Homework V - Chapters 7 and 8

due Friday, 05/27/11, 12:50pm, 370-370

For late homework, you are responsible to arrange drop off with our grader Kaushik Mani, kmani@stanford.edu. Once you have used up your three late days, you will no longer receive points for your homework. Here are our office hours and emails.

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<tr>
<td>Tuesdays</td>
<td>06:00 - 07:30pm</td>
<td>Durand 247</td>
<td>Charbel</td>
<td><a href="mailto:ceid@stanford.edu">ceid@stanford.edu</a></td>
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<td>Wednesdays</td>
<td>02:30 - 04:00pm</td>
<td>Durand 217</td>
<td>Ellen</td>
<td><a href="mailto:ekuhl@stanford.edu">ekuhl@stanford.edu</a></td>
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<td>Durand 393</td>
<td>Chris</td>
<td><a href="mailto:cplor@stanford.edu">cplor@stanford.edu</a></td>
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<td>Durand 203</td>
<td>Joules</td>
<td><a href="mailto:jmgould@stanford.edu">jmgould@stanford.edu</a></td>
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<td><a href="mailto:estevam@stanford.edu">estevam@stanford.edu</a></td>
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For this homework, you need to be familiar with chapters 7 and 8 of your book! Remember, all solutions must include free body diagrams!
e14 - applied mechanics: statics

Wear your E14 T-shirt and take a landscape format photo of yourself in a funny situation. The photo must contain either a shear and moment diagram situation (chapter 7) or a friction problem (chapter 8). Upload your photo through your coursework drop box. The five most creative photos will receive five extra bonus points.

homework #05

7.1 internal forces in beams

making the internal extrenal

internal loading > imaginary section > external loading

normal force $N$, shear force $V$, bending moment $M$

7.2 shear and moment diagrams

example - simply supported beam

statics of the hanging problem

idealized free body diagram
cantilever beam

shear diagram

moment diagram
today’s objectives
- to introduce the concept of dry friction
- to analyze the equilibrium equation of rigid bodies subject to friction
- to present specific applications friction
- to investigate the concept of rolling resistance

8. friction

8.1 characteristics of dry friction

8.2 problems involving dry friction

from friction to heat
- the heat generated by the abrasive action of friction can be noticed when using this drinder to sharpen a metal blade
- friction is a force that resists the movement of two contacting surfaces relative to one another
- friction always acts tangent to the surface and is directed opposite to a possible motion

theory of dry friction

slipping & tipping

pushing on the uniform crate of weight W sitting on a rough surface. if the magnitude P is small, the crate will remain in equilibrium and not move (left FBD). as P increases, the crate will either be on the verge of slipping, \( F = \mu_s \cdot M \), or, if the surface is very rough with large \( \mu_s \), the resultant force moves towards the corner and beyond, \( x > b/2 \), and the crate will tip over. tipping also depends on the height \( h \) of the force \( P \).
example 8.1

The uniform crate shown in Fig. 8-7a has a mass of 20 kg. If a force $P = 80$ N is applied to the crate, determine if it remains in equilibrium. The coefficient of static friction is $\mu_s = 0.3$.

SOLUTION

Free-Body Diagram. As shown in Fig. 8-7b, the resultant normal force $N_C$ must act a distance $x$ from the crate’s center line in order to counteract the tipping effect caused by $P$. There are three unknowns, $F$, $N_C$, and $x$, which can be determined strictly from the three equations of equilibrium.

Equations of Equilibrium.

$$\begin{align*}
\sum F_x &= 0; & 80 \cos 30^\circ N - F &= 0 \\
\sum F_y &= 0; & -80 \sin 30^\circ N + N_C - 196.2 \text{ N} &= 0 \\
\sum M_A &= 0; & 80 \sin 30^\circ \text{ N}(0.4 \text{ m}) - 80 \cos 30^\circ \text{ N}(0.2 \text{ m}) + N_C(x) &= 0
\end{align*}$$

Solving,

$$
F = 69.3 \text{ N} \\
N_C = 236 \text{ N} \\
x = 0.0308 \text{ m} = 3.08 \text{ mm}
$$

Since $x$ is negative it indicates the resultant normal force acts (slightly) to the left of the crate’s center line. No tipping will occur since $x < 0.4$ m. Also, the maximum frictional force which can be developed at the surface of contact is $F_{\text{max}} = \mu_s N_C = 0.3(236 \text{ N}) = 70.8 \text{ N}$.

Since $F = 69.3 \text{ N} < 70.8 \text{ N}$, the crate will not slip, although it is very close to doing so.

example 8.3

The uniform 10-kg ladder in Fig. 8-9a rests against the smooth wall at $B$, and the end $A$ rests on the rough horizontal plane for which the coefficient of static friction is $\mu_s = 0.3$. Determine the angle of inclination $\theta$ of the ladder and the normal reaction at $B$ if the ladder is on the verge of slipping.

Free-Body Diagram. As shown on the free-body diagram, Fig. 8-9b, the frictional force $F_A$ must act to the right since impending motion at $A$ is to the left.

Equations of Equilibrium and Friction. Since the ladder is on the verge of slipping, then $F_A = \mu_s N_A = 0.3 N_A$. By inspection, $N_A$ can be obtained directly.

$$
\sum F_x = 0; \quad N_A - 10(9.81) \text{ N} = 0 \quad N_A = 98.1 \text{ N}
$$

Using this result, $F_A = 0.3 (98.1 \text{ N}) = 29.43 \text{ N}$. Now $N_B$ can be found.

$$
\sum F_y = 0; \quad 29.43 \text{ N} - N_B = 0 \quad N_B = 29.43 \text{ N}
$$

Finally, the angle $\theta$ can be determined by summing moments about point $A$.

$$
\sum M_A = 0; \quad (29.43 \text{ N})(4 \text{ m}) \sin \theta - [10(9.81) \text{ N}](2 \text{ m}) \cos \theta = 0 \\
\quad \sin \theta = \tan \theta = 1.6667 \\
\quad \theta = 59.04^\circ = 59.0^\circ
$$

example 8.2 problems involving dry friction

example 8.2 problems involving dry friction

example 8.2 problems involving dry friction

example 8.2 problems involving dry friction