

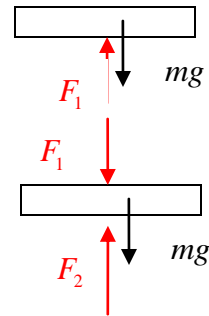
**0-1-1 [US]** Two thermodynamics books, each with a mass of 1 kg, are stacked one on top of another. Neglecting the presence of atmosphere, draw the free body diagram of the book at the bottom to determine the vertical force on its (a) top and (b) bottom faces in kN.

### SOLUTION

(a) From the free body diagram of the book at the top, a vertical force balance produces:

$$F_1 = \frac{mg}{1000} \quad \left[ \text{kg} \frac{\text{m}}{\text{s}^2} \frac{\text{kN}}{\text{N}} = \text{kN} \right]$$

$$\Rightarrow F_1 = \frac{(1)(9.81)}{1000} = 0.00981 \text{ kN}$$



(b) Using the free body diagram of the book at the bottom,

$$F_2 = F_1 + \frac{mg}{1000} \quad [\text{kN}]$$

$$\Rightarrow F_2 = 0.00981 + \frac{(1)(9.81)}{1000} = 0.01962 \text{ kN}$$

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**0-1-2 [UA]** Determine (a) the pressure felt on your palm to hold a textbook of mass 1 kg in equilibrium. Assume the distribution of pressure over the palm to be uniform and the area of contact to be 25 cm<sup>2</sup>. (b) **What-if Scenario:** How would a change in atmospheric pressure affect your answer (0: No change; 1: increase; -1 decrease)?

**SOLUTION**

$$(a) \quad p = \frac{F}{A}; \quad \left[ \frac{\text{kN}}{\text{m}^2} = \text{kPa} \right]$$

$$\Rightarrow p = \frac{mg}{1000A}; \quad \Rightarrow p = \frac{(1)(9.81)}{(1000)(0.0025)};$$

$$\Rightarrow p = 3.924 \text{ kPa}$$

(b) A change in atmospheric pressure would not affect the answer because the net force created by a uniform pressure around any object is zero. Answer: 0

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**0-1-3 [UH]** The lift-off mass of a Space Shuttle is 2 million kg. If the lift off thrust (the net force upward) is 10% greater than the minimum amount required for a lift-off, determine the acceleration.

**SOLUTION**

$$F_{\text{thrust}} - F_{\text{gravity}} = ma;$$

$$1.1mg - mg = ma; \Rightarrow a = 0.1g;$$

$$\Rightarrow a = (0.1)(9.81);$$

$$\Rightarrow a = 0.981 \frac{\text{m}}{\text{s}^2}$$

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**0-1-4 [UF]** A body weighs 0.05 kN on earth where  $g = 9.81 \text{ m/s}^2$ . Determine its weight on (a) the moon, and (b) on mars with  $g = 1.67 \text{ m/s}^2$  and  $g = 3.92 \text{ m/s}^2$ , respectively.

**SOLUTION**

$$m = \frac{w}{g}; \quad \Rightarrow m = \frac{0.05 \times 1000}{9.81}; \quad \Rightarrow m = 5.097 \text{ kg};$$

$$(a) \text{ On the moon: } w = \frac{(5.097)(1.67)}{1000}; \quad \Rightarrow w = 0.008512 \text{ kN}$$

$$(b) \text{ On Mars: } w = \frac{(5.097)(3.92)}{1000}; \quad \Rightarrow w = 0.01998 \text{ kN}$$

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**0-1-5 [UD]** Calculate the weight of an object of mass 50 kg at the bottom and top of a mountain with (a)  $g = 9.8 \text{ m/s}^2$  and (b)  $g = 9.78 \text{ m/s}^2$  respectively.

**SOLUTION**

$$(a) \quad w = \frac{mg}{1000}; \quad \Rightarrow w = \frac{(50)(9.8)}{1000}; \quad \Rightarrow w = 0.49 \text{ kN}$$

$$(b) \quad w = \frac{(50)(9.78)}{1000}; \quad \Rightarrow w = 0.489 \text{ kN}$$

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**0-1-6 [UM]** According to Newton's law of gravity, the value of  $g$  at a given location is inversely proportional to the square of the distance of the location from the center of the earth. Determine the weight of a textbook of mass 1 kg at (a) sea level and (b) in an airplane cruising at an altitude of 45,000 ft. Assume earth to be a sphere of diameter 12,756 km.

### SOLUTION

(a) At sea level

$$w_0 = \frac{GmM}{R^2} = g_0 m;$$

$$\Rightarrow w_0 = (9.81)(1);$$

$$\Rightarrow w_0 = \mathbf{9.81 \text{ N}}$$

(b) At  $h = 45,000 \text{ ft} \times 0.3048(10)^{-3} \frac{\text{km}}{\text{ft}} = 13.716 \text{ km}$

$$w = \frac{GmM}{(R+h)^2}; \quad \Rightarrow w = \frac{GmM}{R^2} \frac{R^2}{(R+h)^2}; \quad \Rightarrow w = g_0 \frac{R^2}{(R+h)^2} m; \quad \Rightarrow w = gm;$$

$$\Rightarrow g = \frac{\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(6,378 \text{ km})^2}{(6,378 \text{ km} + 13.716 \text{ km})^2}; \quad \Rightarrow g = 9.76 \frac{\text{m}}{\text{s}^2};$$

$$\Rightarrow w = (9.767)(1);$$

$$\Rightarrow w = \mathbf{9.76 \text{ N}}$$

**0-1-7 [UJ]** The frictional force on a block of mass  $m_A$  resting on a table (see accompanying figure) is given as  $F = \mu N$ , where  $N$  is the normal reaction force from the table. Determine the maximum value for  $m_B$  that can be supported by friction. Assume the pulley to be frictionless.

### SOLUTION

The maximum value of  $m_B$  that can be supported by the friction:

$$F_A = \frac{\mu m_A g}{1000}; \quad [\text{kN}]$$

$$F_B = \frac{m_B g}{1000}; \quad [\text{kN}]$$

$$F_A = F_B;$$

$$\Rightarrow \mu m_A g = m_B g;$$

$$\Rightarrow m_B = \mu m_A$$

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**0-1-8 [UW]** If the block A in problem 0-1-7 [UJ] sits on a wedge with an angle  $\theta$  with the horizontal, how would the answer change?

### SOLUTION

The normal force on the block is:  $N = \frac{m_A g \cos \theta}{1000}$ ; [kN]

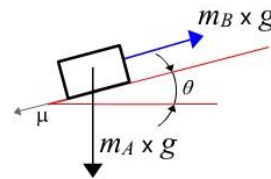
A balance between the tension in the string and friction produces:

The normal force on t

$$\frac{\mu m_A g \cos \theta}{1000} = \frac{m_B g}{1000};$$

$$\Rightarrow \mu m_A g \cos \theta = m_B g;$$

$$\Rightarrow m_B = \mu m_A \cos \theta$$



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**0-1-9 [XR]** A block with a mass of 10 kg is at rest on a plane inclined at  $25^\circ$  to the horizontal. If  $\mu_s = 0.6$ , determine the range of the horizontal push force  $F$  if the block is (a) about to slide down, and (b) about to slide up.

**SOLUTION**

- (a) As the block is about to slide down, friction acts upward and a force balance along the slope yields:

$$F \cos \theta + \mu_s (mg \cos \theta + F \sin \theta) = \frac{mg \sin \theta}{1000};$$

$$\Rightarrow F (\cos \theta + \mu_s \sin \theta) = \frac{mg (\sin \theta - \mu_s \cos \theta)}{1000};$$

$$\Rightarrow F = \frac{mg (\sin \theta - \mu_s \cos \theta)}{1000 (\cos \theta + \mu_s \sin \theta)};$$

$$\Rightarrow F = \frac{(10)(9.81)(\sin 25^\circ - 0.6 \cos 25^\circ)}{(1000)(\cos 25^\circ + 0.6 \sin 25^\circ)};$$

$$\Rightarrow F = -0.010248 \text{ kN}$$

The negative sign indicates that a slight pull force is necessary to overcome friction for the block to slide down.

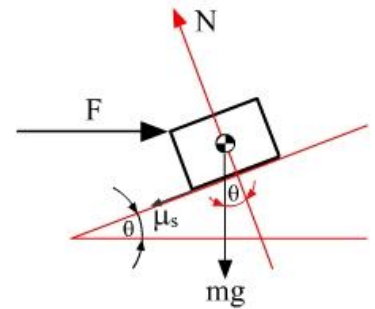
- (b) As the block is about to slide up, friction acts downward and a force balance along the slope yields:

$$F \cos \theta = \frac{\mu_s (mg \cos \theta + F \sin \theta) + mg \sin \theta}{1000};$$

$$\Rightarrow F (\cos \theta - \mu_s \sin \theta) = \frac{mg (\mu_s \cos \theta + \sin \theta)}{1000}; \Rightarrow F = \frac{mg (\mu_s \cos \theta + \sin \theta)}{1000 (\cos \theta - \mu_s \sin \theta)}$$

$$\Rightarrow F = \frac{(10)(9.81)(0.6 \cos 25^\circ + \sin 25^\circ)}{(1000)(\cos 25^\circ - 0.6 \sin 25^\circ)};$$

$$\Rightarrow F = 0.1452 \text{ kN}$$



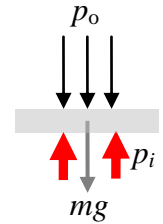
**0-1-10 [XO]** A vertical piston cylinder device contains a gas at an unknown pressure. If the outside pressure is 100 kPa, determine (a) the pressure of the gas if the piston has an area of 0.2 m<sup>2</sup> and a mass of 20 kg. Assume  $g = 9.81 \text{ m/s}^2$ . (b) **What-if Scenario:** What would the pressure be if the orientation of the device were changed and it were now upside down?

### SOLUTION

$$\begin{aligned} \text{(a)} \quad p_i A_{\text{piston}} &= p_0 A_{\text{piston}} + \frac{m_{\text{piston}} g}{1000}; \\ \Rightarrow p_i &= p_0 + \frac{m_{\text{piston}} g}{(1000) A_{\text{piston}}}; \\ \Rightarrow p_i &= 100 + \frac{(20)(9.81)}{(1000)(0.2)}; \\ \Rightarrow p_i &= \mathbf{100.981 \text{ kPa}} \end{aligned}$$

$$\left[ \text{kPa} \cdot \text{m}^2 = \text{kg} \frac{\text{m}}{\text{s}^2} \frac{\text{kN}}{\text{N}} = \text{kN} \right]$$

$$\left[ \text{kPa} = \frac{\text{kN}}{\text{m}^2} = \text{kg} \frac{\text{m}}{\text{s}^2} \frac{\text{kN}}{\text{N}} \frac{1}{\text{m}^2} \right]$$



$$\text{(b)} \quad p_i A_{\text{piston}} + \frac{m_{\text{piston}} g}{1000} = p_0 A_{\text{piston}};$$

$$\left[ \text{kPa} \cdot \text{m}^2 = \text{kg} \frac{\text{m}}{\text{s}^2} \frac{\text{kN}}{\text{N}} = \text{kN} \right]$$

$$\Rightarrow p_i = p_0 - \frac{m_{\text{piston}} g}{(1000) A_{\text{piston}}};$$

$$\Rightarrow p_i = 100 - \frac{(20)(9.81)}{(1000)(0.2)};$$

$$\Rightarrow p_i = \mathbf{99.019 \text{ kPa}}$$