

FRICITION: SLIPPING VS. TIPPING

Learning Objectives

- 1). To evaluate two types of impending motion, *slipping* vs. *tipping*, to determine which will occur first.
- 2). To do an *engineering estimate* of whether a system will slip or tip.

Two Types of Impending Motion

- 1). Slipping
- 2). Tipping



The crane collapsed Wednesday but spared the National Cathedral. (BY CRAIG W. STAPERT/THE NATIONAL CATHEDRAL/AP)

Crane collapses at National Cathedral

By **ERIC TUCKER**
The Associated Press

WASHINGTON — A 500-ton crane at the Washington National Cathedral collapsed Wednesday amid thunderstorms and driving rain, damaging two nearby buildings and several vehicles as crews worked on damage from the recent earthquake.

The collapse came four days before President Barack Obama's scheduled speech at the cathedral to observe the 10th anniversary of the Sept. 11 terrorist attacks. The Sunday night speech is the highlight of three days of events set to start Friday at the cathedral.

No immediate decision was made about whether the com-

memoration, which also includes a concert and vigil, would go on as planned, said Richard Weinberg, a spokesman for the cathedral.

The crane was being used to repair the dings caused by the East Coast earthquake on Aug. 23. The cathedral's limestone exterior towers and some interior areas were damaged.

Notre Dame Scissors'-Lift Tipping Incident



Notre Dame Report Spreads Responsibility in Student Death

By [LYNN ZINSER](#)

Published: April 18, 2011



High wind, a lack of current weather information and a hydraulic lift susceptible to tipping each contributed to the death of a student video trainer at Notre Dame in October, the university said Monday after a six-month internal investigation into the accident.

A report about the October death of a Notre Dame student videographer concluded several factors, but not one person, was responsible. [Notre Dame's report](#) said no one person was responsible for the death of the student, 20-year-old Declan Sullivan, [who was filming football practice from a lift](#) extended to its full height of 40 feet in high wind on Oct. 27 when it toppled.

“Several flaws were exposed that need to be acknowledged and addressed,” the report stated. “Responsibility for these issues is shared by many individuals.”

The president of Notre Dame, the Rev. John I. Jenkins, said at a news conference: “In the grief and distress that follows a tragic accident, it is common to seek the individual or individuals responsible and assign blame. We have reached the conclusion that no one acted in disregard for safety.”

The report said that the lift on which Sullivan was perched was more susceptible to tipping in high wind than other models used by Notre Dame and that its use that day was based on an underestimation of the wind speed. The university had no way to measure on-field wind readings, so the investigation disclosed that staff members were using weather reports from earlier in the afternoon, before 2 p.m. Central. Practice did not begin until 3:45 p.m. Wind from an earlier report was much lower than the 53-miles-per-hour gust that knocked over the lift.

Among the recommendations offered in the investigation report is making sure real-time weather information is available to the football staff and establishing wind limits for lift use. Notre Dame, however, has not used the lifts since Sullivan's death, instead installing remote-controlled cameras mounted on 50-foot poles to film practice. The investigation was led by the Notre Dame executive vice president John Affleck-Graves and was reviewed by Peter Likins, an engineer and a former president of the [University of Arizona](#). Notre Dame said Likins was not paid for the review.

Likins's opinions were released with the report. “As reflected in this report, there were a number of issues that led to the loss of a bright and energetic young man, including the implementation

of the football program's wind-safety procedure without continuous access to real-time weather information at critical periods of time," Likins wrote. "What is clear, however, is that there were a series of factors in the aggregate that led to this tragedy. Though a needless loss of life cries out for one to shoulder blame, the facts here do not support any single individual finding of fault."

The report acknowledged that Coach Brian Kelly was advised by three people about the safety of holding practice outside that day: Clad Klunder, the director of football operations; Jim Russ, the head athletic trainer; and Tim Collins, the director of football video and film. The investigation found that none advised Kelly that practice should have been held indoors because of the conditions.

"Any time there is a death associated with your working on a daily basis, it profoundly affects you personally," Kelly said at the news conference. "You're never quite the same. But I think we're all collectively focused on making sure nothing like this happens again."

Collins, the report said, forgot to schedule the annual inspection for the lift in August 2010, but it also said that oversight was not a factor in the accident.

The report discussed Sullivan's reluctance to film on the lift in the wind that day, expressed in two messages he posted on his Twitter feed that afternoon, but said the investigators could not conclude that Sullivan was genuinely concerned for his safety. One of Sullivan's messages said the winds were "terrifying" and the other included the phrase "I guess I've lived long enough."

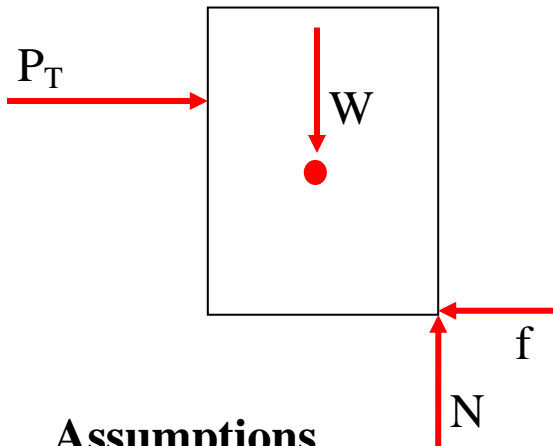
The Indiana [Occupational Safety and Health Administration](#)'s investigation reported that Sullivan had also expressed his worries to an assistant video coordinator.

In March, [that investigation led OSHA to levy \\$77,500 in fines](#) against Notre Dame for safety violations related to Sullivan's death. The university has requested a formal hearing with OSHA over the findings.

A version of this article appeared in print on April 19, 2011, on page B14 of the New York edition with the headline: Notre Dame Report Spreads Responsibility in Student Death.

Free Body Diagrams

Impending Tipping



Assumptions

Impending Tipping

- N & F act at **tipping** edge.
- $F \leq \mu_s N$

Results

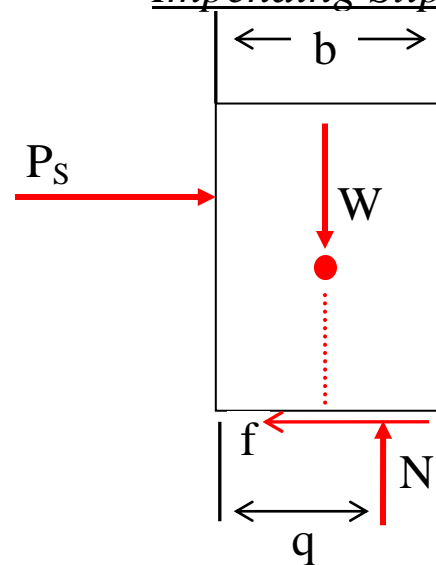
Impending Tipping

- Find P_T and F
- If $F \leq F_s$, then tipping assumption is correct ($P = P_T$)
 - If $F > F_s$, then slipping occurs first.

Comments

- 1). Generally easiest to assume tipping first, unless you're reasonably sure the system will slip.

Impending Slipping



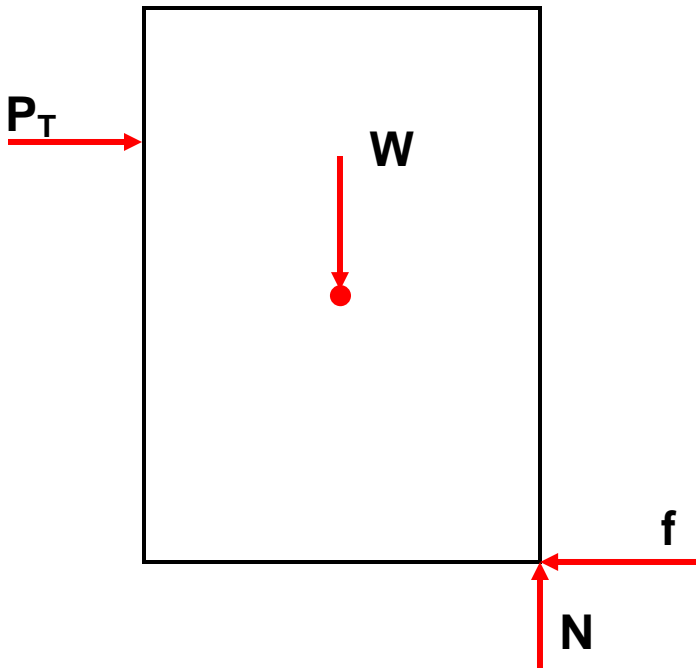
Impending Slipping

- $F = F_s = \mu_s N$
- $q \leq b$

Impending Slipping

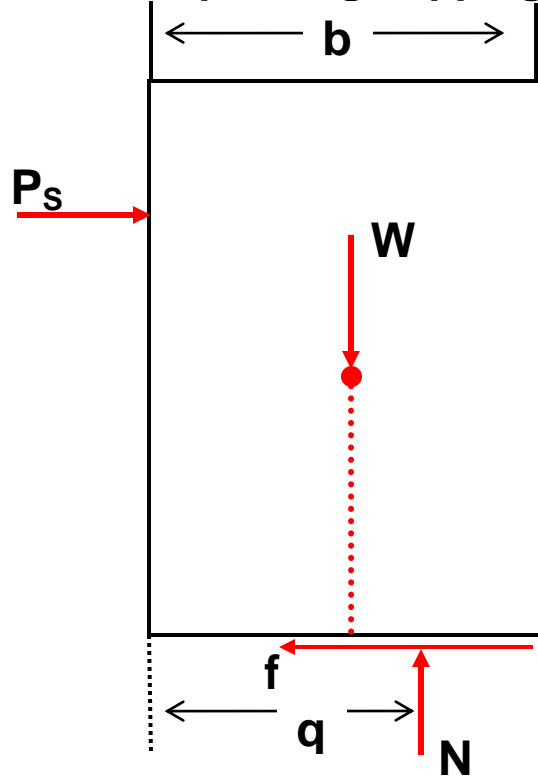
- Find P_s and q
- If $q < b$, then slipping assumption is correct ($P = P_s$)
 - If $q > b$, then tipping then tipping occurs first.

Impending Tipping



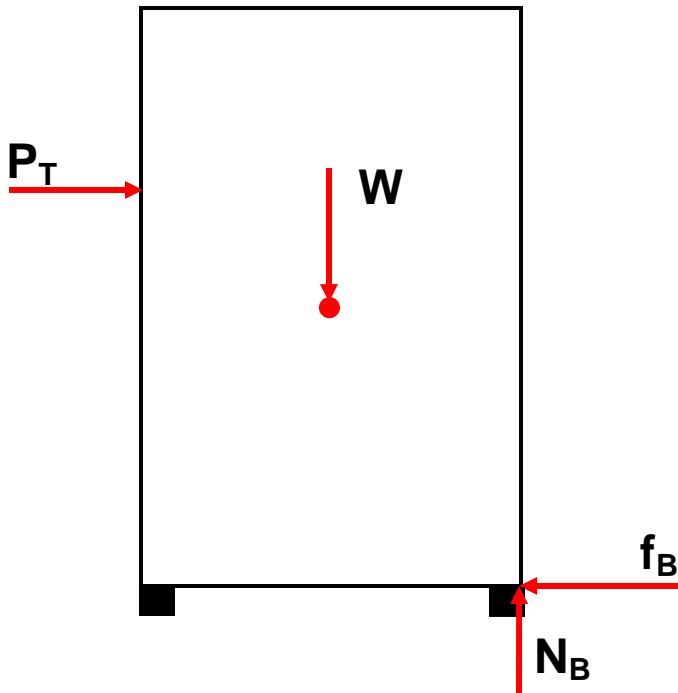
- N and f @ Tipping Edge
- $f \leq f_{MAX}$

Impending Slipping



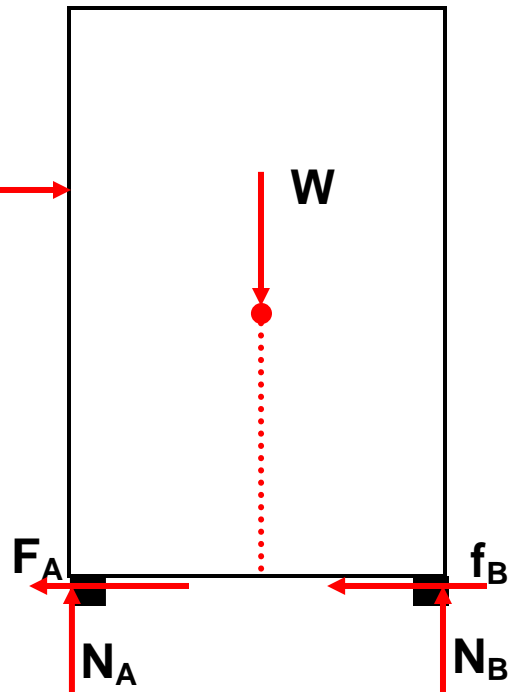
- $f = f_{MAX}$
- q is unknown

Impending Tipping



- $N_A = f_A = 0$
- $f_B \leq f_{Bmax}$

Impending Slipping



- $f_A = f_{Amax}$
- $f_B = f_{Bmax}$
- $N_A \geq 0$

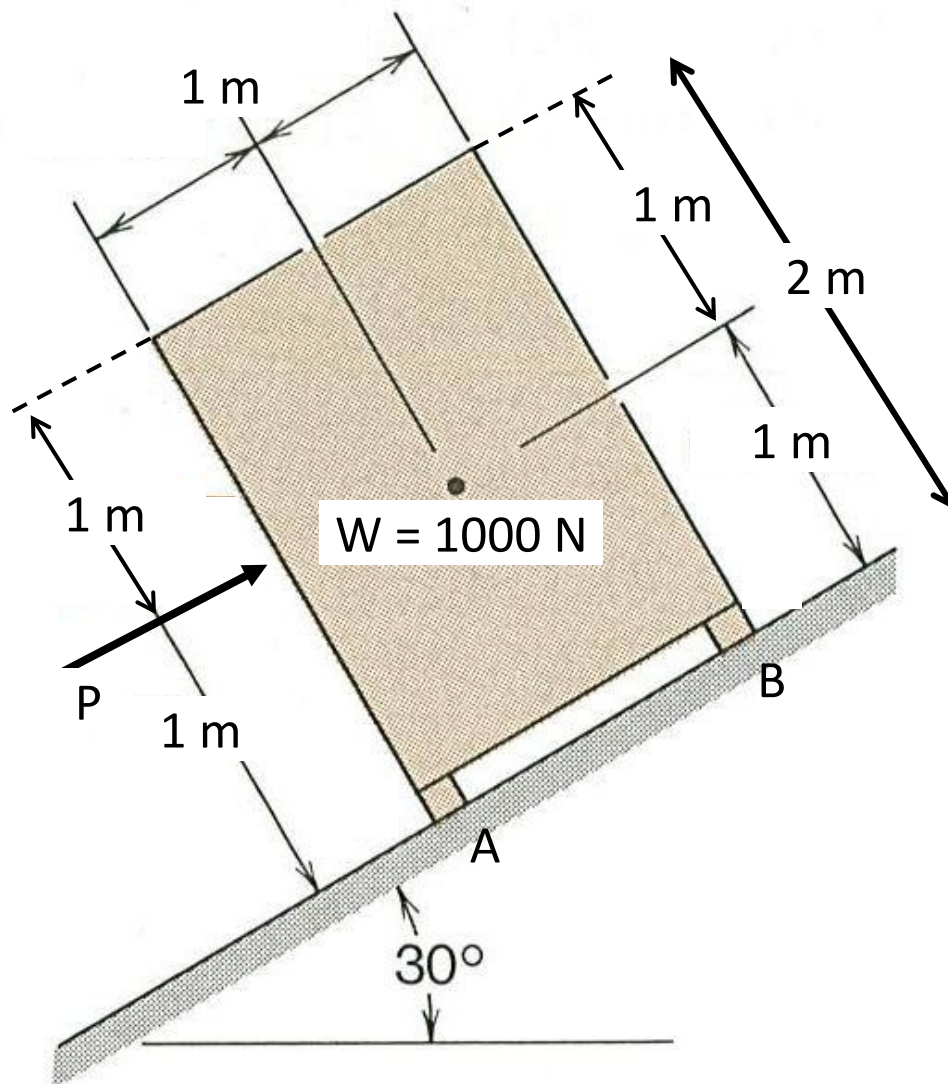
Slipping and Tipping

Example 1

Given: A 1000 N crate rests on a 30° incline. The coefficient of friction between the incline and the crate is $\mu_s = 0.75$.

Find:

- Determine the **minimum** force P to prevent the crate from tipping.
- Determine the **minimum** force P to prevent the crate from slipping.
- What is the nature of the impending motion for the minimum force P ?



Slipping and Tipping

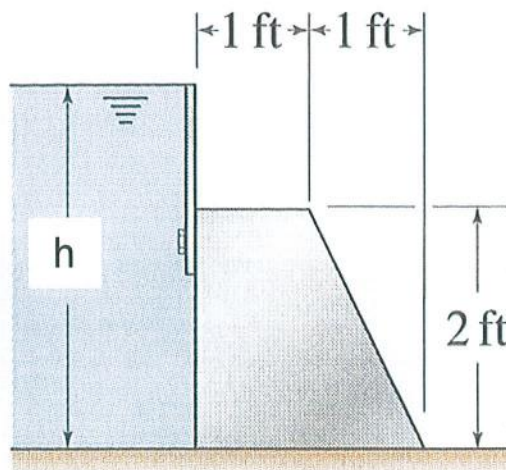
Example 2

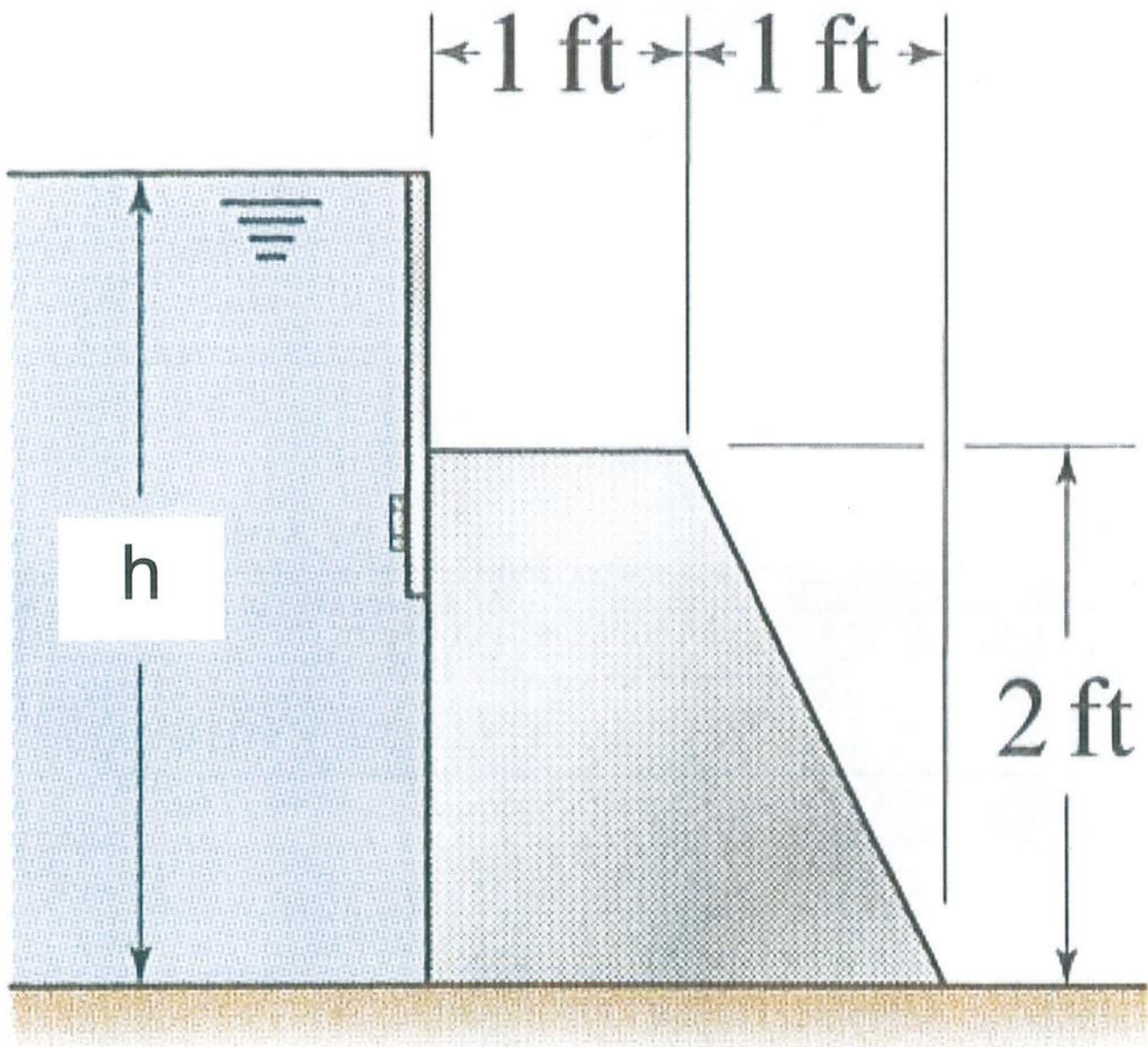
Given: A concrete gravity dam has an attached steel plate that a greater depth of water can be retained. The surface between the dam and earth has coefficients of friction of $\mu_s = 0.6$ and $\mu_k = 0.55$. The specific weights of concrete and water are $\gamma_c = \rho_c g = 150 \frac{1b}{ft^3}$ and

$\gamma_w = \rho_w g = 62.4 \frac{1b}{ft^3}$, respectively. Neglect the weight of the steel plate.

Find:

- Determine the highest depth of water (h) the concrete dam could hold without tipping.
- Determine the highest depth of water (h) the concrete dam could hold without slipping.





Friction: Slipping & Tipping Group Quiz 1

Group #: _____

Group Members: 1) _____
(Present Only)

Date: _____ Period: _____

2) _____

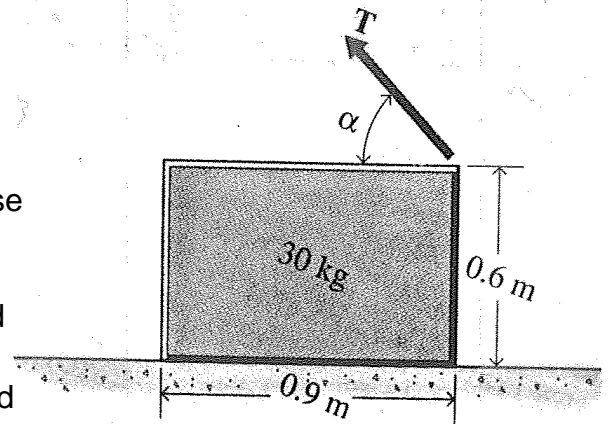
3) _____

4) _____

Given: A 30 kg crate is setting on a flat surface as shown. The coefficient of friction between the box and the surface is $\mu_s = 0.25$ and $\alpha = 60^\circ$.

Find:

- a) Determine the minimum force T necessary to cause impending motion on the crate. Is the impending motion tipping or slipping? Justify your answer.
- b) If the crate were to slip first, how could α be varied to cause tipping.
- c) If the crate were to slip first, how could μ_s be varied to cause tipping?



Solution:

