De Anza College

Introduction to Mechanics
Friction

Lana Sheridan

De Anza College

Mar 11, 2020

Last time

- Atwood machine variation
- kinetic and static friction
- friction example

Overview

- more friction examples

Friction Example 2

For waxed wood on wet snow, $\mu_s = 0.14$ and $\mu_k = 0.1$. You pull horizontally on a sled of mass 10 kg that is at rest initially. How much force do you need to apply to get the sled moving? If you continue to apply that force, what will the magnitude of sled's acceleration be once it is moving?

Friction Example 2

For waxed wood on wet snow, $\mu_s = 0.14$ and $\mu_k = 0.1$. You pull horizontally on a sled of mass 10 kg that is at rest initially. How much force do you need to apply to get the sled moving? If you continue to apply that force, what will the magnitude of sled's acceleration be once it is moving?

Sketch.

Hypothesis: 13.7 N, should be the max static friction force we just worked out in previous example; 1 m/s^2

Friction Example 2

For waxed wood on wet snow, $\mu_s = 0.14$ and $\mu_k = 0.1$. You pull horizontally on a sled of mass 10 kg that is at rest initially. How much force do you need to apply to get the sled moving? If you continue to apply that force, what will the magnitude of sled's acceleration be once it is moving?

Sketch.

Hypothesis: 13.7 N, should be the max static friction force we just worked out in previous example; 1 m/s^2

To get the sled moving $F_{app} \geqslant f_{s,\max}$

$$\begin{aligned} f_{s,\max} &= \mu_s N \\ &= (0.14)(10\ \text{kg})g \\ &= \underline{13.7\ \text{N}} \end{aligned}$$

Friction Example 2

For waxed wood on wet snow, $\mu_s = 0.14$ and $\mu_k = 0.1$. You pull on a sled of mass 10 kg that is at rest initially. How much force do you need to apply to get the sled moving? If you continue to apply that force, what will the magnitude of sled's acceleration be once it is moving?

Friction Example 2

For waxed wood on wet snow, $\mu_s = 0.14$ and $\mu_k = 0.1$. You pull on a sled of mass 10 kg that is at rest initially. How much force do you need to apply to get the sled moving? If you continue to apply that force, what will the magnitude of sled's acceleration be once it is moving?

$$
\begin{aligned}
F_{\text{net},x} &= ma_x \\
F_{app} - F_{kf} &= 13.72 - \mu_k n \\
&= 13.72 - (0.1)(10\text{ kg})g \\
&= 3.92\text{ N}
\end{aligned}
$$

$$a = \frac{F}{m} = \frac{3.92\text{ N}}{10\text{ kg}} = \underline{0.39\text{ ms}^{-2}}$$

Friction Example 2

For waxed wood on wet snow, $\mu_s = 0.14$ and $\mu_k = 0.1$. You pull on a sled of mass 10 kg that is at rest initially. How much force do you need to apply to get the sled moving? If you continue to apply that force, what will the magnitude of sled's acceleration be once it is moving?

$$\begin{aligned} F_{\text{net},x} &= ma_x \\ F_{app} - F_{kf} &= 13.72 - \mu_k n \\ &= 13.72 - (0.1)(10\text{ kg})g \\ &= 3.92\text{ N} \end{aligned}$$

$$a = \frac{F}{m} = \frac{3.92\text{ N}}{10\text{ kg}} = \underline{0.39\text{ ms}^{-2}}$$

Reasonable?: Yes for the force. The acceleration was a bit less than my guess, but same order of magnitude.

Friction Example 6-2

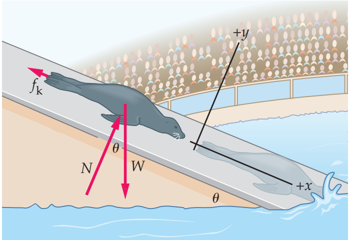
A trained sea lion slides from rest with constant acceleration down a 3.0-m-long ramp into a pool of water. If the ramp is inclined at an angle of 23° above the horizontal and the coefficient of kinetic friction between the sea lion and the ramp is 0.26, how long does it take for the sea lion to make a splash in the pool?

[1] Walker, "Physics".

Friction Example 6-2

A trained sea lion slides from rest with constant acceleration down a 3.0-m-long ramp into a pool of water. If the ramp is inclined at an angle of 23° above the horizontal and the coefficient of kinetic friction between the sea lion and the ramp is 0.26, how long does it take for the sea lion to make a splash in the pool?

Sketch:

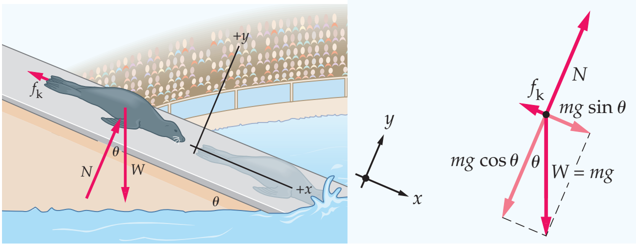


[1]Walker, "Physics".

Friction Example 6-2

A trained sea lion slides from rest with constant acceleration down a 3.0-m-long ramp into a pool of water. If the ramp is inclined at an angle of 23° above the horizontal and the coefficient of kinetic friction between the sea lion and the ramp is 0.26, how long does it take for the sea lion to make a splash in the pool?

Sketch:



[1]Walker, "Physics".

Friction Example 6-2

Hypothesis: About 5 seconds.

Friction Example 6-2

Hypothesis: About 5 seconds.

Strategy: Use Newton's 2nd law, find acceleration, use kinematics equation.

Friction Example 6-2

Hypothesis: About 5 seconds.

Strategy: Use Newton's 2nd law, find acceleration, use kinematics equation.

$\underline{y \text{ direction}}$:

$$\begin{aligned} F_{\text{net},y} = N - mg\cos\theta &= 0 \\ N &= mg\cos\theta \end{aligned}$$

$\underline{x \text{ direction}}$:

$$F_{\text{net},x} = mg\sin\theta - f_k = ma$$

Friction Example 6-2

Hypothesis: About 5 seconds.

Strategy: Use Newton's 2nd law, find acceleration, use kinematics equation.

$\underline{y \text{ direction}}$:

$$\begin{aligned} F_{\text{net},y} = N - mg\cos\theta &= 0 \\ N &= mg\cos\theta \end{aligned}$$

$\underline{x \text{ direction}}$:

$$\begin{aligned} F_{\text{net},x} = mg\sin\theta - f_k &= ma \\ mg\sin\theta - \mu_k N &= ma \\ mg\sin\theta - \mu_k(mg\cos\theta) &= ma \\ a &= g(\sin\theta - \mu_k\cos\theta) \end{aligned}$$

Friction Example 6-2

Hypothesis: About 5 seconds.

Strategy: Use Newton's 2nd law, find acceleration, use kinematics equation.

$\underline{y \text{ direction}}$:

$$
\begin{aligned}
F_{\text{net},y} = N - mg\cos\theta &= 0 \\
N &= mg\cos\theta
\end{aligned}
$$

$\underline{x \text{ direction}}$:

$$
\begin{aligned}
F_{\text{net},x} = mg\sin\theta - f_k &= ma \\
mg\sin\theta - \mu_k N &= ma \\
mg\sin\theta - \mu_k(mg\cos\theta) &= ma \\
a &= g(\sin\theta - \mu_k\cos\theta) \\
a &= 1.5 \text{ m/s}^2
\end{aligned}
$$

Friction Example 6-2

Given: $\Delta x = 3$ m, $a = 1.5$ m/s^2, $v_0 = 0$ m/s.
Asked for: t.

Friction Example 6-2

Given: $\Delta x = 3$ m, $a = 1.5$ m/s^2, $v_0 = 0$ m/s.
Asked for: t.

$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

$$\underline{t = 2.0 \text{ s}}$$

Friction Example 6-2

Given: $\Delta x = 3$ m, $a = 1.5$ m/s^2, $v_0 = 0$ m/s.
Asked for: t.

$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

$$\underline{t = 2.0 \text{ s}}$$

Reasonable?: Less than half my guess, but 23° is a pretty steep slope, so the answer is plausible.

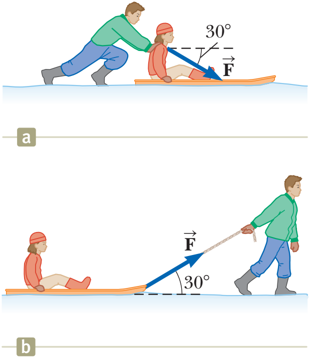
Friction Question

Quick Quiz 5.7.[1] You are playing with your daughter in the snow. She sits on a sled and asks you to slide her across a flat, horizontal field. You have a choice of:

(A) pushing her from behind by applying a force downward on her shoulders at 30° below the horizontal or

(B) attaching a rope to the front of the sled and pulling with a force at 30° above the horizontal.

Which would be easier for you and why?



[2]Serway & Jewett, page 132.

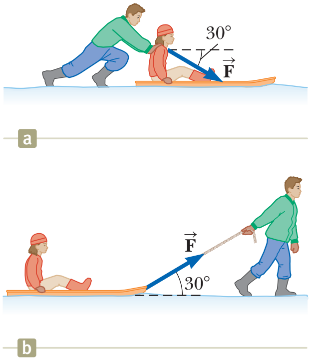
Friction Question

Quick Quiz 5.7.[1] You are playing with your daughter in the snow. She sits on a sled and asks you to slide her across a flat, horizontal field. You have a choice of:

(A) pushing her from behind by applying a force downward on her shoulders at 30° below the horizontal or

(B) attaching a rope to the front of the sled and pulling with a force at 30° above the horizontal. ←

Which would be easier for you and why?



[2]Serway & Jewett, page 132.

Friction Question

Ch 6 #5, page 178

Hopping into your Porsche, you floor it and accelerate at 12 m/s^2 without spinning the tires. Determine the minimum coefficient of static friction between the tires and the road needed to make this possible.

[1] Walker, "Physics".

Friction Question

Ch 6 #5, page 178

Hopping into your Porsche, you floor it and accelerate at 12 m/s^2 without spinning the tires. Determine the minimum coefficient of static friction between the tires and the road needed to make this possible.

Sketch a free body diagram for the car. (What force causes the car's forward acceleration?)

[1] Walker, "Physics".

Friction Question

Ch 6 #5, page 178

Hopping into your Porsche, you floor it and accelerate at 12 m/s^2 without spinning the tires. Determine the minimum coefficient of static friction between the tires and the road needed to make this possible.

Sketch a free body diagram for the car. (What force causes the car's forward acceleration?)

Hypothesis: coefficients of friction are usually between 0 and 1. Car tires are designed not to slip on asphalt. μ_s should be high, but we are looking for the minimum it could be. Guess: 0.5.

[1] Walker, "Physics".

Friction Question

Hopping into your Porsche, you floor it and accelerate at 12 m/s^2 without spinning the tires. Determine the minimum coefficient of static friction between the tires and the road needed to make this possible.

Strategy: Newton's 2nd law.

$$F_{\text{net}} = ma$$

$F_{\text{net}} = f_s$. If we want to find the *minimum* coefficient of static friction, assume that we are getting the max possible force from that coefficient: $f_s = f_{s,\text{max}} = \mu_s N$.

$$\begin{aligned} \mu_s mg &= ma \\ \mu_s &= \frac{a}{g} \\ \mu_s &= \frac{12 \text{ m/s}^2}{9.81 \text{ m/s}^2} = \underline{1.2} \end{aligned}$$

Friction Question

Hopping into your Porsche, you floor it and accelerate at 12 m/s^2 without spinning the tires. Determine the minimum coefficient of static friction between the tires and the road needed to make this possible.

$$\mu_s \;=\; \underline{1.2}$$

Reasonable?: Woah! This is not only much bigger than my guess, it is bigger than 1!

This would mean that it requires less force to pick up the entire Porsche and move it to one side than it does to push it along the ground starting from rest.

Friction Question

Hopping into your Porsche, you floor it and accelerate at 12 m/s^2 without spinning the tires. Determine the minimum coefficient of static friction between the tires and the road needed to make this possible.

$$\mu_s \;=\; \underline{1.2}$$

Reasonable?: Woah! This is not only much bigger than my guess, it is bigger than 1!

This would mean that it requires less force to pick up the entire Porsche and move it to one side than it does to push it along the ground starting from rest.

Research → Apparently, yes! This is the sort of number you can get for high-performance racing tires. Cool.

Summary

- friction examples

Quiz Monday

Homework

Walker Physics:

- prev: Ch 6, onwards from page 177. Questions: 3, 15; Problems: 1, 3, 7, 11, 13, 15, 87 (friction)
- new: Ch 6, Problem: 109 (friction)