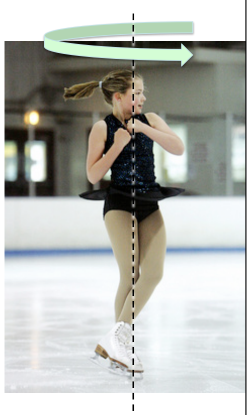
PHY131H1S - Class 19

Today:

- Angular Velocity Vector
- Angular Momentum
- Review of chapters 5 to 12
- Test 2 tomorrow at 8pm on chapters 5 though 12, including what is discussed in class today



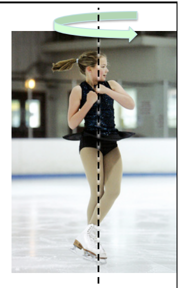
Ch.12 reading quiz:

- If a figure skater pulls in her arms while rotating, what happens to her angular speed ω?

A. ω decreases

B. ω increases

C. ω stays the same



Static Equilibrium Problems

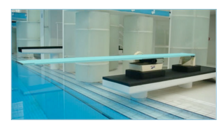
- In equilibrium, an object has no net force and no net torque.
- Draw an extended free-body diagram that shows where each force acts on the object.
- Set up x and y axes, and choose a rotation axis. All of these choices should be done to simplify your calculations.
- Each force has an x and y component and a torque. Sum all of these up.
- Three equations which you can use are:

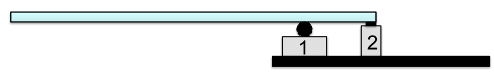
$$\sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum \tau = 0$$

Static Equilibrium Question

Remember from last time:

A diving board has two supports, 1 and 2. What are the directions of the forces of these supports on the diving board?





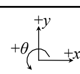
A. Both forces are up

B. Both forces are down

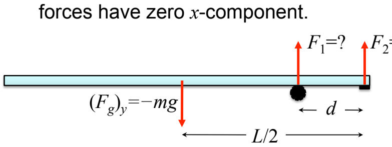
C. F_1 is up, F_2 is down

D. F_1 is down, F_2 is up

Static Equilibrium Question, choose:



$\sum F_x = 0$ can be satisfied by requiring that all forces have zero x-component.



Choose pivot point = support 1

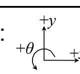
$\sum \tau = 0$ means $mg(L/2 - d) + F_2 d = 0 \Longrightarrow F_2 = -\frac{mg(L/2-d)}{d}$

So F_2 must be negative, or down.

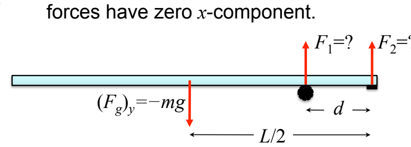
$\sum F_y = 0$ means $F_1 + F_2 - mg = 0 \Longrightarrow F_1 = mg - F_2$

So F_1 must be positive, or up.

Static Equilibrium Question, choose:



$\sum F_x = 0$ can be satisfied by requiring that all forces have zero x-component.



Choose pivot point = support 2

$\sum \tau = 0$ means $mgL/2 - F_1 d = 0 \Longrightarrow F_1 = mgL/(2d)$

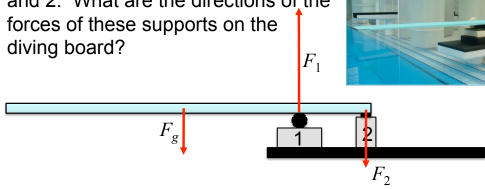
So F_1 must be positive, or up.

$\sum F_y = 0$ means $F_1 + F_2 - mg = 0 \Longrightarrow F_2 = mg - mgL/(2d)$

Since $L > 2d$, F_{12} must be negative, or down.

Remember from last time: Equilibrium Question

A diving board has two supports, 1 and 2. What are the directions of the forces of these supports on the diving board?



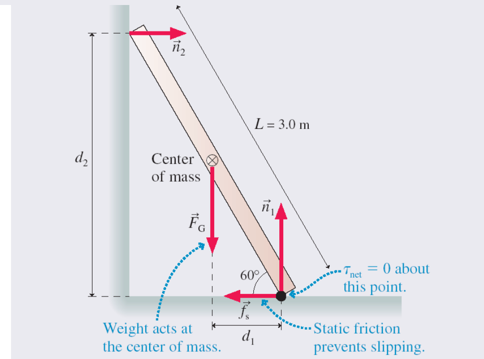
A. Both forces are up

B. Both forces are down

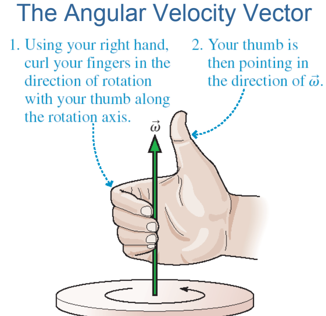
C. F_1 is up, F_2 is down

D. F_1 is down, F_2 is up

A 3.0-m-long ladder leans against a frictionless wall at an angle of 60°. What is the minimum value of μ_s, the coefficient of static friction with the ground, that prevents the ladder from slipping?



The Angular Velocity Vector

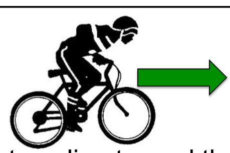


- The magnitude of the angular velocity vector is ω.
- The angular velocity vector points along the axis of rotation in the direction given by the right-hand rule as illustrated above.

Linear / Rotational Analogy

Linear	Rotational Analogy
$\vec{s}$, $\vec{v}$, $\vec{a}$	θ, ω, α
Force: $\vec{F}$	Torque: τ
Mass: m	Moment of Inertia: I

- Newton's 2nd law: $\vec{a} = \dfrac{\vec{F}_{net}}{m}$ $\qquad$ $\alpha = \dfrac{\tau_{net}}{I}$
- Kinetic energy: $K_{cm} = \dfrac{1}{2}mv^2$ $\qquad$ $K_{rot} = \dfrac{1}{2}I\omega^2$
- Momentum: $\vec{p} = m\vec{v}$ $\qquad$ $\vec{L} = I\vec{\omega}$



- A bicycle is traveling toward the right.
- What is the direction of the angular momentum of the wheels?

A. left

B. right

C. into page

D. out of page

E. up

The Law of Conservation of Momentum

- If there is no net external force on a system, then its momentum is a constant.

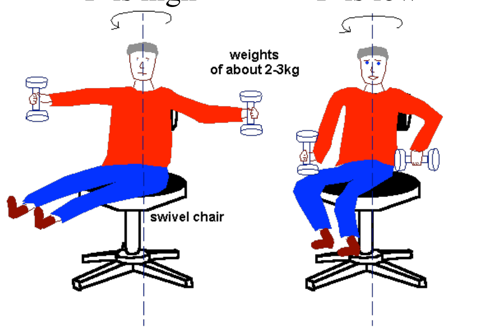
The Law of Conservation of Energy

- If there is no work or heat being exchanged with a system and its surroundings, then its energy is constant.

The Law of Conservation of Angular Momentum

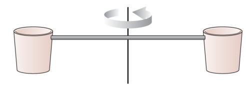
- If there is no net external torque on a system, then its angular momentum is a constant.

I is high I is low



$\vec{L} = I\vec{\omega}$ is constant when there are no external torques.

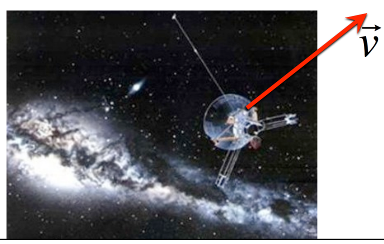
Two buckets spin around in a horizontal circle on frictionless bearings. Suddenly, it starts to rain. As a result,



A. The buckets speed up because the potential energy of the rain is transformed into kinetic energy.
B. The buckets continue to rotate at constant angular velocity because the rain is falling vertically while the buckets move in a horizontal plane.
C. The buckets slow down because the angular momentum of the bucket + rain system is conserved.
D. The buckets continue to rotate at constant angular velocity because the total mechanical energy of the bucket + rain system is conserved.
E. None of the above.

1 Newton's First Law

The natural state of an object with no net external force on it is to either remain at rest or continue to move in a straight line with a constant velocity.



2 Newton's Second Law

The acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass.

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$

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.

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

4 Newton's Universal Law of Gravitation

Two particles of mass m_1 and m_2, a distance r apart, will experience an attractive force:

$$F_{1\text{ on }2} = F_{2\text{ on }1} = \frac{Gm_1m_2}{r^2}$$

where $G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2}. Near the surface of the Earth, the dominant source of gravity is from the Earth itself. On an object of mass, m, this force is:

$$\vec{F}_G = (mg, \text{straight down})$$

where $g = 9.80$ N kg^{-1}.

- Consider a basketball in freefall.
- **Action:** Earth pulls down on ball
- **Reaction:** ball pulls up on Earth, with equal force. But the acceleration is not equal.

$$a = \frac{F_{net}}{m}$$

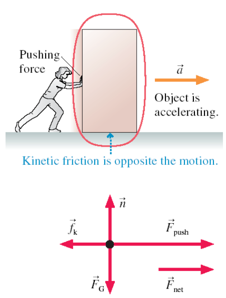
$$a = \frac{F_{net}}{m}$$

Fictitious Forces

- WARNING: Newton's Laws only apply in a "inertial reference frames". They are not valid if your reference frame is accelerating!
- An **inertial reference frame** is one that is not accelerating.
- If you are in a reference frame that is accelerating at $+a$, your own inertia will cause you to accelerate relative to this frame at $-a$. If you try to use Newton's laws in this accelerating frame, you must add a fictitious force of $-ma$ to each object of mass m in the frame.
- Centrifugal force is an example of a fictitious force.
- The equivalence principle states that the force of gravity is similar to a fictitious force; being in this gravitational field is *equivalent* to accelerating upward at $+9.8\ \mathrm{m/s^2}$.

Kinetic Friction

FIGURE 6.13 The kinetic friction force is opposite the direction of motion.



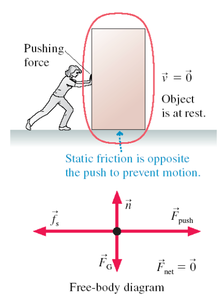
When two surfaces slide against one another, the size of the normal force is related to the size of the kinetic friction force. Many experiments show the following approximate relation:

$$f_k = \mu_k n$$

where n is the magnitude of the normal force, and the proportionality constant μ_k is called the "coefficient of kinetic friction".

Static Friction

FIGURE 6.11 Static friction keeps an object from slipping.



Example: The box is in static equilibrium, so the static friction must exactly balance the pushing force:

$$f_s = F_{push}$$

This is not a general, "all-purpose" equation. It is found from looking at the free body diagram and applying horizontal equilibrium, since $a_x = 0$.

Static Friction

- There's a limit to how big f_s can get. If you push hard enough, the object slips and starts to move. In other words, the static friction force has a *maximum* possible size $f_{s\,max}$.
- The two surfaces don't slip against each other as long as $f_s \le f_{s\,max}$.
- A static friction force $f_s > f_{s\,max}$ is not physically possible. Many experiments have shown the following approximate relation usually holds:

$$f_{s\,max} = \mu_s n$$

where n is the magnitude of the normal force, and the proportionality constant μ_s is called the "coefficient of static friction".

A box of mass 100 kg is in the back of a truck. The truck is accelerating to the right at 3.0 m/s². The box does not slide. The coefficient of static friction between the box and the floor of the truck is μ_s = 1.0. What is the magnitude of the force of static friction on the box?

A. Equal to 980 N
B. Equal to 300 N
C. less or equal to 980 N
D. less or equal to 300 N
E. not enough information to determine

- Test 2 tomorrow evening at 8:00pm on Chs. 5-12
- Don't forget: calculator, aid sheet and T-card

Mon

	Group	Room
1:00	M2A	EX 100
	M2B	EX 320
3:00	M3A	EX 320
	M3B	EX 320

Tue

	Group	Room
10:00	T1A	EX 200
	T1B	EX 200
1:00	T2A	EX 200
	T2B	EX 100
3:00	T3A	EX 200
	T3B	EX 200

Wed

	Group	Room
1:00	W2A	EX 310
	W2B	EX 200
3:00	W3A	EX 200
	W3B	EX 200
6:00	W4A	EX 100
	W4B	EX 200

Thu

	Group	Room
10:00	R1A	EX 200
12:00	R2A	EX 200
	R2B	EX 100
2:00	R3A	EX 310
	R3B	EX 310

Fri

	Group	Room
10:00	F1A	EX 100
	F1B	EX 100
12:00	F2A	EX 100
2:00	F3A	EX 100
	F3B	EX 100