PHY131 F Fall 2020
Class 12

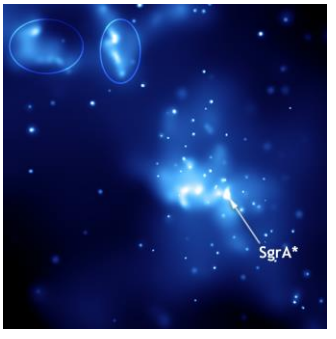
Today:

- Projectile Motion Demonstration
- Rolling Without Slipping
- More Ch.4 examples

1

2020 Nobel Prize in Physics

- Andrea Ghez discovered Sagittarius A*, the supermassive black hole at the centre of our galaxy.
- It has a mass of 4.15 million times the mass of our Sun. And the Sun has a mass of 300,000 times that of the Earth.
- Theoretically, all of this mass is concentrated at a “singularity”, a point at the centre which has zero volume and infinite density. All 400 billion stars in the Milky Way (including our Sun) orbit this point.



2

2020 Nobel Prize in Physics

- The award also includes $1 million USD
- Also there are a few special parking spots near the physics building at Cal Tech labeled “NL”.

3

The PHY131 Help Centre

- https://gather.town/app/z4gwTUwt8gKBKOk0/phy131
  - Mondays: 12:30-1:30pm
  - Tuesdays: 9:30-10:30am
  - Wednesdays: 12:30-1:30pm
  - Thursdays: 2-3pm
  - Fridays: 12:30-1:30pm
  - Sundays: 1:30-2:30pm
  - Also every Monday the day before a midterm 7:00-10:00pm.
- You may need to raise your hand and/or direct-message the TA to get their attention in Gather Town.
- The TA will have the letters "TA" as part of their name, to help you identify them.

4

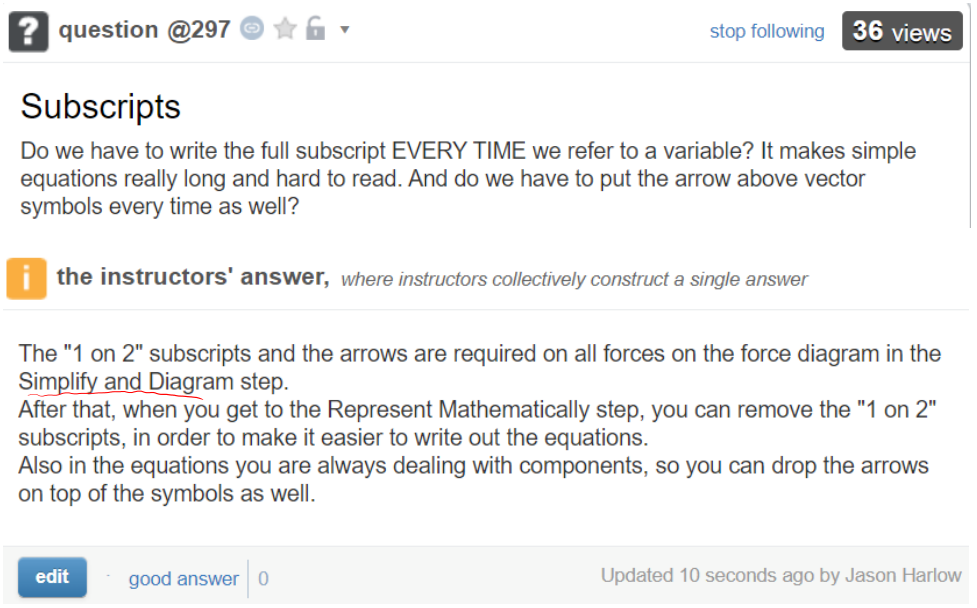
Midterm Assessment 2
Alternate Sitting

- Midterm Assessment 2 is Tue. Oct. 13th from 8:10pm - 8:40pm on Quercus. The Alternate Sitting is exactly 2 hours later on the same day: 10:10pm - 10:40pm (All Toronto Time)
- If you wrote the Alternate Sitting for Midterm Assessment 1, then you will be automatically registered for the Alternate Sitting for Midterm Assessment 2. You don't have to do anything.
- If you did not write the Alternate Sitting for Midterm Assessment 1, and you need to write the Alternate Sitting for Midterm Assessment 2, then you need to fill out the form from the link in the Quercus Announcement.
- If you wrote the Alternate Sitting for Midterm Assessment 1, and you do not want to write the Alternate Sitting for Midterm Assessment 2, then you should email us at phy131fall@physics.utoronto.ca .

5

piazza

Midterm Assessment 2

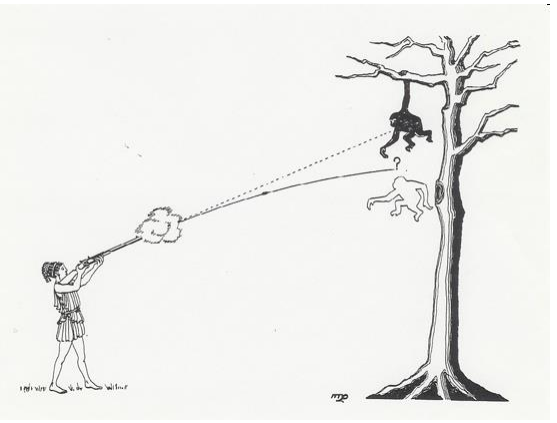


6

Monkey and Hunter Demonstration (and poll question)

The classic problem: "A monkey hanging from the branch of a tree is spotted by a hunter. The monkey sees that the barrel of the gun is pointed directly at him. At the exact instant the gun is fired, the monkey lets go of the branch. Will the bullet (A) go above the monkey, (B) go below the monkey, or (C) hit the monkey?

Our demonstration uses a tiny ball in a blow gun. You can look through the blow-gun to see that it is aimed directly at the Roman Centurion, which is supported by an electromagnet. As the tiny ball leaves the tube, it breaks a connection that releases the magnet.
Let's try it!

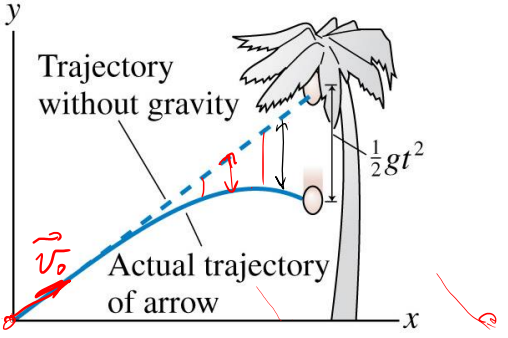


7

Monkey and Hunter Demonstration (and poll question)

The classic problem: "A monkey hanging from the branch of a tree is spotted by a hunter. The monkey sees that the barrel of the gun is pointed directly at him. At the exact instant the gun is fired, the monkey lets go of the branch. Will the bullet (A) go above the monkey, (B) go below the monkey, or **(C) hit the monkey**!

- Had the monkey stayed on the tree, the ball would have curved under its target as gravity causes it to fall a distance $\frac{1}{2}gt^2$ below the straight line.
- But $\frac{1}{2}gt^2$ is also the distance the monkey falls while the ball is in flight.
- So *yes*, the bullet hits the monkey!



8

unbalanced

Poll

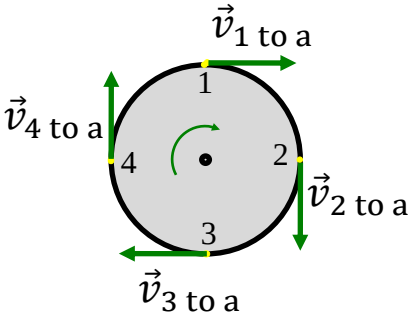
A car accelerates away from a stop-sign.
What is the main external force on the car which provides the **net force on the car** which causes it to accelerate?

A. Gravity
B. Kinetic friction
C. Normal Force
D. Static friction
E. Thrust

9

Rotation

Rotational motion relative to the **a**xle.
The centre of the wheel is not moving.



$|\vec{v}_{1 \text{ to a}}| = v$

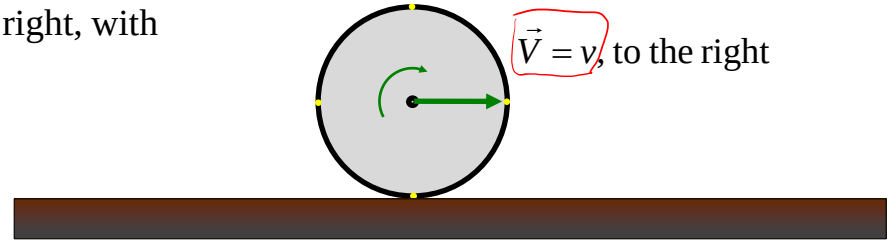
The wheel rotates clockwise.

The tangential speed of any point on the rim is v, relative to the axle.
The four points shown are all moving in different directions.

10

Rolling without slipping

Relative to the ground, the axle is moving toward the right, with velocity $\vec{V}$.



In "rolling without slipping", the axle moves at speed $|\vec{V}| = v$.

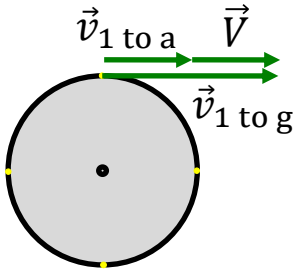
11

Rolling without slipping

Relative to **g**round.

Point 1: Top of the wheel

$$\vec{v}_{1 \text{ to ground}} = \vec{v}_{1 \text{ to axle}} + \vec{V}$$



$$|\vec{v}_{1 \text{ to ground}}| = v + v = 2v$$

In the ground frame, the top point moves at speed $2v$.

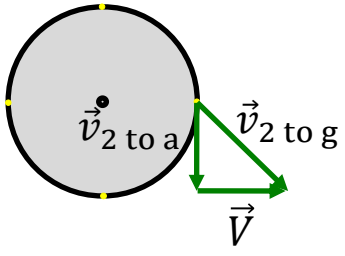
12

Rolling without slipping

Relative to **g**round.

$$\vec{v}_{2 \text{ to ground}} = \vec{v}_{2 \text{ to axle}} + \vec{V}$$

Point 2: Right side of the wheel



$$\left|\vec{v}_{2 \text{ to ground}}\right| = \sqrt{v^2 + v^2} = \sqrt{2}v$$

In the ground frame, the right side of the wheel is moving on a diagonal down and to the right.

13

Rolling without slipping

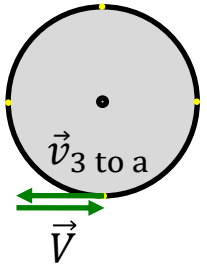
Relative to **g**round.

$$\vec{v}_{3 \text{ to ground}} = \vec{v}_{3 \text{ to axle}} + \vec{V}$$

Point 3: Bottom of the wheel

$|\vec{v}_{3 \text{ to a}}| = v$

$|\vec{V}| = v$



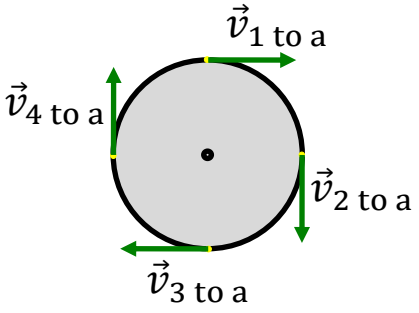
$$\left|\vec{v}_{3 \text{ to ground}}\right| = v - v = 0$$

In the ground frame, the bottom point is *at rest*.

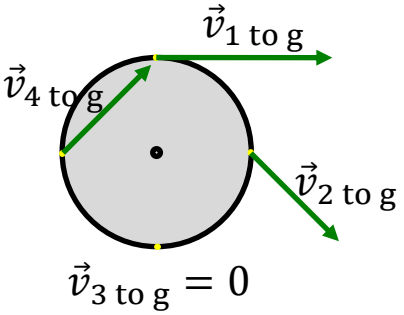
14

Rolling without slipping

Relative to the axle.



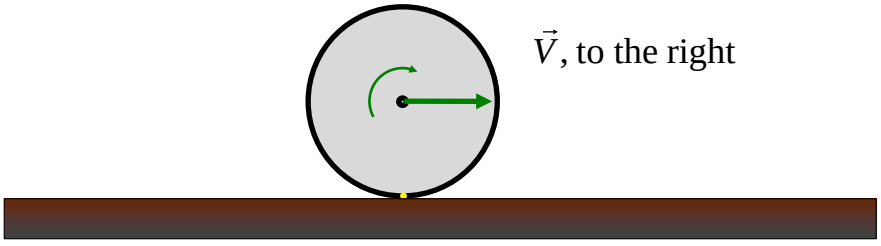
Relative to the ground.



$\vec{V} = v$, to the right

15

Rolling without slipping



The wheel rotates ~~counter~~clockwise.

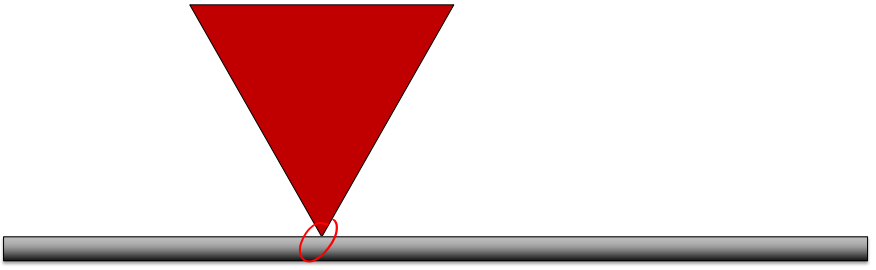
The axle moves with speed $V = v$, relative to the ground, to the right, where v is the tangential speed of the edge of the wheel relative to the axle.

Since the bottom point is always at rest, it is *static friction* which acts between the ground and the wheel.

16

Another way to look at it…

Rolling Without Slipping

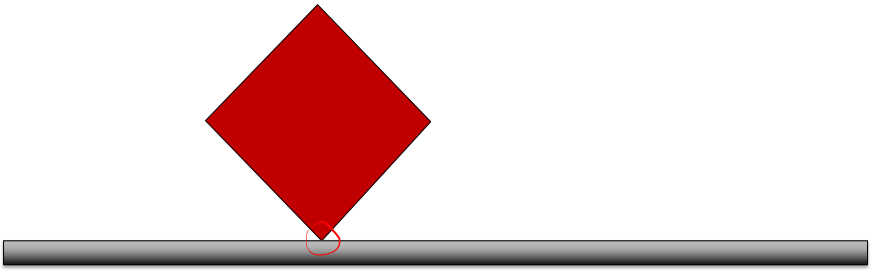


3 sides: bottom pivot point does not move: fixed point.

17

Another way to look at it…

Rolling Without Slipping

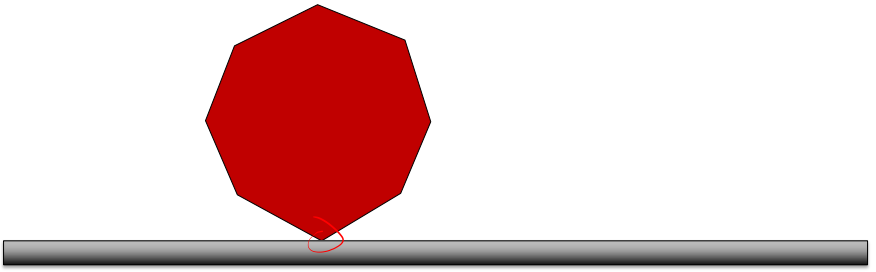


4 sides: bottom pivot point does not move: fixed point.

18

Another way to look at it…

Rolling Without Slipping



8 sides: bottom pivot point does not move: fixed point.
….etc, etc.
If you have an infinite number of sides (circle), the bottom pivot point still should **not move**.

19

Rolling without slipping

- No matter what the speed, four points on this car are always ***at rest!***
- Which points? The bottoms of the four tires!

- A wheel rolls much like the treads of a tank.
- The bottom of the wheel is ***at rest*** relative to the ground as it rolls.

20

The Last Poll: Explanation

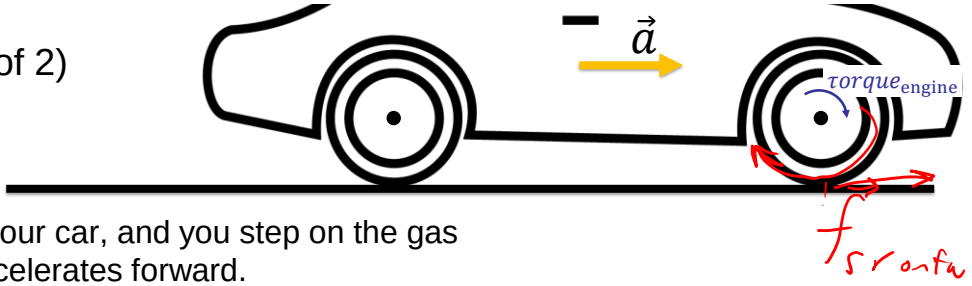
A car accelerates away from a stop-sign.
What is the main external force on the car which provides the **net force on the car** which causes it to accelerate?

A. Gravity
B. Kinetic friction
C. Normal Force
D. Static friction
E. Thrust

1. Engine provides torque which gives the back wheels counterclockwise angular acceleration.
2. Bottom of tire presses backward on the road.
3. By Newton's 3rd Law, the road presses forward on the tire .

21

Poll (part 1 of 2)



You are sitting in your car, and you step on the gas pedal. The car accelerates forward.

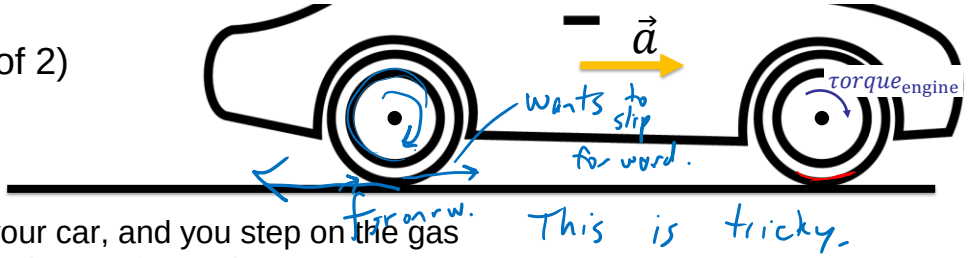
Your car has Front Wheel Drive (FWD). That means the front two wheels are connected to the engine, but the back two wheels just freely rotate on their axles.

As you accelerate, what is the direction of the force of static friction of the road upon the **front** wheels?

A. Forward
B. Backward
C. The static friction force on the front wheels is zero

22

Poll (part 2 of 2)



You are sitting in your car, and you step on the gas pedal. The car accelerates forward.

Your car has Front Wheel Drive (FWD). That means the front two wheels are connected to the engine, but the back two wheels just freely rotate on their axles.

As you accelerate, what is the direction of the force of static friction of the road upon the **rear** wheels?

A. Forward

B. Backward

C. The static friction force on the rear wheels is zero

This is tricky. The rear wheels do rotate as car accelerates. This backward friction force is small, just enough to spin a tire.

23

Example

- In principle, what is the shortest possible amount of time you can accelerate from 0 to 100 km/h?

TABLE 4.5 The coefficients of kinetic and static friction between two surfaces

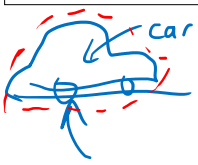
Contacting surfaces	Coefficient of static friction μ_s	Coefficient of kinetic friction μ_k
Rubber on concrete (dry)	1	0.6–0.85
Steel on steel	0.74–0.78	0.42–0.57
Aluminum on steel	0.61	0.47
Glass on glass	0.9–1	0.4
Wood on wood	0.25–0.5	0.20
Waxed skis on wet snow	0.14	0.1
Teflon on Teflon	0.04	0.04
Greased metals	0.1	0.06
Surfaces in a healthy human joint	0.01	0.003

24

Example

- In principle, what is the shortest possible amount of time you can accelerate from 0 to 100 km/h?

SKETCH & TRANSLATE.



Rolling without slipping. Define system = car.

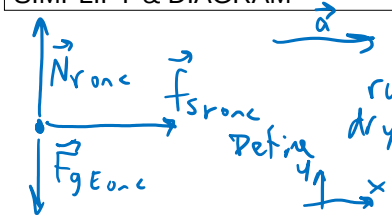
$v_0 = 0$

$v = 100$ km/h

$v = 100 \frac{\text{km}}{\text{h}} \left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right)$

$v = 27.8$ m/s

SIMPLIFY & DIAGRAM



Assume rubber tire, dry concrete, $\mu_s = 1$

REPRESENT MATHEMATICALLY

$\Sigma F_y = N - mg = 0$

$a_y = 0$ $\Rightarrow$ $N = mg$

$\Sigma F_x = f_s = f_{s\max} = \mu_s N = \mu_s mg$

maximum acceleration.

$a_x = \frac{\Sigma F_x}{m} = \frac{\mu_s mg}{m}$

SOLVE & EVALUATE

$a_x = \mu_s g = (1)9.8 = 9.8\ \text{m/s}^2$

Use $v_x = v_{0x} + a_x t$

$t = \frac{v_x}{g} = \frac{27.8}{9.8} = 2.8$ seconds

Bugatti can do it in 2.3 s.

25

Friday's TeamUp Quiz

- U of T Biology Professor Melody Neumann wrote Team Up! — a secure browser-based app that works on a phone, iPad or laptop.
- Team Up! lets students work together on problems in class in real time.
- The software, supported by Quercus, also enables partial marks for partial understanding and (unlike classroom response tools such as Top Hat) is **free**.

26

Friday's TeamUp Quiz

- For 10 minutes during Friday's class (around 11:30) every student should go on Microsoft Teams and someone (most recent Facilitator) should place a video call to all 3 or 4 members of your Pod-Chat.
- The first step is to decide who will be the TeamUp **Driver**
- All students must log-in to Quercus [You will now have three windows open: my zoom lecture, Microsoft Teams, and Quercus]
- Click on the TeamUp Quiz Module 2, click **Go To Tool**
- The Driver must Create a New Group, and obtain your pod's unique Group ID for this session.
- The Driver then shares the unique Group ID with the other pod members in Microsoft Teams, allowing them to join the newly established group.

27

Friday's TeamUp Quiz

Your Role as the Driver:

- The Driver acts as team leader, responsible for navigating the quiz , confirming the team's final agreed upon answer to a question, and submitting the completed quiz score to Quercus.
- The Driver has a steering wheel next to their ID.

Your Role as a Team Member:

- Team Members participate and choose their answers by chatting in Microsoft Teams, so all team mates can see what they have chosen, but they cannot submit their choices to Team Up!.

• If the answer is correct, you will be awarded the full score or "diamonds" for that question. (1 diamond = 1 homework credit)

• If your team's answer is not correct, discuss the question and choose again. You get fewer diamonds the more wrong answers you submit.

28

Before Class 13 on Friday

- Please read the first two sections of Chapter 5:
- 5.1 Motion on a Circular Path
- 5.2 Turning at Constant Speed is Acceleration!
- Plan to meet up with your Practical Pod during Friday's class – you should be able to turn on your microphone in order to participate in the TeamUp Quiz Module 2.
- If you cannot do the TeamUp quiz during class, it can be done either with your pod or on your own at any time over the weekend.

29