PHY131H1F Summer – Class 7 (there was no 6…)

Today:
- Action / Reaction Pairs
- Newton's Third Law
- Ropes and Pulleys
- Dynamics in Two Dimensions
- Dynamics of Uniform Circular Motion
- Numerical Approximation with Python

Pre-class Reading Quiz. (Chapter 7)

Newton's Third Law States

A. Any object at rest or moving with a constant velocity will continue to stay at rest or move with a constant velocity unless acted upon by a net outside force.
B. The acceleration of an object is proportional to the net force on it, and inversely proportional to the object's mass.
C. If object 1 exerts a force on object 2, object 2 exerts an equal and opposite force on object 1.
D. All bodies attract one another with a force that is proportional to the product of their masses, and inversely proportional to the square of the distance between them.

Pre-class Reading Quiz. (Chapter 8)

For uniform circular motion, the net force

A. points toward the center of the circle.
B. points toward the outside of the circle.
C. is tangent to the circle.
D. is zero.

- This net force is called the ***centripetal force***
- Without it, the object would move in a straight line, not a circle!

3 Newton's Third Law

If object 1 acts on object 2 with a force, then object 2 acts on object 1 with an equal force in the opposite direction.

$$\vec{F}_{1\text{ on }2} = -\vec{F}_{2\text{ on }1}$$

FIGURE 7.1 The hammer and nail are interacting with each other.

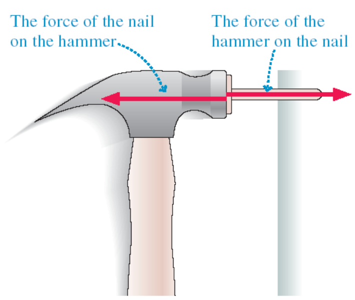
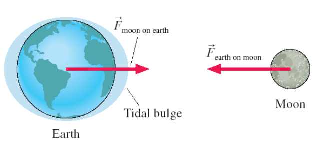
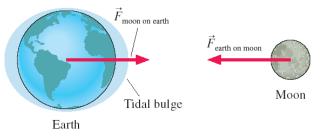


FIGURE 7.3 The ocean tides are an indication of the long-range gravitational interaction of the earth and the moon.



- The entire Earth accelerates toward the Moon, due to this pulling force.
- To find the total acceleration, you use the force as calculated for the centre-to-centre distance.
- Since $F_G = GMm/r^2$, the force on the ocean nearer to the moon will be greater, so it will accelerate more than the rest of the Earth, bulging out.

FIGURE 7.3 The ocean tides are an indication of the long-range gravitational interaction of the earth and the moon.



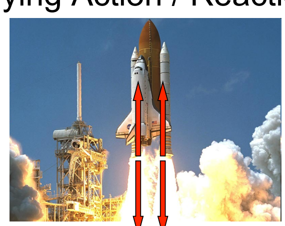
- Similarly, since $F_G = GMm/r^2$, the force on the ocean further from the moon will be less, so it will accelerate ***less*** than the rest of the Earth, remaining behind, forming a bulge.
- In general, tidal effects tend to ***stretch*** objects both toward and away from the object causing the tides.

Identifying Action / Reaction Pairs

- Consider an accelerating car.
- **Action:** tire pushes on road.
- **Reaction:** road pushes on tire

Both of these forces are static friction.

Identifying Action / Reaction Pairs



- Consider a rocket accelerating upward.
- **Action:** rocket pushes on gas.
- **Reaction:** gas pushes on rocket

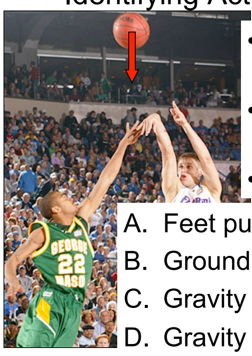
Both of these forces are due to gas pressure.

Identifying Action / Reaction Pairs

- **Action force:** man pulls on rope to the left.
- **Reaction force?**

A. Feet push on ground to the right.
B. Ground pushes on feet to the left.
C. Rope pulls on man to the right.
D. Gravity of Earth pulls man down.
E. Gravity of man pulls Earth up.

Identifying Action / Reaction Pairs

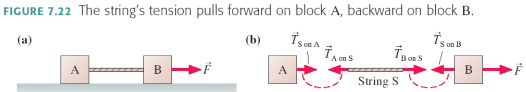


- Consider a basketball in freefall.
- **Action force:** gravity of Earth pulls ball down.
- **Reaction force?**

A. Feet push ground down.
B. Ground pushes feet up.
C. Gravity of Earth pulls man down.
D. Gravity of ball pulls Earth up.
E. Air pushes ball up.

The Massless String Approximation

FIGURE 7.22 The string's tension pulls forward on block A, backward on block B.



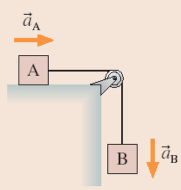
Often in physics problems the mass of the string or rope is much less than the masses of the objects that it connects. In such cases, we can adopt the following **massless string approximation**:

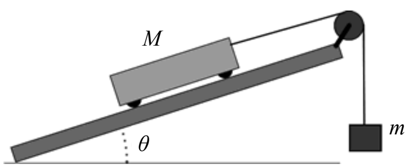
$$T_{B \text{ on } S} = T_{A \text{ on } S} \qquad \text{(massless string approximation)}$$

Pulleys

Acceleration constraints

Objects that are constrained to move together must have accelerations of equal magnitude: $a_A = a_B$. This must be expressed in terms of components, such as $a_{Ax} = -a_{By}$.



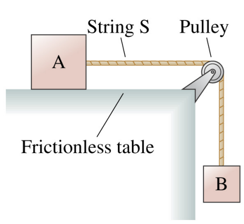


Example

A cart of mass M is on a track which is at an angle of θ above the horizontal. Rolling friction between the cart and the track is negligible.
The cart is attached to a string which goes over a pulley; the other end of the string is attached to a hanging mass, m. The mass of the string and pulley are both negligible. The friction in the pulley is negligible.
What is the acceleration of the cart?

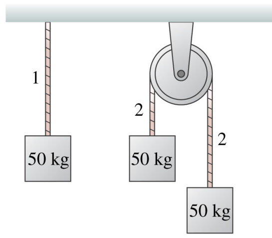
In the figure to the right, is the tension in the string greater than, less than, or equal to the force of gravity on block B?

A. Equal to
B. Greater than
C. Less than



All three 50 kg blocks are at rest. Is the tension in rope 2 greater than, less than, or equal to the tension in rope 1?

A. Equal to
B. Greater than
C. Less than



Chapter 8

Dynamics in Two Dimensions

Suppose the x- and y-components of acceleration are *independent* of each other. That is, a_x does not depend on y or v_y, and a_y does not depend on x or v_x.
You can then use Newton's second law in component form:

$$(F_{net})_x = \sum F_x = ma_x \quad \text{and} \quad (F_{net})_y = \sum F_y = ma_y$$

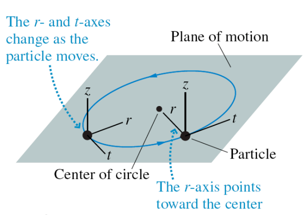
The force components (including proper signs) are found from the free-body diagram. The kinematics equations apply to the x and y components, ie:

$$x_f = x_i + v_{ix}\Delta t + \tfrac{1}{2}a_x(\Delta t)^2 \qquad y_f = y_i + v_{iy}\Delta t + \tfrac{1}{2}a_y(\Delta t)^2$$

$$v_{fx} = v_{ix} + a_x\Delta t \qquad v_{fy} = v_{iy} + a_y\Delta t$$

Uniform Circular Motion

FIGURE 8.3 The *rtz*-coordinate system.



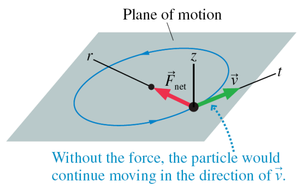
$$a_r = \frac{v^2}{r} = \omega^2 r$$

$$a_t = 0$$

$$a_z = 0$$

Dynamics of Uniform Circular Motion

FIGURE 8.6 The net force points in the radial direction, toward the center of the circle.



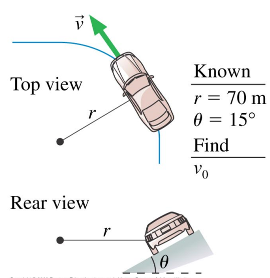
$$(F_{net})_r = \sum F_r = ma_r = \frac{mv^2}{r} = m\omega^2 r$$

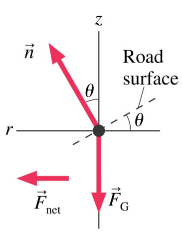
$$(F_{net})_t = \sum F_t = ma_t = 0$$

$$(F_{net})_z = \sum F_z = ma_z = 0$$

Example 8.5, pg.217

- A highway curve of radius 70 m is banked at a 15° angle. At what speed v_0 can a car take this curve without assistance from friction?

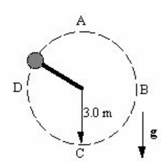




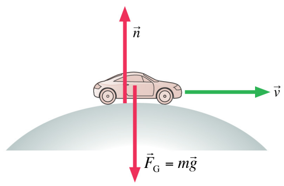
Vertical Circular Motion

- A ball is whirled on a string in a vertical circle. As it is going around, the tension in the string is

A. greatest at the top of the motion
B. constant.
C. greatest at the bottom of the motion
D. greatest somewhere in between the top and bottom.

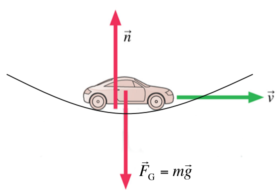


A car is rolling over the top of a hill at speed *v*. At this instant,



A. $n > F_G$.
B. $n < F_G$.
C. $n = F_G$.
D. We can't tell about n without knowing v.

A car is driving at the bottom of a valley at speed *v*. At this instant,



A. $n > F_G$.
B. $n < F_G$.
C. $n = F_G$.
D. We can't tell about n without knowing v.

Projectile Motion

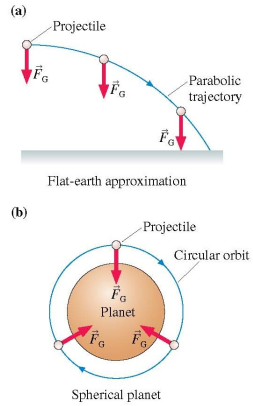
In the absence of air resistance, a projectile has only one force acting on it: the gravitational force, $F_G = mg$, in the downward direction. If we choose a coordinate system with a vertical y-axis, then

$$\vec{F}_G = -mg\hat{j}$$

$$a_x = \frac{(F_G)_x}{m} = 0$$

$$a_y = \frac{(F_G)_y}{m} = -g$$

The vertical motion is free fall, while the horizontal motion is one of constant velocity.



Circular Orbits

An object moving in a circular orbit of radius r at speed v_{orbit} will have centripetal acceleration of

$$a_r = \frac{(v_{\text{orbit}})^2}{r} = g$$

That is, if an object moves parallel to the surface with the speed

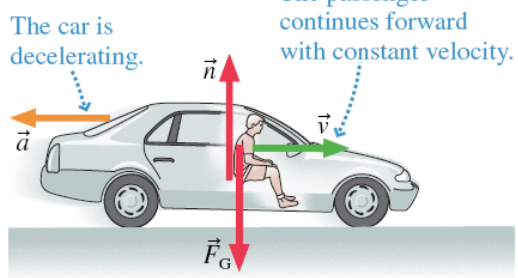
$$v_{\text{orbit}} = \sqrt{rg}$$

then the free-fall acceleration provides exactly the centripetal acceleration needed for a circular orbit of radius r. An object with any other speed will not follow a circular orbit.

Fictitious Forces

- If you are riding in a car that makes a sudden stop, you may feel as if a force "throws" you forward toward the windshield.
- There really is no such force.
- The real force is the backwards force of the dashboard on you when you hit it.
- Some books (not Knight) describe the experience in terms of what are called **fictitious forces**.
- These are not real, but they help describe motion *in a noninertial reference frame.*
- Knight avoids fictitious forces by doing all the calculations in inertial frames (better).

• This is what *really* happens in a sudden stop (no forward forces on passenger):



Inertial reference frame of the ground

"Centrifugal Force" (a fictitious force)

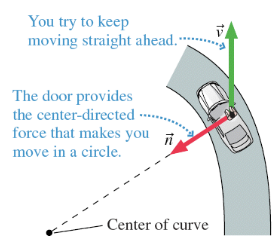
• If the car you are in turns a corner quickly, you feel "thrown" against the door.

• The fictitious "force" that seems to push an object to the outside of a circle is called the "*centrifugal force*".

• It helps describe your experience *relative to a noninertial reference frame*.

• In the inertial frame of the ground, the only real force is toward the centre not away.

Reality: Bird's-eye view of a passenger as a car turns a corner.



Why Does the Water Stay in my coffee cup?

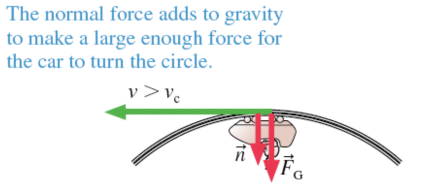
• Watch Harlow swing a cup of water over his head. If he swings the cup quickly, the water stays in. But the students in the front row will get a shower if he swings too slowly.

•The critical angular velocity ω_c is that at which gravity alone is sufficient to cause circular motion at the top.

$$\omega_c = \sqrt{\frac{g}{r}}$$

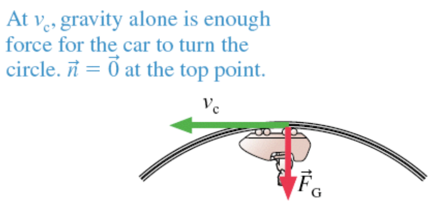
More than enough angular speed

FIGURE 8.18 A roller coaster car at the top of the loop.

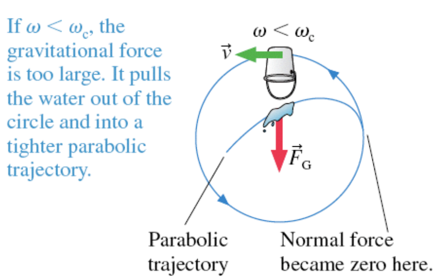


The point is: Normal force must always be *away* from the surface. It can never be *toward* the surface (unless the surface is covered with glue!)

Just enough angular speed



Not enough angular speed



Before Next Class:

- Read Chapter 9 of Knight and Chapter 10 sections 10.1 to 10.5.
- Complete MasteringPhysics.com Problem Set 5 due by tomorrow at 11:59pm
- Something to think about:
- Consider a car accident in which a car, initially traveling at 50 km/hr, collides with a large, massive bridge support.
- The car comes to an abrupt stop, and so does its only occupant, the driver (who is intoxicated).
- The airbag inflates, saving the driver.
- Why is the force of the hard plastic steering wheel greater than the force of the airbag in stopping the driver?