Motion in Our Daily Lives

Emphasis on amusement parks, circular motion

What kind of motions do we feel?

- Aside from vibrations, don’t feel constant velocity
  - Earth moves 30,000 m/s around sun
    - only curves 3 mm toward sun each second, so compared to the 30,000 meters, you could say that our path is almost straight
- But we can feel acceleration
  - It’s that “visceral” feeling…
  - *vis*cera*al* adj. 1. Relating to, situated in, or affecting the viscera. 2. Perceived in or as if in the viscera.
  - *vis*cera* *pl.n.* 1. The soft internal organs of the body, especially those contained within the abdominal and thoracic cavities. 2. The intestines. [3. Your gut.]

Questions:

- Why do we feel acceleration? What is it about our *gut* that tells us we’re moving? What other organs in our body tell us we are accelerating?
  - Think in terms of amusement park rides, where acceleration is extreme (or like how my sister drives).
- Can you feel gravity when you’re sitting still? Standing? Laying down? Falling?

Motion in our lives

- We’ll ignore constant velocity: just like sitting still
  - boring
- But accelerating motion…
  - that’s where things get interesting
- Direction of acceleration is the same as the direction of net force
- Acceleration perpendicular to the velocity vector acts to change the direction of motion.
The Amusement Park: Acceleration Central

- Zero-\(g\) (no acceleration) motion
  - Free-fall, cresting roller coaster
- Linear acceleration
  - Log flume deceleration, roller coaster abrupt stop
- Directional changes (bread & butter of parks)
  - Curves of roller coaster, tilt-a-whirl, swings
  - Loops, crests, troughs of roller coasters
  - Spinning drum (pinned against wall)

Free fall

- By dropping a carriage, or by launching a car on a parabolic path, experience momentary zero-\(g\)
- You are accelerating downwards toward the earth, but no longer feel accelerated: don’t feel weight
  - Only lasts a brief moment: 15-story (45 m) drop only lasts about 3 seconds

NASA conducts zero-\(g\) flights lasting 30 seconds by flying a parabolic path in a plane that has come to be known as the “vomit comet”.

www.avweb.com/articles/vcomet/

Linear Acceleration (in velocity direction)

- This is the familiar stoplight acceleration along a straight line
- Zero to Sixty-Seven (30 m/s) in 5 seconds:
  - 30 m/s in 5 seconds means 6 m/s\(^2\) (~0.6g)
- Typical car acceleration, normal driving ~0.2g
- Fun activity: drive with helium balloons in car
  - They move into acceleration—counter-intuitive
  - They simply point the way a plumb bob hung from the rear-view mirror doesn’t

Questions:

- During which part of a roller coaster ride do you feel heaviest: at the bottom of a dip or at the crest of a hill? Where do you feel the lightest?
- If you’re in an elevator with an upward/downward acceleration rate of 1 m/s\(^2\) and you normally weigh 100 pounds, how much will you weigh when the elevator accelerates upwards? Downwards?
  - Assume gravity is 10 m/s\(^2\) for numerical simplicity
Curves, Centrifugal, Centripetal Forces

- Going around a curve smushes you against window
  - Understand this as inertia: you want to go straight

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your body wants to keep going straight
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but the car is accelerating towards the center of the curve

Car acceleration is \( v^2/r \)

\( \Rightarrow \) you think you're being accelerated by \( v^2/r \) relative to the car

Centripetal, Centrifugal Forces, continued

- The car is accelerated toward the center of the curve by a **centripetal** (center seeking) force
- In your reference frame of the car, you experience a "fake", or fictitious centrifugal "force"
  - Not a real force, just inertia relative to car’s acceleration

Pictorial “Derivation” of Centripetal Acceleration

- In uniform circular motion the acceleration is constant, directed towards the center. The velocity has constant magnitude, and is tangent to the path.

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a = v^2/r (r is radius of curve)
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Rotating Drum Ride

- Vertical drum rotates, you’re pressed against wall
  - Friction force against wall matches gravity
  - Seem to stick to wall, feel very heavy

The forces real and perceived

- Real Forces:
  - Friction: up
  - Centripetal: inwards
  - Gravity (weight): down

- Perceived Forces:
  - Centrifugal: outwards
  - Gravity (weight): down
  - Perceived weight: down and out
Works in vertical direction too…

- Roller coaster loops:
  - Loop accelerates you downward (at top) with acceleration greater than gravity
  - You are “pulled” into the floor, train stays on track
    - it’s actually the train being pulled into you!

Sustained vertical spinning

- Ever wonder what a bike tire feels like?
- At constant speed, the centripetal acceleration is constant \( \frac{v^2}{r} \), but the direction of gravity keeps changing!
- Feel heavier at bottom than at top
- This ride definitely turns your world around!

Old-Fashioned Swings

- The angle of the ropes tells us where the forces are:
  - Ropes and gravity pull on swingers
  - If no vertical motions (level swing), vertical forces cancel
  - Only thing left is horizontal component pointing toward center: centripetal force
- Centripetal force is just \( m\frac{v^2}{r} \) \((F = ma; a = \frac{v^2}{r})\)

Airplanes in high-g turn

- Airplanes don’t have “rubber on the road”, so no friction to keep them from going sideways around turns
- Wings produce lift force, so proper bank angle supplies necessary horizontal component of force to produce turn

Pilot accelerated by orange (lift) vector, feels heavier than normal.
In this case, pilot feels about 3 g’s (orange arrow about 3 times longer than gravity arrow)
What about our circular motions on Earth?

- Earth revolves on its axis once per day
- Earth moves in (roughly) a circle about the sun
- What are the accelerations produced by these motions, and why don’t we feel them?

Earth Rotation

- Velocity at equator: \(2\pi r / (86,400 \text{ sec}) = 463 \text{ m/s}\)
- \(v^2/r = 0.034 \text{ m/s}^2\)
  - \(~300\) times weaker than gravity, which is 9.8 m/s^2
- Makes you feel lighter by 0.3% than if not rotating
- No rotation at north pole → no reduction in \(g\)
- If you weigh 150 pounds at north pole, you’ll weigh 149.5 pounds at the equator
  - actually, effect is even more pronounced than this (by another half-pound) owing to stronger gravity at pole: earth’s oblate shape is the reason for this

Earth Orbit

- The earth is also traveling in an orbit around the sun
  - \(v = 30,000 \text{ m/s}, r = 1.5 \times 10^{11} \text{ m} \rightarrow v^2/r = 0.006 \text{ m/s}^2\)
  - but gravitational acceleration on our bodies from the sun is exactly this same amount.
    - in other words, the acceleration that makes the earth accelerate in a circular orbit also acts on us directly, causing us to want to follow the same path as earth
    - this is to be contrasted with the car going around a curve, in which friction between pavement and tires applies a force on the car, but not on us directly, causing us to want to go straight
  - another way to say this: we are in free-fall around the sun

Assignments

  - may benefit you to look at them early, or even do them
- Review Session TBA
- Exam mostly MC/TF, some short answer
- Need:
  - scantron (light green; form # X-101864-PARL)
  - No. 2 pencil
  - calculator of any type
  - sit with one empty seat between yourself and nearest neighbor