gear A is $M_i = 30$ N·m, find the load F on the rack.

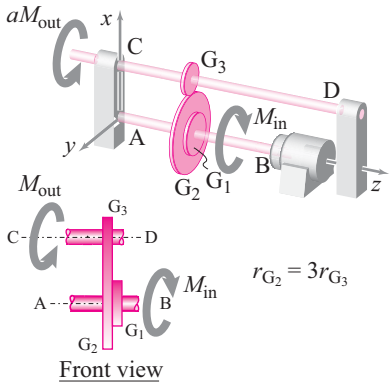


Problem 7.2.9

7.2.10 In the gear arrangement shown, gears G_1 and G_2 are welded together. The output gear G_3 is one third the size of gear G_2.

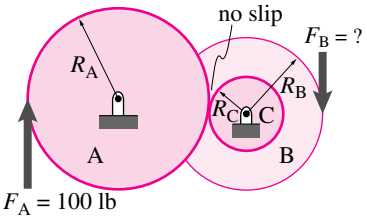
a) Is this gear train for torque amplification or for torque reduction?

b) If the input torque M_{in} on gear G_1 is 300 N·m, find the output torque M_{out}.



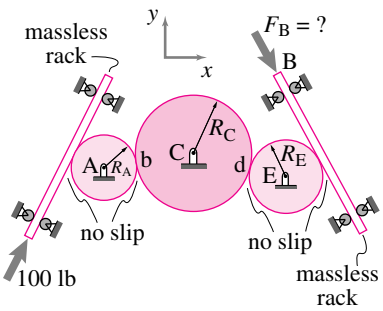
Problem 7.2.10

7.2.11 At the input to a gear box, a 100 lbf force is applied to gear A. At the output, the machinery (not shown) applies a force of F_B to the output gear. Assume the system of gears is at rest. What is F_B?



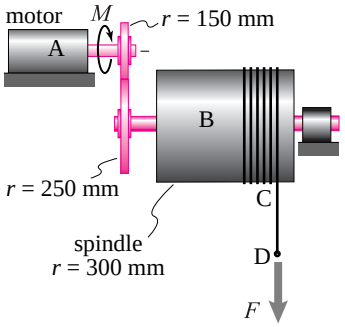
Problem 7.2.11

7.2.12 A 100 lbf force is applied to one rack. At the output, the machinery (not shown) applies a force of F_B to the other rack. Assume the gear-train is at rest. What is F_B?



Problem 7.2.12

7.2.13 The gear train and spindle shown in the figure are used for hoisting heavy loads. For the dimensions given, if the load $F = 2$ kN, find the torque M that the motor A must apply for equilibrium.



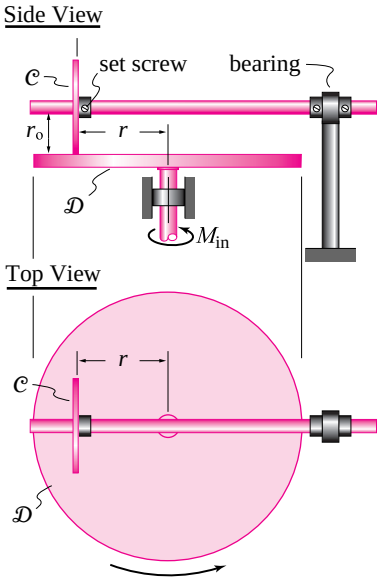
Problem 7.2.13

7.2.14 The figure shows a brush gear (also called a crown wheel) where wheel $\mathcal{C}$ of radius r_o, rolls on the surface of wheel $\mathcal{D}$ without slipping. In addition, the position r of wheel $\mathcal{C}$ from the center of wheel D can be varied. Let the input torque on wheel $\mathcal{D}$ be M_i.

a) Find the output torque M_o on wheel $\mathcal{C}$ as a function of r.

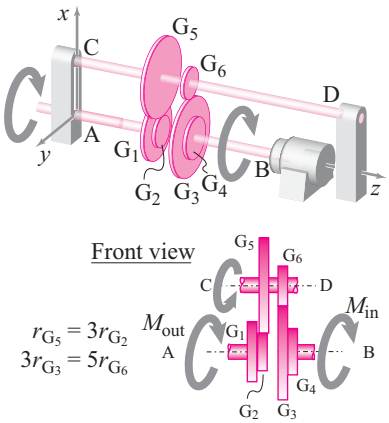
b) Find the output torque M_o when $r = r_o$ and when $r = r_o/4$.

c) If the output torque were not to exceed 100 times the input torque, where will you put safety latches on the axle of wheel $\mathcal{C}$?



Problem 7.2.14

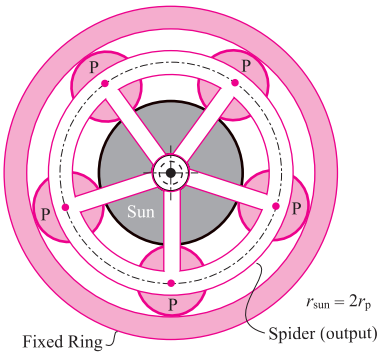
7.2.15 For the gear train shown in the figure, find the torque amplification M_{out}/M_{in}.



Problem 7.2.15

7.2.16 A torque amplifying planetary gear is shown in the figure where the sun-gear is free to rotate but the ring-gear is fixed. The sun-gear drives five planet-gears that drive the spider-gear through

their axles housed in bearings in the spider. The radius of the planet-gears r_p = 50 mm and the radius of the sun-gear is twice as big. If the input torque on the sun-gear is 2000 N·m, find the output torque on the spider.

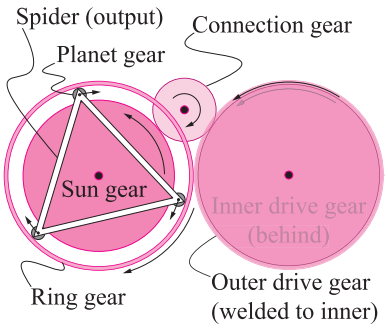


Problem 7.2.16

7.2.17 Consider the high gear ratio planetary gear discussed on page 406 of the text. Let r_{D_i} and r_{D_o} be the inner and outer radii, respectively, of the drive gear, and r_{R_i} and r_{R_o} be the inner and outer radii, respectively, of the ring-gear. Let r_s and r_p denote the radii of the sun and the planet-gear respectively. Show that the ratio of the output torque M_{out} on the spider-gear to the input torque M_{in} on the drive gear is approximately given by

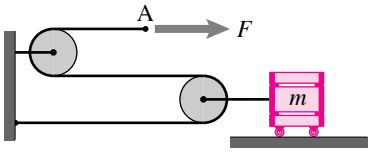
$$\frac{M_{\text{out}}}{M_{\text{in}}} \approx \frac{2}{\frac{R_D}{R_R} - 1}$$

where $R_D = r_{D_i}/r_{D_o}$ and $R_R = r_{R_i}/r_{R_o}$.



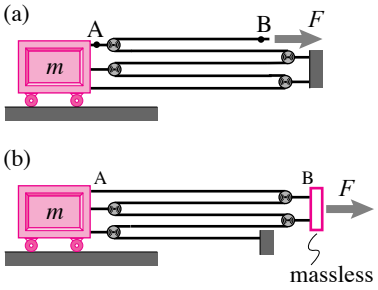
Problem 7.2.17

7.2.18 A force F = 100 N acts at A. The pulleys are frictionless. Find the force on the box applied by the pulley. *



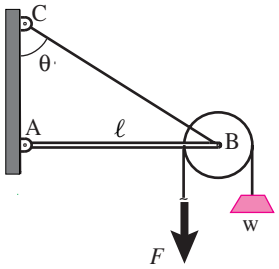
Problem 7.2.18

7.2.19 A force F is applied as shown in the pulley arrangements shown in (a) and (b). Which arrangement gives a bigger force amplification on the box?



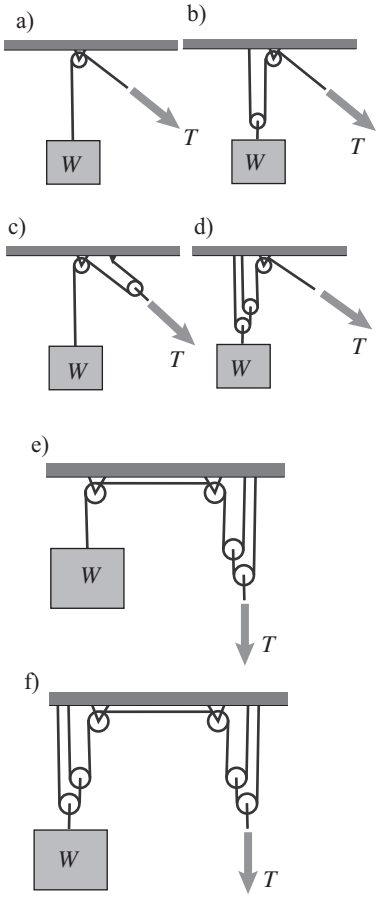
Problem 7.2.19

7.2.20 A weight W is held in place with a force F = 100 N applied through a massless pulley as shown in the figure. The pulley is attached to a rod AB which, in turn, is held horizontal with the help of a string CB. Find the tension (or compression) in rod AB.



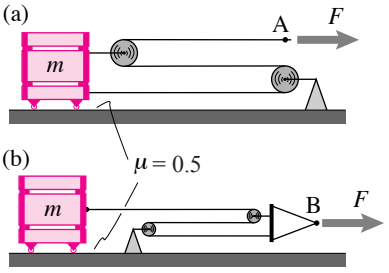
Problem 7.2.20

7.2.21 Given W and the frictionless pulleys shown find the tension T needed to lift the weight in the situations shown.



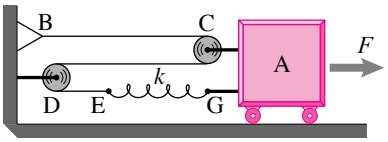
Problem 7.2.21

7.2.22 In the two cases shown in (a) and (b), find the maximum force F that can be applied before the box starts skidding on the ground. Take m = 50 kg and $g \approx 10\,\text{m/s}^2$. Which arrangement requires smaller force and why?



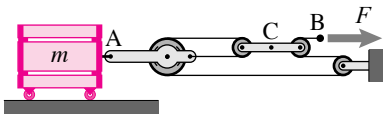
Problem 7.2.22

7.2.23 The pulley arrangement shown in the figure uses a spring EG of stiffness k = 200 N/cm. If the spring is stretched by 1.5 cm under the application of force F for equilibrium, find F.

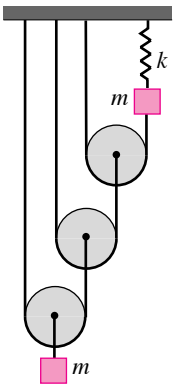


Problem 7.2.23

7.2.24 Find the force on the mass at A in terms of F and thus find the force amplification provided by the pulley arrangement used.

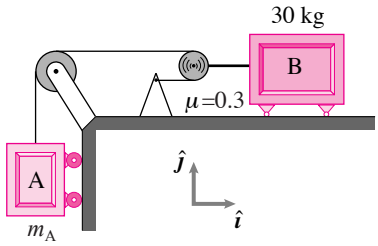


Problem 7.2.24



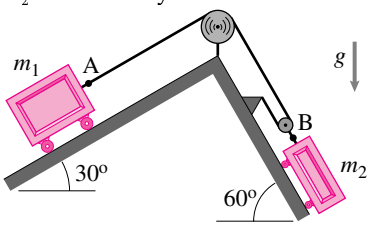
Problem 7.2.27

7.2.25 In the figure shown, there is no friction between block A and the vertical wall but there is friction ($\mu = 0.3$) between block B and the floor. If $m_B = 30$ kg, find the mass of block A for equilibrium.



Problem 7.2.25

7.2.26 Find the ratio of the masses m_1 and m_2 so that the system is at rest.



Problem 7.2.26

7.2.27 If the mass and pulley system shown in the figure is in equilibrium when the spring is stretched by 3 cm, find m, given $k = 500$ N/m and $g \approx 10$ m/s^2.