Department of Mechanical Engineering (NITC)

S1ME **ZZ1001D ENGINEERING MECHANICS** **Tutorial Test 4-Set3**

Time: One Hour **Answer Key** Maximum Marks: 20

1. Find the supporting forces at *A* and *B* (Fig. 1). At *D* there is a cylinder weighing 300 N.

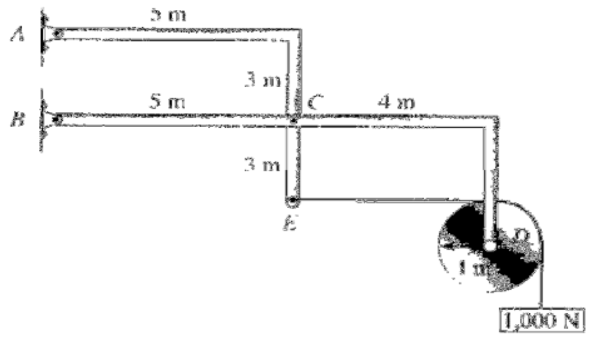
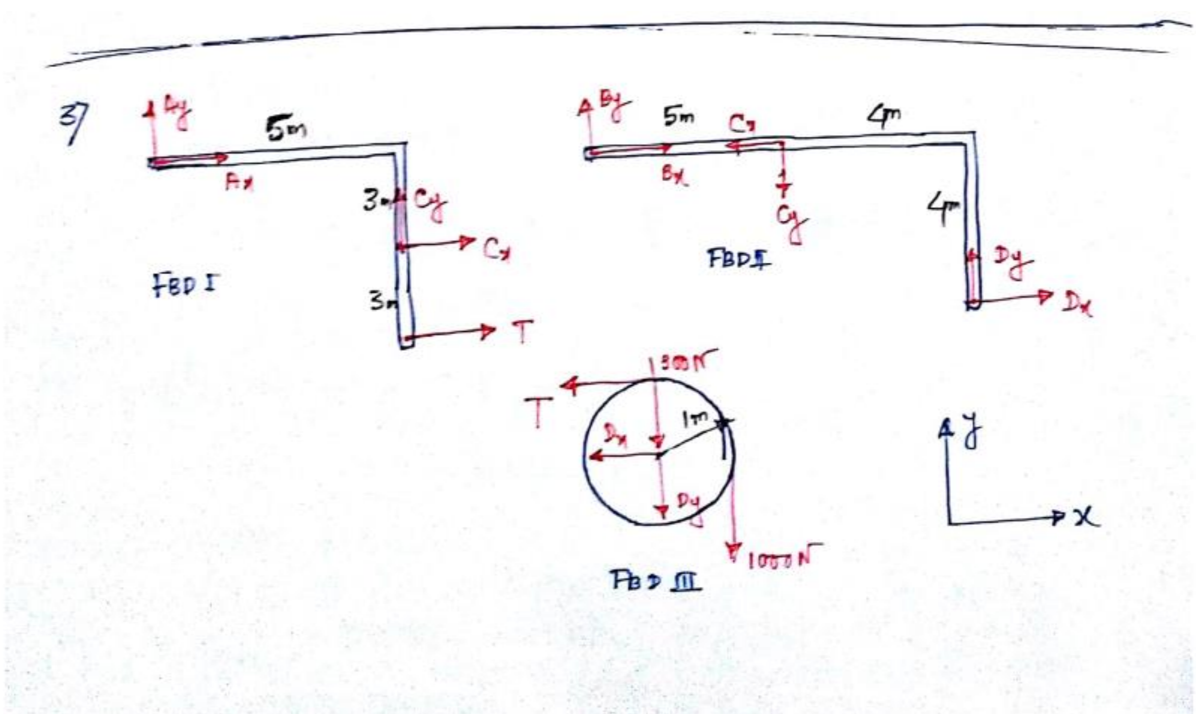


Figure 1

Solution:



FBD III : $\Sigma M_D = 0, \Rightarrow T(1) = 1000(1) \Rightarrow T = 1000\ N$

$\Sigma F_x = 0 \Rightarrow D_x = -T = -1000\ N$

$\Sigma F_y = 0 \Rightarrow D_y = -1300\ N$

FBD I: $\Sigma M_A = 0 \Rightarrow 6T + 3C_x + 5C_y = 0$

$\Rightarrow 3C_x + 5C_y = -6000\ N \quad (i)$

FBD II: $\Sigma M_B = 0 \Rightarrow 4D_x + 9D_y - 5C_y = 0$

$\Rightarrow 5C_y = 4(-1000) + 9(-1300)$

$\Rightarrow C_y = -3140\ N$

$(i) \Rightarrow C_x = \frac{1}{3}(-6000 + 5 \times 3140) = 3233.33\ N$

FBD I: $\Sigma F_x = 0 \Rightarrow A_x + C_x + T = 0$

$\Rightarrow A_x = -(3233.33 + 1000) = \underline{\underline{-4233.33\ N}}$

$\Sigma F_y = 0 \Rightarrow A_y = -C_y = \underline{\underline{3140\ N}}$

FBD II: $\Sigma F_x = 0 \Rightarrow B_x - C_x + D_x = 0$

$\Rightarrow B_x = C_x - D_x = 3233.33 - (-1000)$

$\Rightarrow B_x = \underline{\underline{4233.33\ N}}$

$\Sigma F_y = 0 \Rightarrow B_y = C_y - D_y = -3140 - (-1300)$

$\Rightarrow B_y = \underline{\underline{-1840\ N}}$

2. The member shown in Fig. 2 is pin-connected at *A* and rests against a smooth support at *B*. Determine the horizontal and vertical components of reaction at the pin *A*.

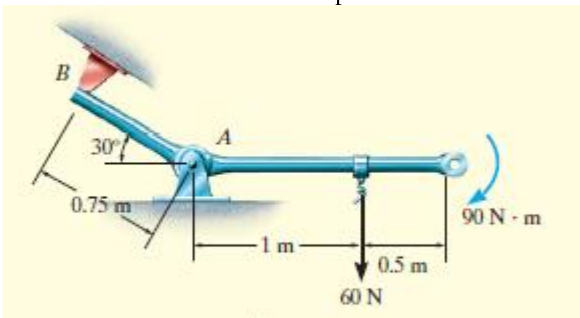


Figure 2

Solution:

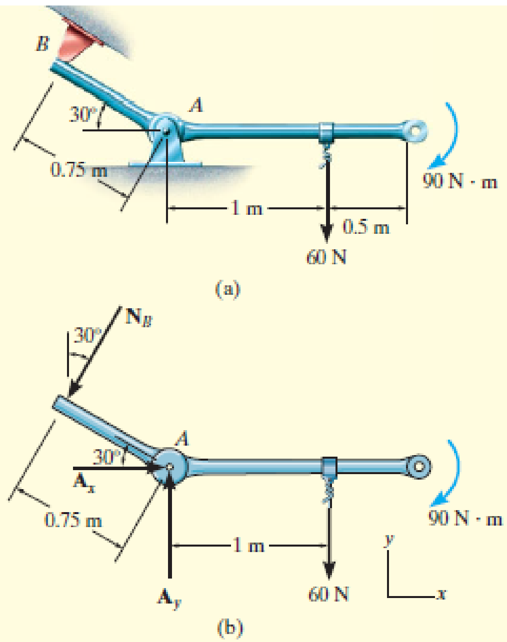


Fig. 5–14

SOLUTION

Free-Body Diagram. As shown in Fig. 5–14*b*, the reaction $\mathbf{N}_B$ is perpendicular to the member at *B*. Also, horizontal and vertical components of reaction are represented at *A*.

Equations of Equilibrium. Summing moments about *A*, we obtain a direct solution for N_B,

$$\zeta + \Sigma M_A = 0; \quad -90\text{ N}\cdot\text{m} - 60\text{ N}(1\text{ m}) + N_B(0.75\text{ m}) = 0$$

$$N_B = 200\text{ N}$$

Using this result,

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad A_x - 200 \sin 30^\circ\text{ N} = 0$$

$$A_x = 100\text{ N} \qquad \textit{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \qquad A_y - 200 \cos 30^\circ\text{ N} - 60\text{ N} = 0$$

$$A_y = 233\text{ N} \qquad \textit{Ans.}$$

3. The box wrench in Fig. 3 is used to tighten the bolt at *A*. If the wrench does not turn when the load is applied to the handle, determine the torque or moment applied to the bolt and the force of the wrench on the bolt.

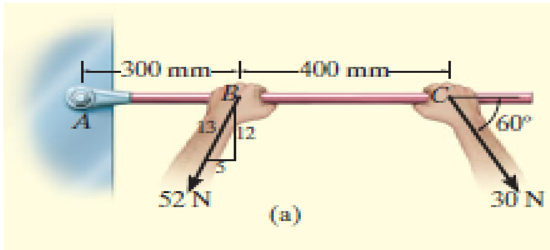


Figure 3

Solution:

SOLUTION

Free-Body Diagram. The free-body diagram for the wrench is shown in Fig. 5–15*b*. Since the bolt acts as a "fixed support," it exerts force components $\mathbf{A}_x$ and $\mathbf{A}_y$ and a moment $\mathbf{M}_A$ on the wrench at *A*.

Equations of Equilibrium.

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad A_x - 52\left(\tfrac{5}{13}\right)\text{N} + 30\cos 60^\circ\ \text{N} = 0$$

$$A_x = 5.00\ \text{N} \qquad \textit{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \qquad A_y - 52\left(\tfrac{12}{13}\right)\text{N} - 30\sin 60^\circ\ \text{N} = 0$$

$$A_y = 74.0\ \text{N} \qquad \textit{Ans.}$$

$$\circlearrowleft + \Sigma M_A = 0;\ M_A - \left[52\left(\tfrac{12}{13}\right)\text{N}\right](0.3\ \text{m}) - (30\sin 60^\circ\ \text{N})(0.7\ \text{m}) = 0$$

$$M_A = 32.6\ \text{N}\cdot\text{m} \qquad \textit{Ans.}$$

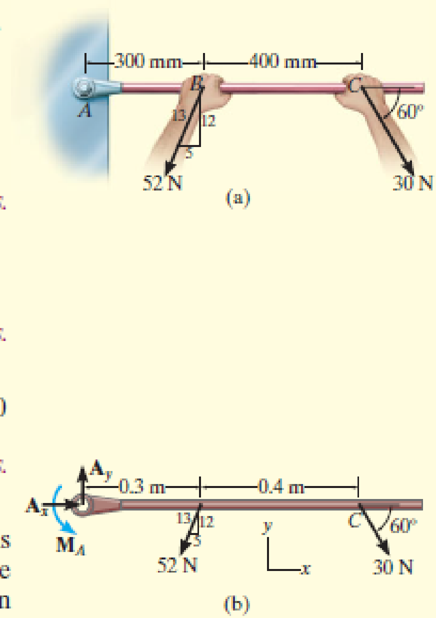


Fig. 5–15

Note that $\mathbf{M}_A$ must be *included* in this moment summation. This couple moment is a free vector and represents the twisting resistance of the bolt on the wrench. By Newton's third law, the wrench exerts an equal but opposite moment or torque on the bolt. Furthermore, the resultant force on the wrench is

$$F_A = \sqrt{(5.00)^2 + (74.0)^2} = 74.1\ \text{N} \qquad \textit{Ans.}$$

NOTE: Although only *three* independent equilibrium equations can be written for a rigid body, it is a good practice to *check* the calculations using a fourth equilibrium equation. For example, the above computations may be verified in part by summing moments about point *C*:

$$\circlearrowleft + \Sigma M_C = 0;\ \left[52\left(\tfrac{12}{13}\right)\text{N}\right](0.4\ \text{m}) + 32.6\ \text{N}\cdot\text{m} - 74.0\ \text{N}(0.7\ \text{m}) = 0$$

$$19.2\ \text{N}\cdot\text{m} + 32.6\ \text{N}\cdot\text{m} - 51.8\ \text{N}\cdot\text{m} = 0$$

4. Two smooth pipes, each having a mass of 300 kg, are supported by the forked tines of the tractor in Fig.4 . Draw the free-body diagrams for each pipe and both pipes together.

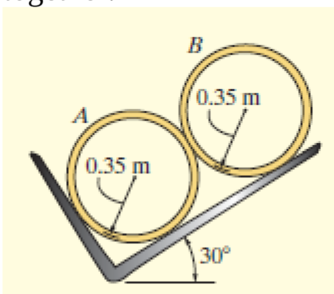
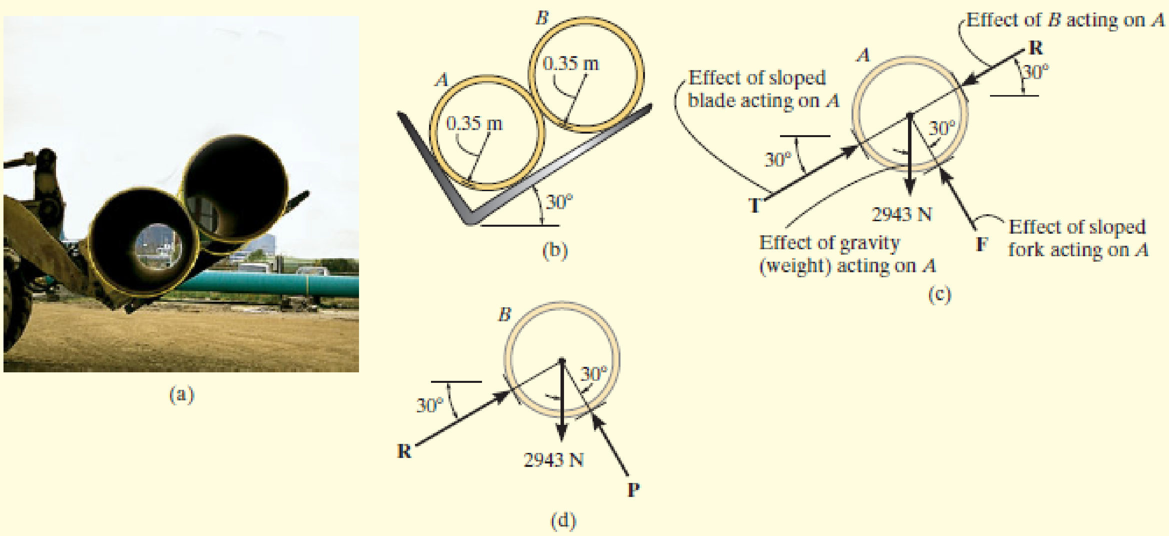


Figure 4

Solution:

EXAMPLE 5.3

Two smooth pipes, each having a mass of 300 kg, are supported by the forked tines of the tractor in Fig. 5–9*a*. Draw the free-body diagrams for each pipe and both pipes together.



SOLUTION

The idealized model from which we must draw the free-body diagrams is shown in Fig. 5–9*b*. Here the pipes are identified, the dimensions have been added, and the physical situation reduced to its simplest form.

The free-body diagram for pipe *A* is shown in Fig. 5–9*c*. Its weight is $W = 300(9.81)\text{ N} = 2943\text{ N}$. Assuming all contacting surfaces are *smooth*, the reactive forces **T**, **F**, **R** act in a direction *normal* to the tangent at their surfaces of contact.

The free-body diagram of pipe *B* is shown in Fig. 5–9*d*. Can you identify each of the three forces acting *on this pipe*? In particular, note that **R**, representing the force of *A* on *B*, Fig. 5–9*d*, is equal and opposite to **R** representing the force of *B* on *A*, Fig. 5–9*c*. This is a consequence of Newton's third law of motion.

The free-body diagram of both pipes combined ("system") is shown in Fig. 5–9*e*. Here the contact force **R**, which acts between *A* and *B*, is considered as an *internal* force and hence is not shown on the free-body diagram. That is, it represents a pair of equal but opposite collinear forces which cancel each other.

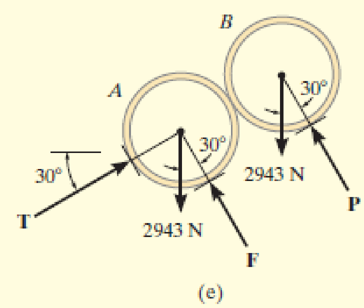


Fig. 5–9