Discussion - 5

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Outline

1. Dynamics!

2. Applying Newton’s Laws

3. Various forms of Contact Forces
Newton’s Second Law

The most useful, since it tells us how to calculate acceleration.

Recall: In kinematics, we were given the acceleration. Second law tells us how to calculate it given the forces.

\[ \vec{F} = m\vec{a} \]  

(1)

In words: the acceleration...

- in magnitude, is proportional to the force
- is in the same direction as the force
- is lower if the mass is higher (more inertia)
Newton’s Second Law

The second law is a vector equation. So we can resolve it into components:

\[ F_x = ma_x \]  \quad (2)
\[ F_y = ma_y \]  \quad (3)

Units of Force

Force is measured in newtons (N).

\[ 1 \text{ N} = 1 \text{ kg} \text{ m s}^{-2} \]  \quad (4)
Newton’s Third Law

Every action has an equal and opposite reaction.

⇒ If you push the wall, the wall pushes you.

\[ \vec{F}_{12} = -\vec{F}_{21} \quad (5) \]
The four fundamental interactions

- **Electromagnetism** – chemical bonding, friction, springiness (upon pulling things)
- **Gravity** – solar system, keeps stars together in galaxies, large-scale structure of the universe

Not part of this course:
- **Strong** – keeps the nucleus together
- **Weak** – responsible for radioactivity (β-decay etc.)
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Taming the Second Law

Dynamics!
Applying Newton's Laws
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Taming the Second Law

Problem Solving Strategy:

- Start by drawing a figure, identify the forces
- Draw a free body diagram, mark the forces – magnitude and direction
- Choose a reference frame
- Resolve all forces into x and y components
- Use $\vec{F} = m\vec{a}$ to find the acceleration
- Use kinematics to answer any further questions about the motion
The key to applying Newton’s second law correctly to quantitative problems is practice and the attitude of not giving up till the problem is conquered.
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Contact Forces!

- Seen when things are in contact
- Wide in variety – but all the same
- Origin: Electromagnetic (sshh... and quantum mechanical)
Most contact forces are adjustable.
- They adjust the magnitude to satisfy some condition
- They have some “limits” to their adjustment

**WARNING**
In the following slides, I’m going to deviate from making “technically sound” and “precise” statements, and rely more on “intuition” and “common-sense” kinda understanding. Don’t take my comments too seriously. Thanks ;-}
String Tension

Model: Massless, Inextensible strings

Don’t get tensed!
- Massless inextensible strings “transmit” force equally from one end to another when fully stretched
- Direction: Use your intuition to fix the direction

Another view
The string is like a spring of infinite stiffness. Tries to pull the objects attached to its ends towards each other, if fully stretched.

How does it adjust?
String tensions adjust to prevent the string from stretching as much as possible, until the string snaps
A typical example involving string tensions – Atwood’s “machine”.

**Checking your answer**

See if your answer makes sense in the various cases. For the Atwood’s machine, the acceleration of the more massive block should be downward.
Normal Force

- Appears when one surface touches another
- Normal (perpendicular) to the surface of contact

How does it adjust?

Adjusts to prevent the solid surfaces from “passing through” each other, until the surface breaks
Friction

Model: When there is no relative motion, adjustable till saturation \((f_s = \mu_s N)\). \(\mu_k N\) when in relative motion.

- Appears when one surface touches another
- Tangential (parallel) to the surface of contact, opposing direction of relative motion (or attempted motion)

How does it adjust?
Adjusts to prevent the surfaces from sliding past each other, until it can “no longer hold”. Limit is \(\mu_s N\)
Springs


- **Magnitude:** $F_{\text{spring}} = -k \Delta x$
- Springs try to avoid a change in their “normal” state.
Infinitely stiff rods

- Stiff rods neither tolerate compression or expansion
- Like a spring with infinite stiffness

**How does it adjust?**
Adjusts to prevent the rod from compression or expansion, until the rod snaps
Rods of finite stiffness

- Will be taught later (or maybe not)
- Young’s modulus – a measure of “elasticity”. How prone is the rod to compression?
- Other elastic moduli
- The rod *compresses* and adjusts
- Modelled as “linear response”