

# Active Learning and Interactive Teaching: Peer Instruction



2020 Pedagogy Buffet  
Wesleyan University  
Middletown, CT, 21 January 2020





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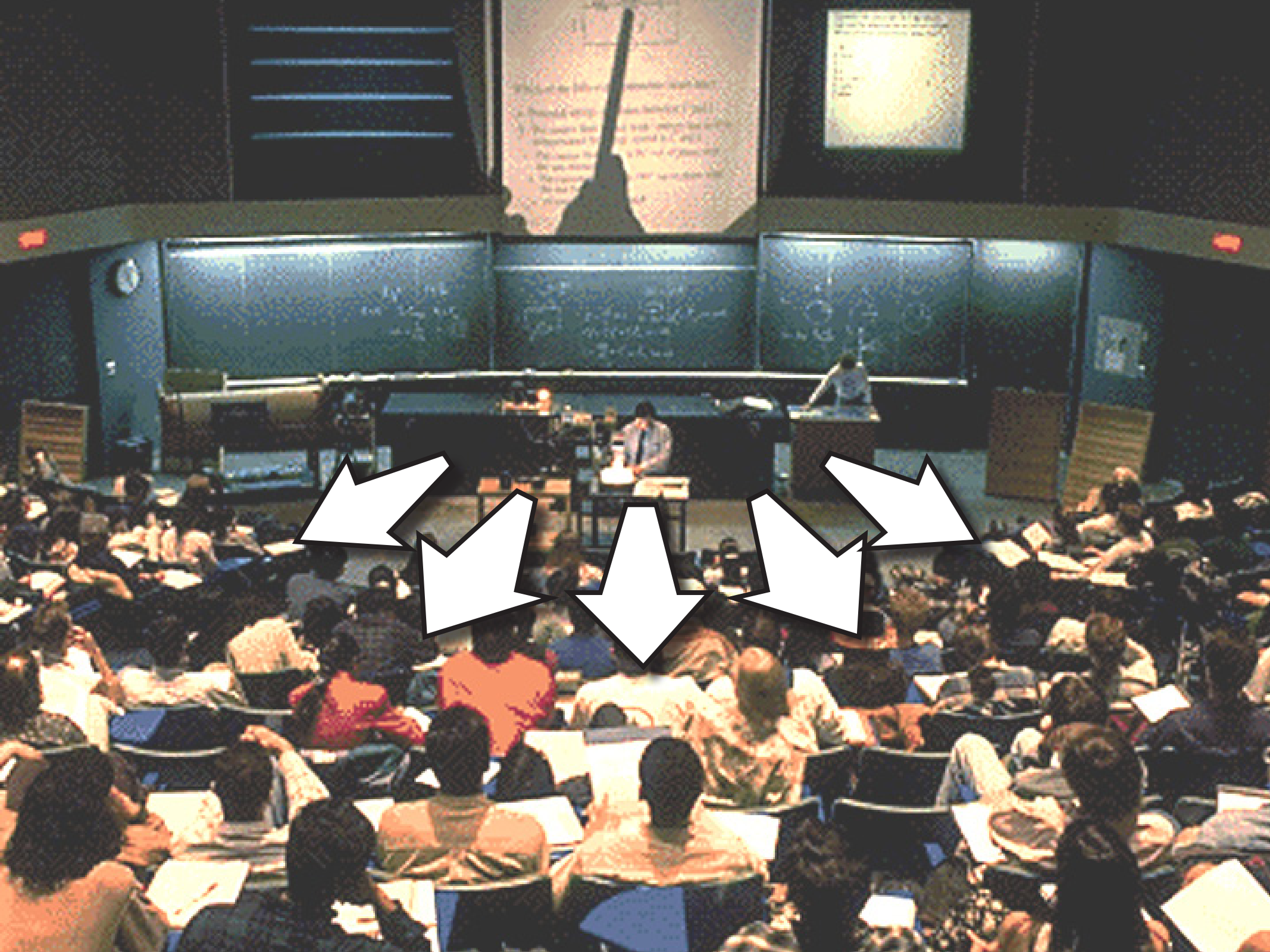




















**an illusion. . .**









# **1. transfer of information**





**1. transfer of information**

**2. assimilation of that information**





**1. transfer of information (in class)**

**2. assimilation of that information**





1. transfer of information (in class)

2. assimilation of that information (out of class)





**Should focus  
on THIS!**

1. transfer of information (in class)

**2. assimilation of that information (out of class)**





**1. transfer of information (in class)**

**2. assimilation of that information (out of class)**





**1. transfer of information (out of class)**

**2. assimilation of that information (in class)**



The word "Peer" is written in a large, white, sans-serif font with a light blue outline. A dashed yellow line with an arrow at the end forms a circle around the two 'e's. A dotted blue line with an arrow at the end starts from the right side of the word and points towards the bottom right.

# Peer

**1. transfer of information (out of class)**

**2. assimilation of that information (in class)**

The word "INSTRUCTION" is written in a white, sans-serif font, tilted at an angle. A dotted blue line with an arrow at the end starts from the top left and points towards the word. A dashed yellow line with an arrow at the end starts from the bottom left and points towards the word.

# INSTRUCTION



**question**



**question**



**think**



**question**



**think**



**poll**



**question**



**think**



**poll**



**discuss**



**question**



**think**



**poll**



**discuss**



**repoll**



**question**



**think**



**poll**



**discuss**



**repoll**



**explain**



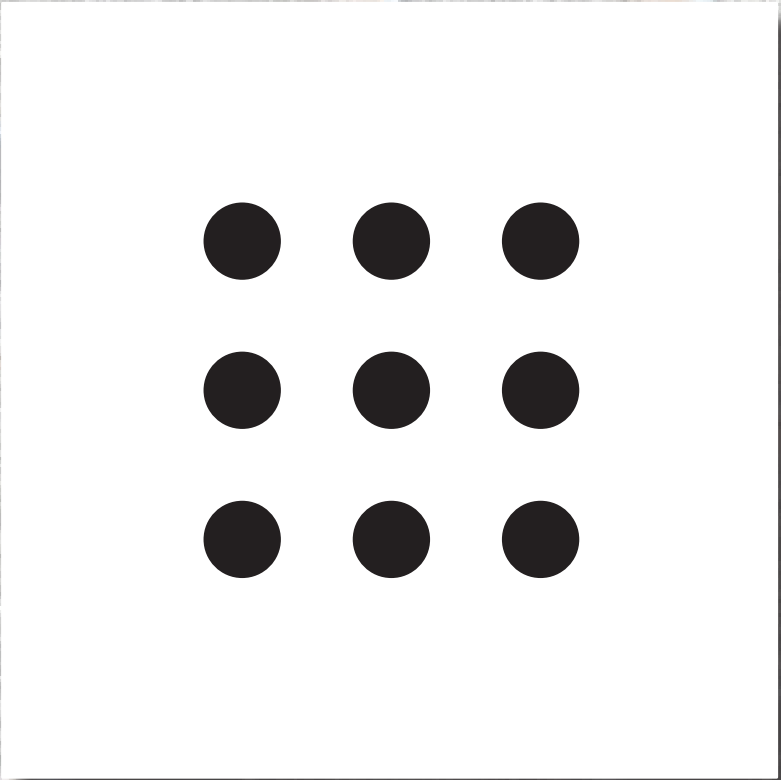
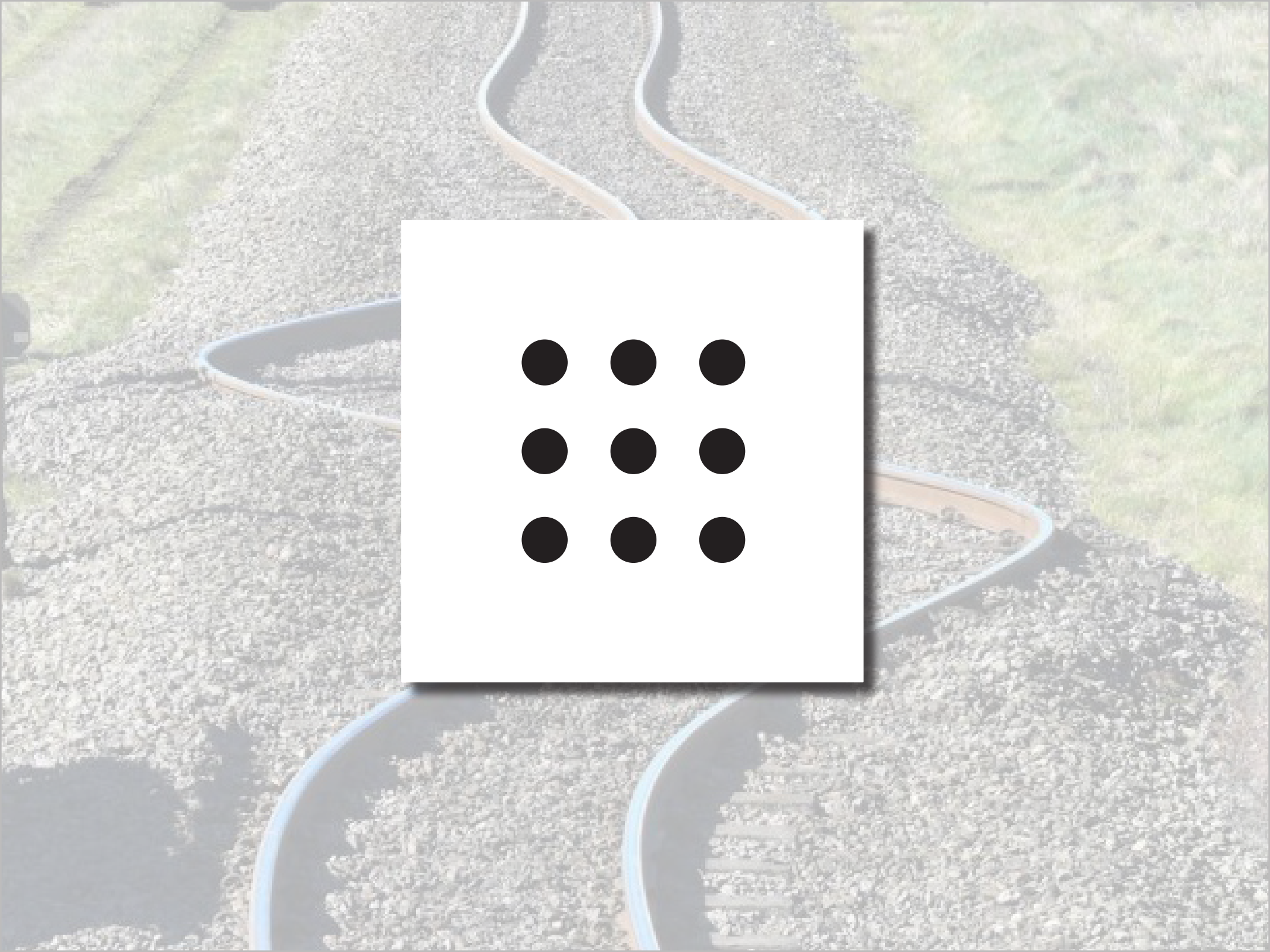




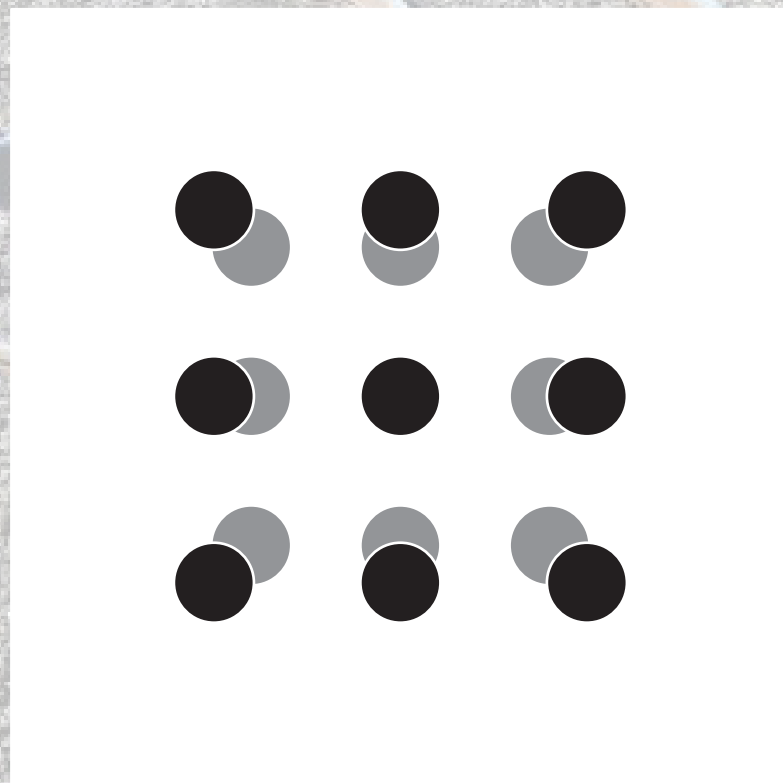


A photograph of a railway track with a wavy, undulating path, illustrating the concept of thermal expansion. The track is made of gravel and has a blue line painted along its length. The track is set against a background of green grass. The text "thermal expansion" is overlaid on the image.

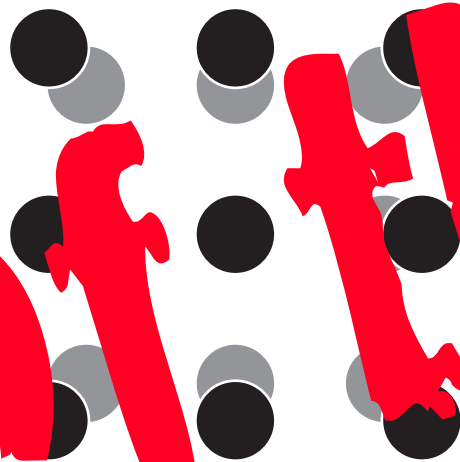
**thermal expansion**







**all of them**



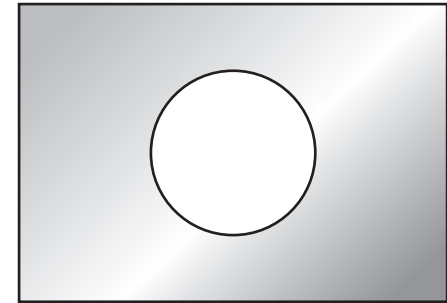


**Consider a rectangular metal plate  
with a circular hole in it.**



**Consider a rectangular metal plate with a circular hole in it.**

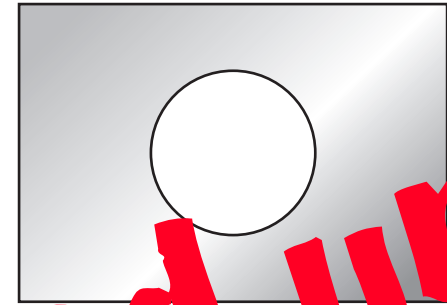
**When the plate is uniformly heated, the diameter of the hole**



- 1. increases.**
- 2. stays the same.**
- 3. decreases.**



Consider a rectangular metal plate with a circular hole in it.



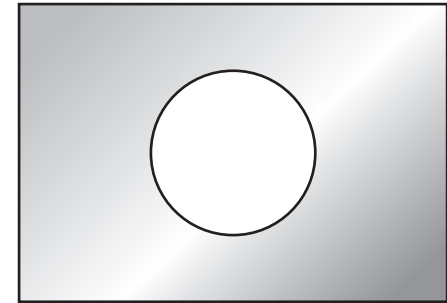
When the plate is uniformly heated, the diameter of the hole

1. increases.
2. stays the same.
3. decreases.

**you got all fired up!**

**Consider a rectangular metal plate with a circular hole in it.**

**When the plate is uniformly heated, the diameter of the hole**



- 1. increases.**
- 2. stays the same.**
- 3. decreases.**



**Before I tell you the answer, let's analyze what happened.**

**Before I tell you the answer, let's analyze what happened.**

**You...**



**Before I tell you the answer, let's analyze what happened.**

**You...**

**1. made a commitment**

**Before I tell you the answer, let's analyze what happened.**

**You...**

- 1. made a commitment**
- 2. externalized your answer**



**Before I tell you the answer, let's analyze what happened.**

**You...**

- 1. made a commitment**
- 2. externalized your answer**
- 3. moved from the answer/fact to reasoning**

**Before I tell you the answer, let's analyze what happened.**

**You...**

- 1. made a commitment**
- 2. externalized your answer**
- 3. moved from the answer/fact to reasoning**
- 4. became emotionally invested in the learning process**



**Consider a rectangular metal plate with a circular hole in it.**



**When the plate is uniformly heated, the diameter of the hole**

- 1. increases.**
- 2. stays the same.**
- 3. decreases.**

**Consider a rectangular metal plate with a circular hole in it.**

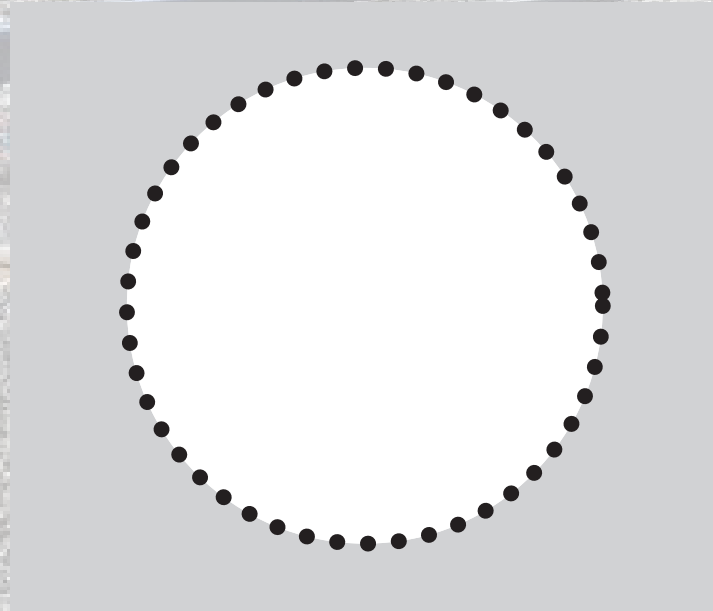


**When the plate is uniformly heated, the diameter of the hole**

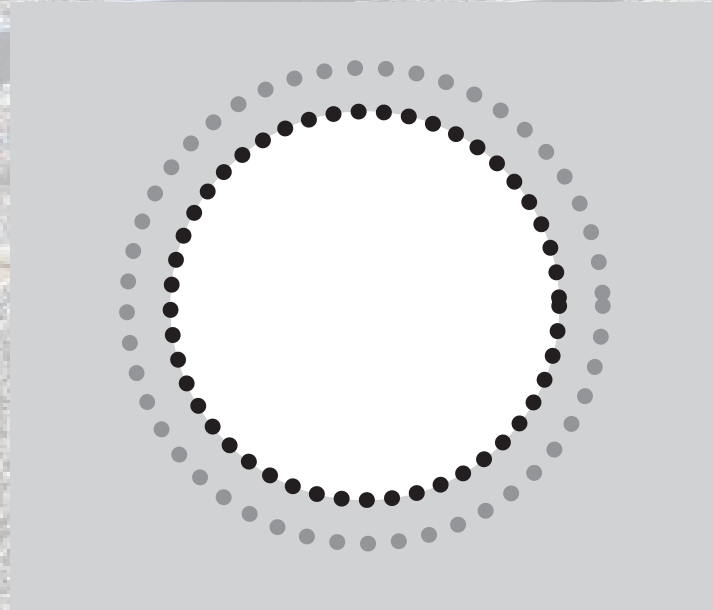
- 1. increases. ✓**
- 2. stays the same.
- 3. decreases.



**consider atoms at rim of hole**

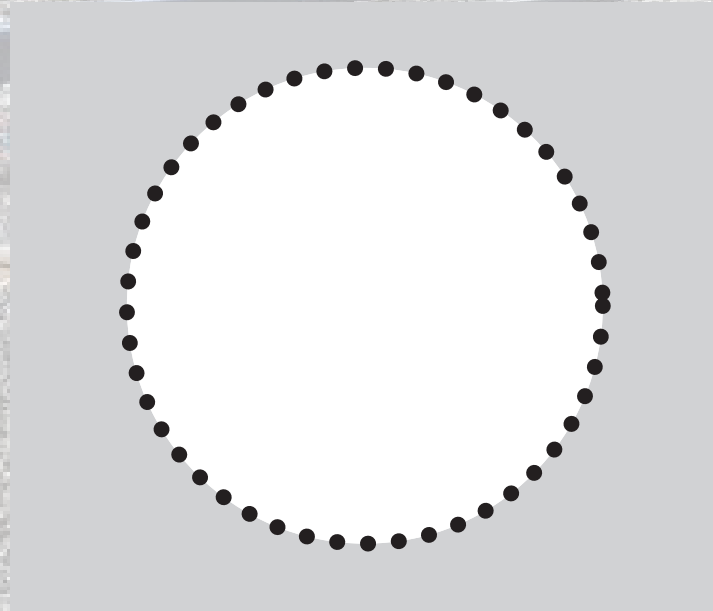


**consider atoms at rim of hole**

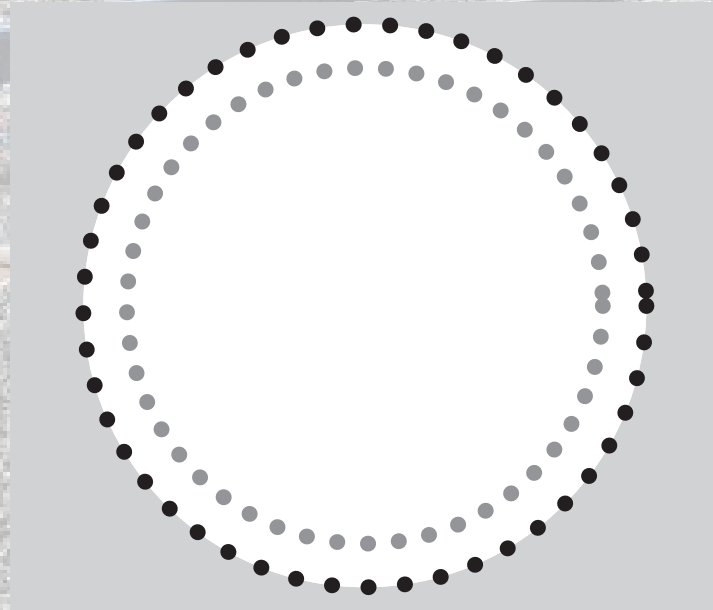




**consider atoms at rim of hole**



**consider atoms at rim of hole**



consider atoms at rim of hole

**you won't forget this**



The image features a light red background with a diagonal split into a light blue section on the left and a light red section on the right. The word 'Peer' is written in a large, white, sans-serif font, tilted upwards from left to right. A dashed yellow line with a yellow arrowhead at its end curves around the 'ee' portion of the word. Below 'Peer', the words 'back to pl' are written in a bold, red, sans-serif font, also tilted upwards. A dotted blue line starts near the end of 'back to pl' and extends diagonally down towards the word 'INSTRUCTION'. The word 'INSTRUCTION' is written in a white, sans-serif font, tilted upwards, and is positioned below the dotted blue line. A dashed yellow line with a yellow arrowhead at its end starts near the bottom left and points towards the word 'INSTRUCTION'.

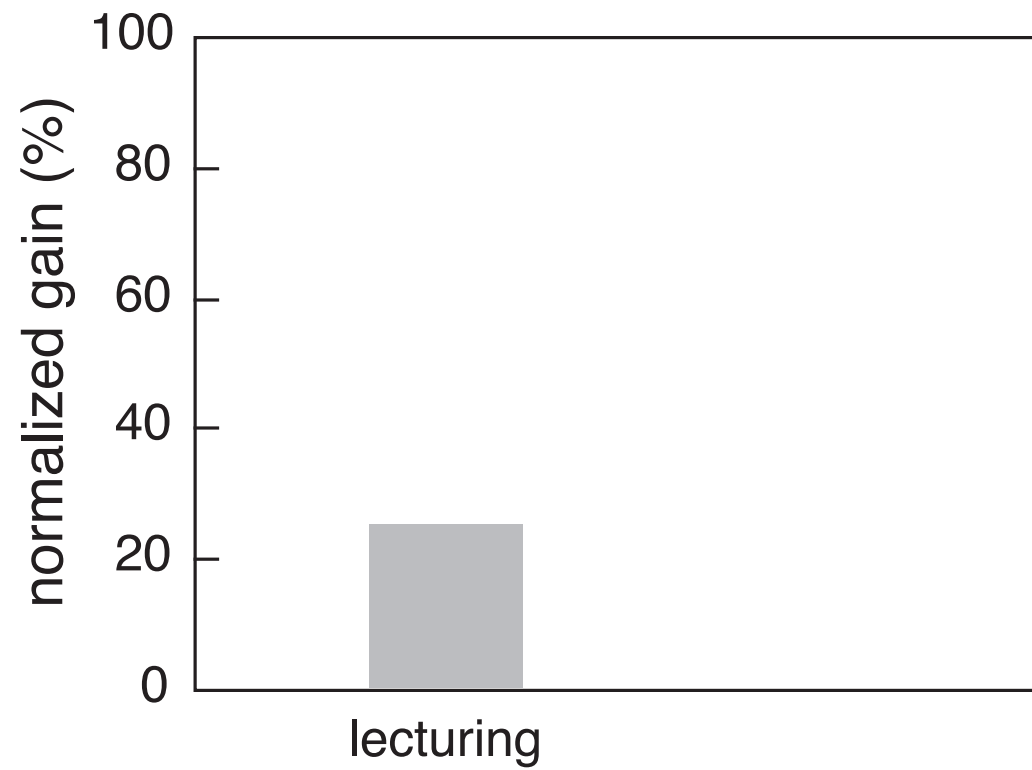
Peer

back to pl

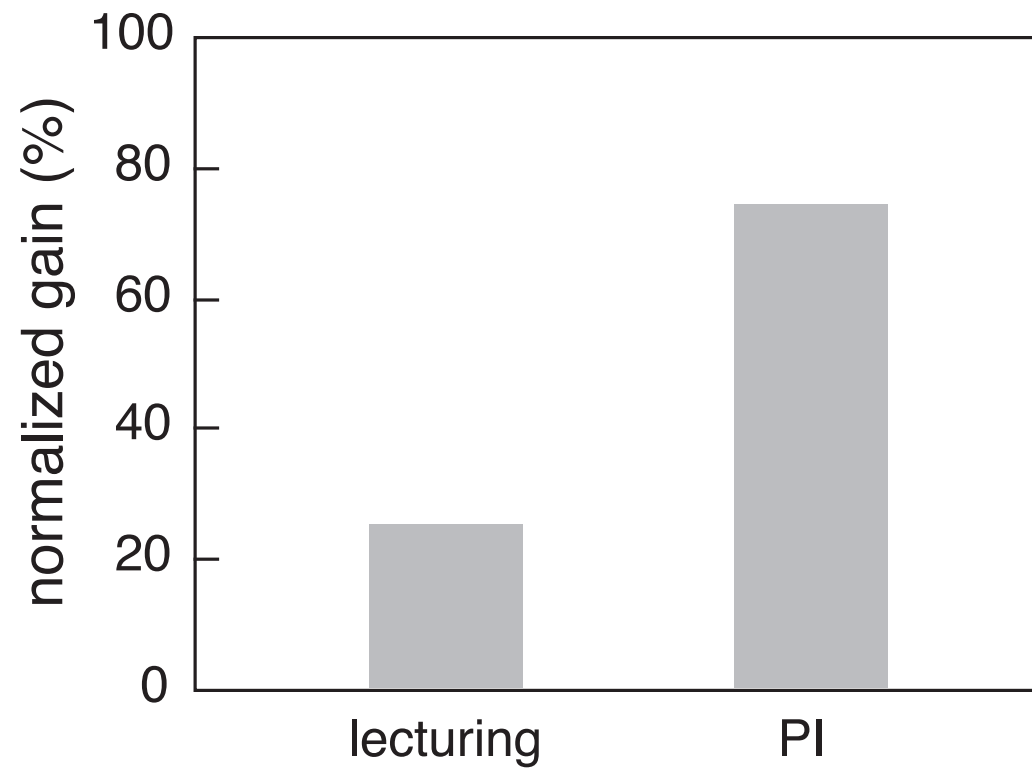
INSTRUCTION

**Higher learning gains**

INSTRUCTION





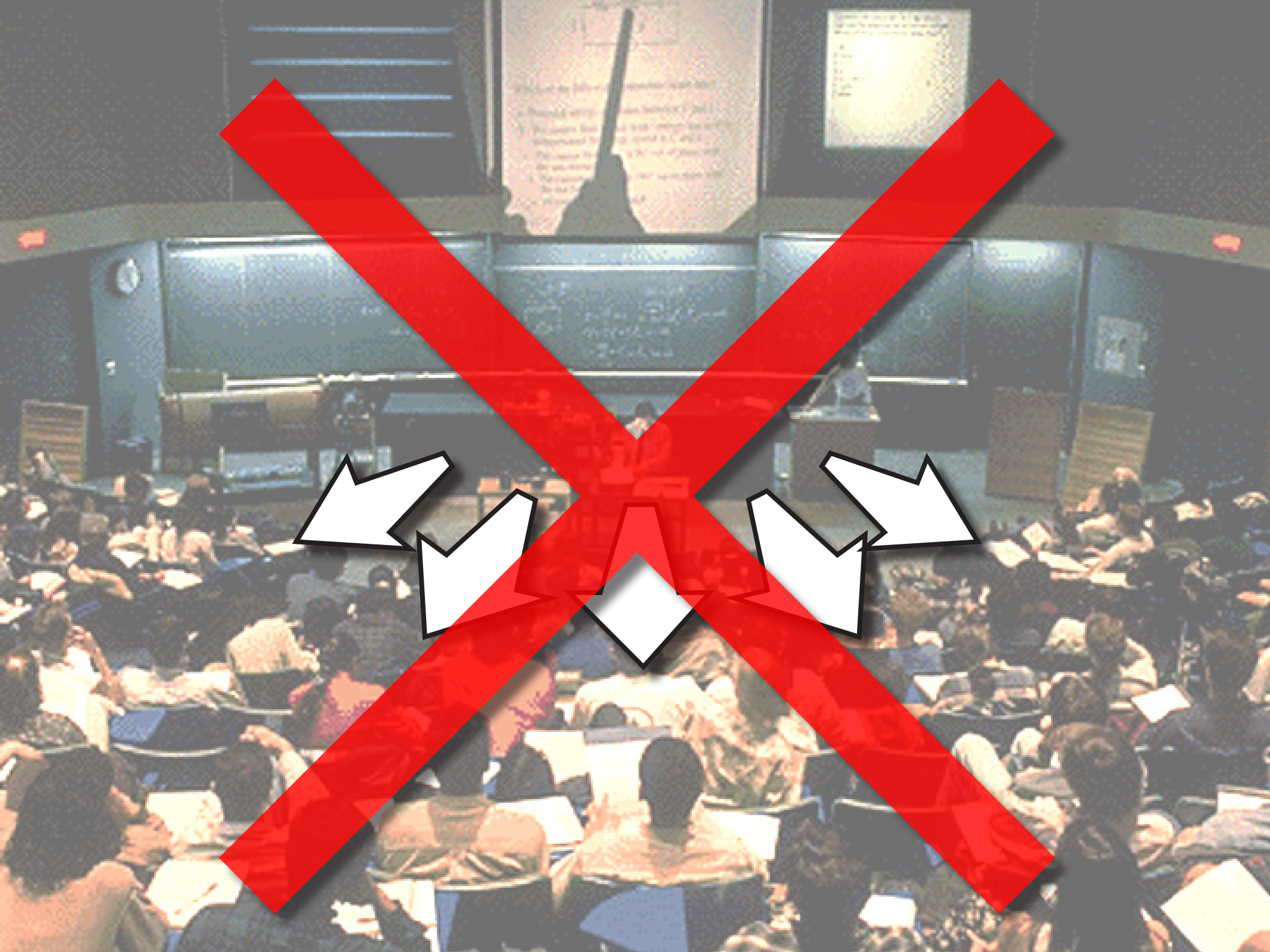




**Higher learning gains**

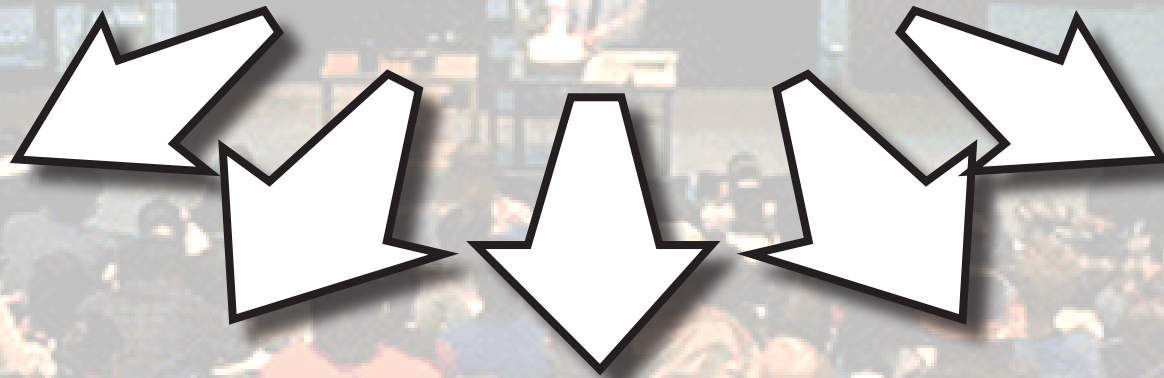
**Better retention**

**INSTRUCTION**





**how to effectively transfer information outside classroom?**







**but...**





- transfer pace set by video
- viewer passive
- viewing/attention tanks as time passes
- isolated/individual experience



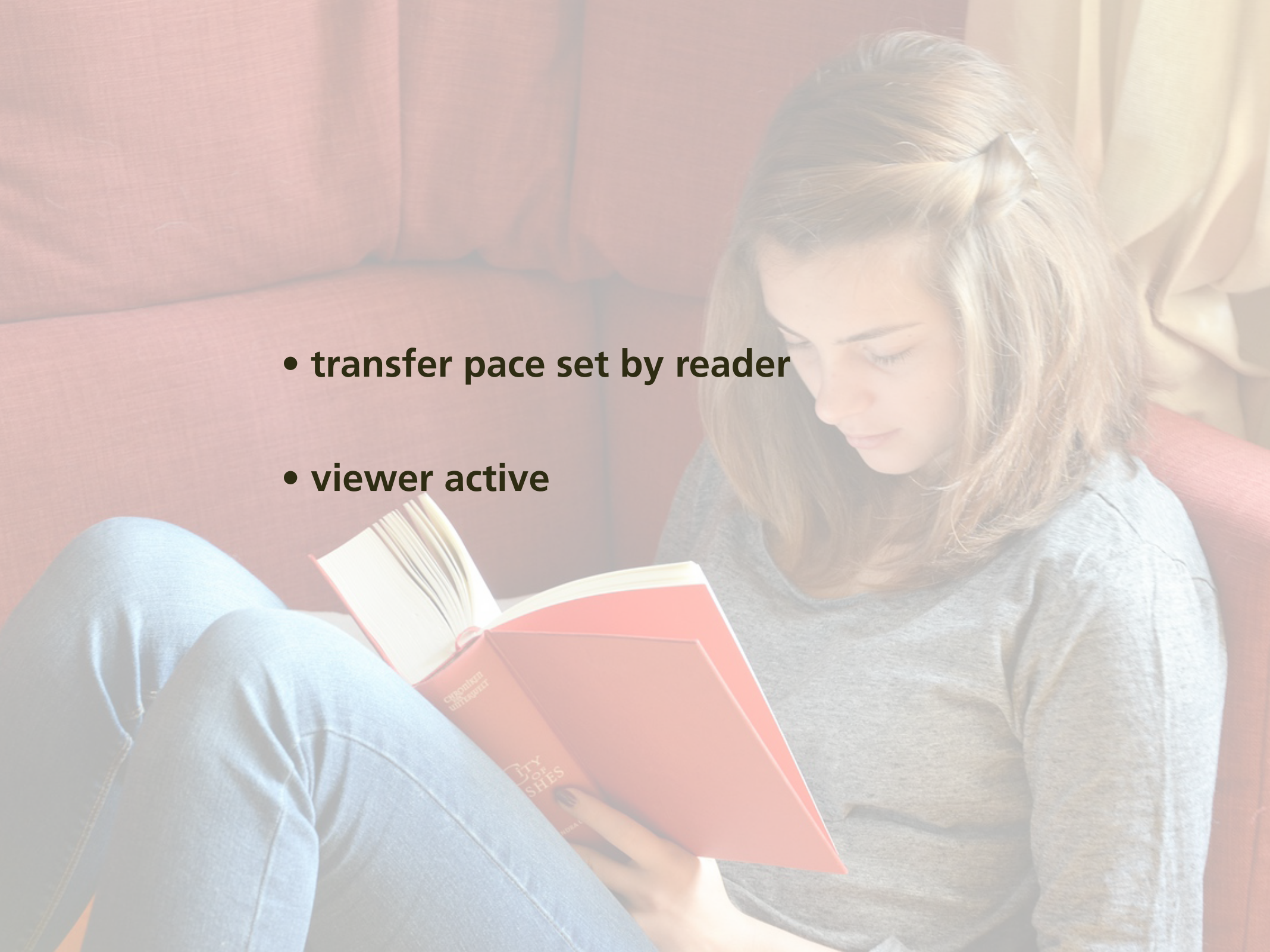


**we're simply moving this outside classroom!**








- 
- **transfer pace set by reader**
  - **viewer active**



**but...**







**isolated/individual experience &  
no real accountability**





**want:**  
***every student prepared for every class***





**want:**  
***every student prepared for every class***  
**(without additional instructor effort)**

A stylized illustration of a classroom. Several students are seated at rows of desks, facing forward. The students are depicted in various colors (yellow, green, blue, purple, pink, light green) and are holding pens or pencils, suggesting they are taking notes or participating in a lesson. The background is a solid light color.

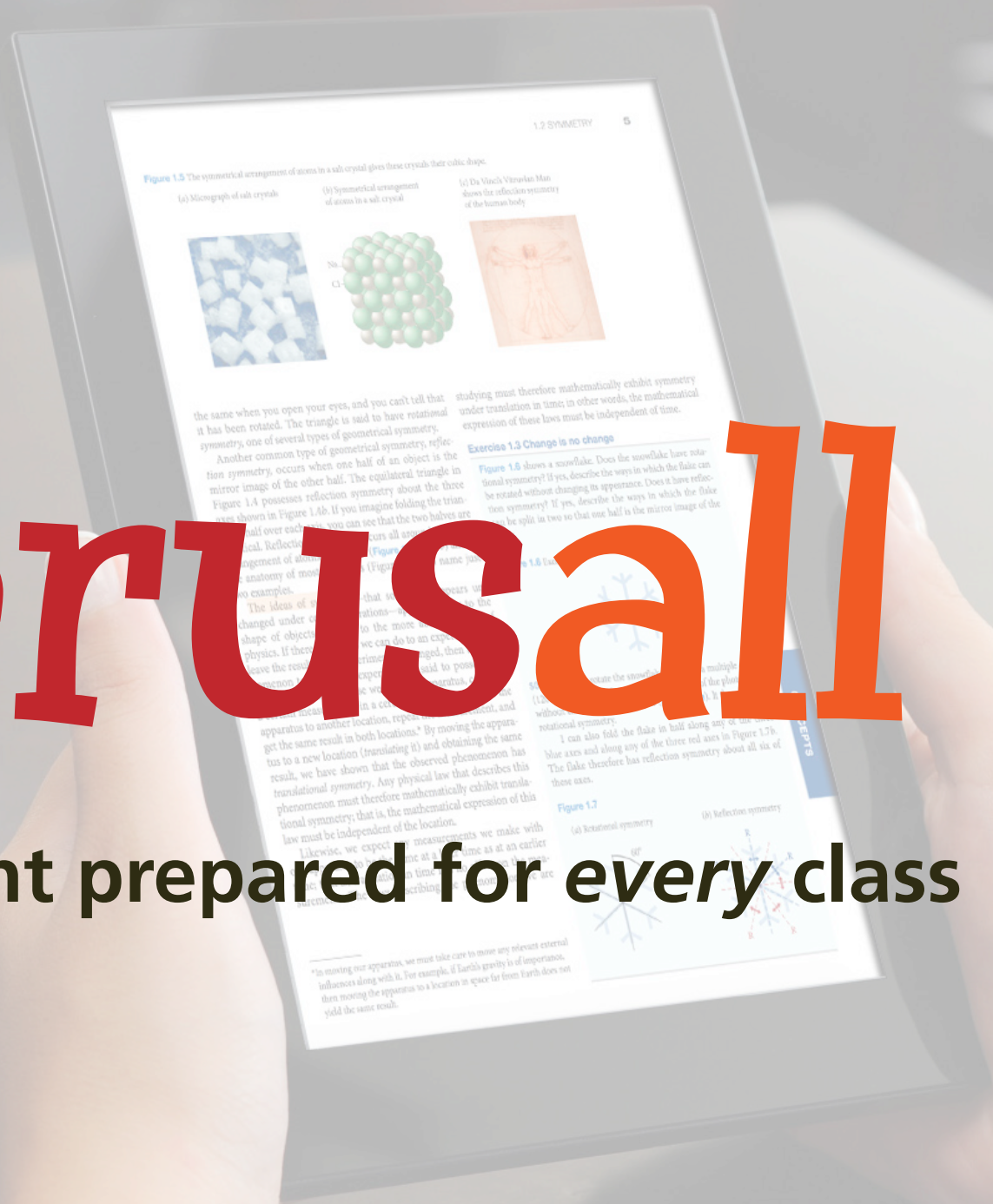
**Solution**

**turn out-of-class component  
also into a social interaction!**



# Perusall

every student prepared for every class



## 76 CHAPTER 4 MOMENTUM

In the preceding two chapters, we developed a mathematical framework for describing motion along a straight line. In this chapter, we continue our study of motion by investigating inertia, a property of objects that affects their motion. The experiments we carry out in studying inertia lead us to discover one of the most fundamental laws in physics—conservation of momentum.

## 4.1 Friction

Picture a block of wood sitting motionless on a smooth wooden surface. If you give the block a shove, it slides some distance but eventually comes to rest. Depending on the smoothness of the block and the smoothness of the wooden surface, this stopping may happen sooner or it may happen later. If the two surfaces in contact are very smooth and slippery, the block slides for a longer time interval than if the surfaces are rough. Notice that you have had a very ordinary day experience: A hockey puck slides easily on ice but not on a rough road.

Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that, during the interval covered by the velocity-versus-time graph, the velocity decreases as the block slides over ice; it is hardly observable. The block slides easily over ice because there is very little friction between the two surfaces. The effect of friction is to bring two objects to rest with respect to each other—in this case the wooden block and the surface it is sliding on. The less friction there is, the longer it takes for the block to come to rest.

**Figure 4.1** Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.



**Figure 4.2** Low-friction track and carts used in the experiments described in this chapter.



You may wonder whether it is possible to make surfaces that have no friction at all, such that an object, once given a shove, continues to glide forever. There is no totally frictionless surface over which objects slide forever, but there are ways to minimize friction. You can, for instance, float an object on a cushion of air. This is most easily accomplished with a low-friction surface—like a smooth surface of water. The air serves as a cushion on which a conveniently shaped object can float, with friction between the object and the track all but eliminated. Alternatively, one can use wheeled carts with low-friction bearings on an ordinary track. Figure 4.2 shows low-friction carts you may have encountered in your lab or class. Although there is still some friction both for low-friction tracks and for the track shown in Figure 4.2, this friction is so small that it can be ignored during an experiment. For example, if the track in Figure 4.2 is horizontal, carts move along its length without slowing down appreciably. In other words:

**In the absence of friction, objects moving along a horizontal track keep moving without slowing down.**

Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.



**4.1** (a) Are the accelerations of the motions shown in Figure 4.1 constant? (b) For which surface is the acceleration largest in magnitude?

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Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that the velocity decreases more rapidly on the rougher surfaces. The block slides easily over the smooth surface. To bring two objects to rest with no friction between the two surfaces, you would have to exert a force on them. In this case the wooden block and the surface are perfectly smooth. The less friction there is, the longer it takes for the block to come to rest.

Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.



Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.



You may wonder whether it is possible to make surfaces that have no friction at all, such that an object, once given a shove, continues to glide forever. There is no totally frictionless surface over which objects slide forever, but there are ways to minimize friction. You can, for instance, float an object on a cushion of air. This is most easily accomplished with an air hockey table, in which the puck is cushioned with a thin layer of air that reduces friction. Alternatively, one can use wheeled carts with low-friction bearings on an ordinary track. Figure 4.2 shows low-friction carts you may have encountered in your physics lab. Although there is still some friction between the wheels and the track, it is so small that it can be neglected. For example, if the track is perfectly horizontal, the carts move along its length with constant velocity. In other words:

In the absence of friction, objects on a horizontal track keep moving without slowing down.

Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.



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**Figure 4.1** Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.



**Figure 4.2** Low-friction track and carts used in the experiments described in this chapter.



You may wonder whether it is possible to make surfaces that have no friction at all, such that an object, once given a shove, continues to glide forever. There is no totally frictionless surface over which objects slide forever, but there are ways to minimize friction. You can, for instance, float an object on a cushion of air. This is most easily accomplished with a low-friction track—a track whose surface is dotted with little holes through which pressurized air blows. The air serves as a cushion on which a conveniently shaped object can float, with friction between the object and the track all but eliminated. Alternatively, one can use wheeled carts with low-friction bearings on an ordinary track. Figure 4.2 shows low-friction carts you may have encountered in your lab or class. Although there is still some friction both for low-friction tracks and for the track shown in Figure 4.2, this friction is so small that it can be ignored during an experiment. For example, if the track in Figure 4.2 is horizontal, carts move along its length without slowing down appreciably. In other words:

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Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.



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Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that, during the interval covered by the velocity-versus-time graph, the velocity decreases as the block slides over ice; it hardly decreases on the rough surface. The block slides easily over ice because there is very little friction between the two surfaces. The effect of friction is to bring two objects to rest with respect to each other—in this case the wooden block and the surface it is sliding on. The less friction there is, the longer it takes for the block to come to rest.

Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.



Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.



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Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the force that opposes the motion of an object encountered during the interaction. In the velocity-versus-time graph, the velocity decreases as the block slides over ice is hardly observable. The block slides easily over ice because there is very little friction between the two surfaces. The effect of friction is to bring two objects to rest with respect to each other—in this case the wooden block and the surface it is sliding on. The less friction there is, the longer it takes for the block to come to rest.

**Figure 4.1** Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.



**Figure 4.2** Low-friction track and carts used in the experiments described in this chapter.



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...opens chat window



Enter your comment or question and press Enter

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Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.



Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.



You may wonder whether it is possible to make surfaces that have no friction at all, such that an object, once given a shove, continues to glide forever. There is no totally frictionless surface over which objects slide forever, but there are ways to minimize friction. You can, for instance, float an object on a cushion of air. This is most easily accomplished with a low-friction track—a track whose surface is dotted with little holes through which pressurized air blows. The air serves as a cushion on which a conveniently shaped object can float, with friction between the object and the track all but eliminated. Alternatively, one can use wheeled carts with low-friction bearings on an ordinary track. Figure 4.2 shows low-friction carts you may have encountered in your lab or class. Although there is still some friction both for low-friction tracks and for the track shown in Figure 4.2, this friction is so small that it can be ignored during an experiment. For example, if the track in Figure 4.2 is horizontal, carts move along its length without slowing down appreciably. In other words:

**In the absence of friction, objects moving along a horizontal track keep moving without slowing down.**

Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.



4.1 (a) Are the accelerations of the motions shown in Figure 4.1 constant? (b) For which surface is the acceleration largest in magnitude?

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## 76 CHAPTER 4 MOMENTUM

In the preceding two chapters, we developed a mathematical framework for describing motion along a straight line. In this chapter, we continue our study of motion by investigating inertia, a property of objects that affects their motion. The experiments we carry out in studying inertia lead us to discover one of the most fundamental laws in physics—conservation of momentum.

## 4.1 Friction

Picture a block of wood sitting motionless on a smooth wooden surface. If you give the block a shove, it slides some distance but eventually comes to rest. Depending on the smoothness of the block and the smoothness of the wooden surface, this stopping may happen sooner or it may happen later. If the two surfaces in contact are very smooth and slippery, the block slides for a longer time interval than if the surfaces are rough or sticky. This you know from everyday experience: A hockey puck slides easily on ice but not on a rough road.

Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that, during the interval covered by the velocity-versus-time graph, the velocity decreases as the block slides over ice; it is hardly observable. The block slides easily over ice because there is very little friction between the two surfaces. The effect of friction is to bring two objects to rest with respect to each other—in this case the wooden block and the surface it is sliding on. The less friction there is, the longer it takes for the block to come to rest.

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No friction at all seems impossible. Isn't there always some friction in any real case?



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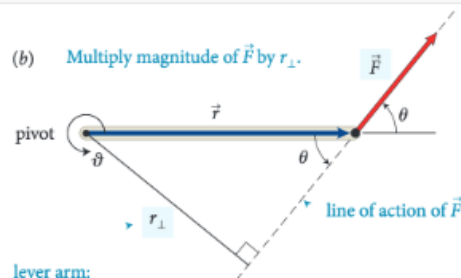
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(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



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perpendicular distance  
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action of the force and the axis of rotation. So, the torque caused by a force exerted on an object is the product of the magnitude of the force and its lever arm distance. It can be written equivalently as  $rF_{\perp}$  and as  $r_{\perp}F$ .

Like other rotational quantities, torque carries a sign that depends on the choice of direction for increasing  $\vartheta$ . In Figure 12.4, for example, the torque caused by  $\vec{F}_1$  about the pivot tends to rotate the rod in the direction of increasing  $\vartheta$  and so is positive; the torque caused by  $\vec{F}_2$  is negative. The sum of the two torques about the pivot is then  $r_1F_1 + (-r_2F_2)$ . As we've seen, the two torques are equal in magnitude when the rod is balanced, and so the sum of the torques is zero. When the sum of the torques is not zero, the rod's rotational acceleration is nonzero, and so its rotational velocity and angular momentum change.

In the situations depicted in Figures 12.4 and 12.5 we used the pivot to calculate the lever arm distances. This is a natural choice because that is the point about which the object under consideration is free to rotate. However, torques also play a role for stationary objects that are suspended or supported at several different points and that are not free to rotate—for example, a plank or bridge supported at either end. To determine what reference point to use in such cases, complete the following exercise.

### Exercise 12.1 Reference point

Consider again the rod in Figure 12.4. Calculate the sum of the torques about the left end of the rod.

**SOLUTION** I begin by making a sketch of the rod and the three forces exerted on it, showing their points of application on the rod (Figure 12.6).

reference point



The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force  $\vec{F}_1$  to this point is zero, and so the torque caused by that force about the left end of the rod is zero. If I choose counterclockwise as the positive direction of rotation,  $\vec{F}_2$  causes a negative torque about the left end of the rod; the force  $\vec{F}_{pr}$  exerted by the pivot causes a positive torque about the left end of the rod. The lever arm distance of  $\vec{F}_2$  about the left end of the rod is  $r_1 + r_2$ ; that of  $\vec{F}_{pr}$  is  $r_1$ . Because the rod is at rest, the magnitude of the force exerted by the pivot is equal to the sum of the forces  $\vec{F}_1$  and  $\vec{F}_2$ . Taking into account the signs of the torques, we find that the sum of the torques about the left end of the rod is  $r_1(F_1 + F_2) - (r_1 + r_2)F_2 = r_1F_1 - r_2F_2$ . This is the same result we obtained for the torques about the pivot, and so the sum of the torques about the left end is zero. ✓

Exercise 12.1 shows that the sum of the torques about the left end of the rod is zero, just like the sum of the torques about the pivot. You can repeat the calculation for the torques about the right end of the rod or any other point, and each time you will find that the sum of the torques is zero. The reason is that the rod is not rotating about any point, and so the sum of the torques must be zero about any point. In general we can say:

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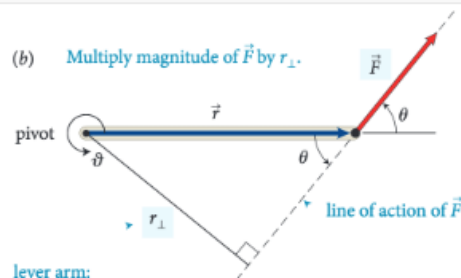


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### Example 12.2 Torques on lever

Three forces are exerted on the lever of Figure 12.7. Forces  $\vec{F}_1$  and  $\vec{F}_3$  are equal in magnitude, and the magnitude of  $\vec{F}_2$  is half as great. Force  $\vec{F}_1$  is horizontal,  $\vec{F}_2$  and  $\vec{F}_3$  are vertical, and the lever makes an angle of  $45^\circ$  with the horizontal. Do these forces cause the lever to rotate about the pivot? If so, in which direction?

(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



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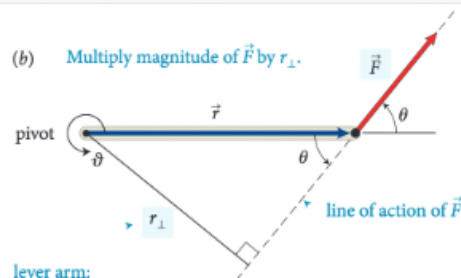
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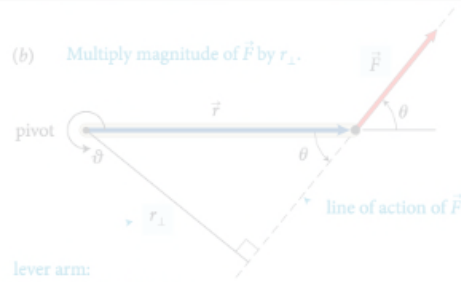
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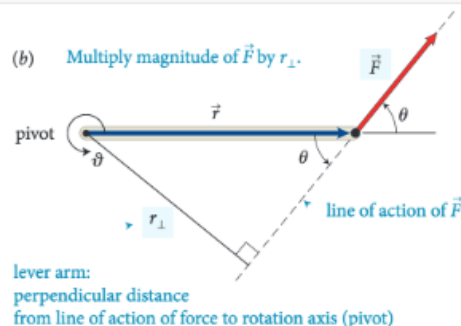
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Oct 22 8:48 pm

Enter your comment or question and press Enter

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21 minutes ago, you asked this question on Perusall:

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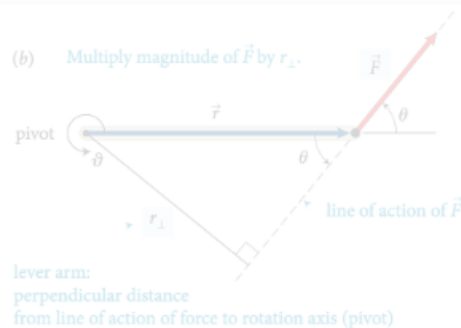
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## option 3: mark as answered





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# how to get students to participate?

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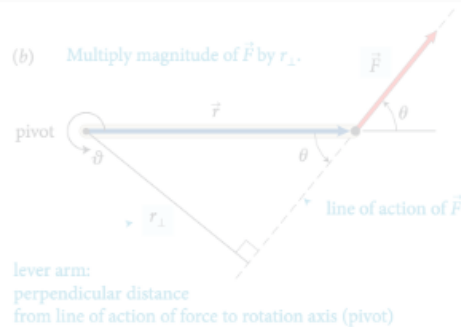
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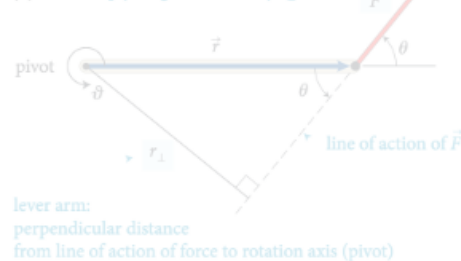
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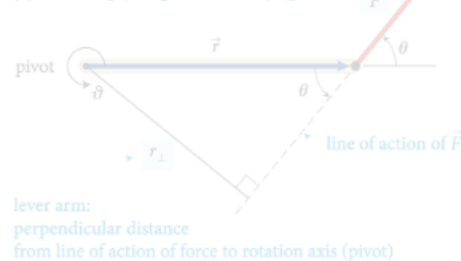


# rubric-based assessment

## must demonstrate thoughtful reading & interpretation

- quantity (10–20)

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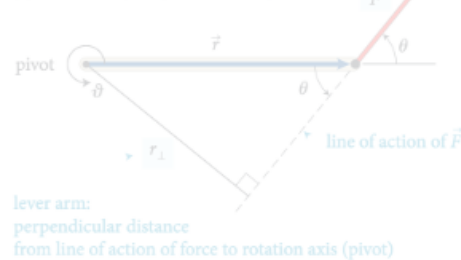
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## must demonstrate thoughtful reading & interpretation

- quantity (10–20)

- timeliness (before class)

I don't understand how this combination of factors tells you anything about direction? Aren't magnitude and lever arm distance both scalar quantities? It seems like we would need to know some sort of direction to calculate torque.

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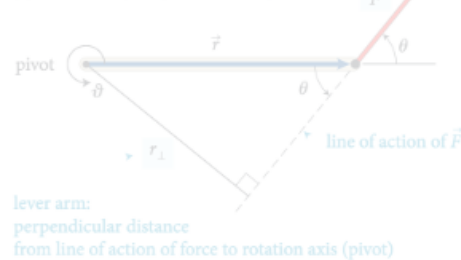
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# rubric-based assessment

(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



lever arm:  
perpendicular distance  
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## must demonstrate thoughtful reading & interpretation

- quantity (10–20)

- timeliness (before class)

- distribution (not clustered)

I don't understand how this comment factors tells you anything about direction? Aren't magnitude and lever arm distance both scalar quantities? It seems like we would need to know some sort of direction to calculate torque.

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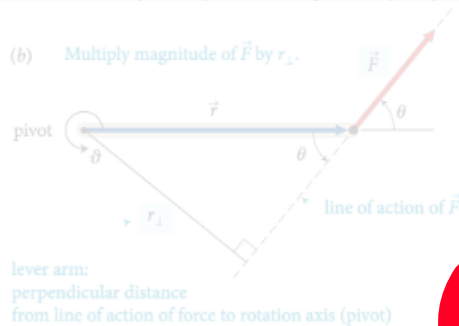
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## rubric-based assessment

(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



lever arm:  
perpendicular distance  
from line of action of force to rotation axis (pivot)

- quality (thoughtful reading & interpretation)

- quantity (minimum)

- timeliness (before class)

- distribution (not clustered)

over 20,000 annotations!

The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force  $\vec{F}_1$  about the left end of the rod is zero, and so the torque caused by this force about the left end of the rod is zero. If I choose the counter-clockwise direction as positive for rotation,  $\vec{F}_2$  causes a negative torque about the left end of the rod; the force  $\vec{F}_2$  is applied at a point a distance  $r_2$  from the left end of the rod, and the lever arm distance is  $r_2$ . The lever arm distance of  $\vec{F}_3$  about the left end of the rod is  $r_3$ , and the torque caused by this force is equal to  $r_3 F_3$ . The sum of the torques about the left end of the rod is  $\tau = -r_2 F_2 + r_3 F_3$ . The result we obtain is the same as if we had chosen the pivot at the right end of the rod. The sum of the torques about the right end of the rod is  $\tau = r_1 F_1 - r_2 F_2$ . The result is the same as if we had chosen the pivot at the left end of the rod.

For the sum of the torques about the left end of the rod to be zero, just like the sum of the forces about the pivot. You can repeat the calculation for the torques about the right end of the rod for any other point, and each time you will find that the sum of the torques is zero. The reason is that the rod is not rotating about any point, and so the sum of the torques is zero about any point. In general we can choose any point as the reference point for the calculation.

For a rotating object, we choose a reference point and we like to calculate the torque about a reference point that is convenient for the calculation. As you have seen, we do not need to know any details about the forces at the reference point. We only need to know the point at the point of application of the force and the magnitude of the force.

12.2 In the situation depicted in Figure 12.2a, you must continue to exert a force on the seesaw to keep the child off the ground. The force you exert causes a torque on the seesaw, and yet the seesaw's rotational acceleration is zero. How can this be if torques cause objects to accelerate rotationally?

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- It's... the white ...
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# rubric-based assessment

(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



lever arm:  
perpendicular distance  
from line of action of force to rotation axis (pivot)

- quality (thoughtful reading & interpretation)

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The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force  $\vec{F}_1$  to this point is zero, and so the torque caused by that force about the left end of the rod is zero. If I choose counterclockwise as the positive direction of rotation,  $\vec{F}_2$  causes a negative torque about the left end of the rod; the force  $\vec{F}_{pr}$  exerted by the pivot causes a positive torque about the left end of the rod. The lever arm distance of  $\vec{F}_2$  about the left end of the rod is  $r_1 + r_2$ ; that of  $\vec{F}_{pr}$  is  $r_1$ . Because the rod is at rest, the magnitude of the force exerted by the pivot is equal to the sum of the forces  $\vec{F}_1$  and  $\vec{F}_2$ . Taking into account the signs of the torques, we find that  $r_1(F_1 + F_2) - (r_1 + r_2)F_2 = r_1F_1 - r_2F_2$ . This is the same result we obtained for the torques about the pivot, and so the sum of the torques about the left end is zero. ✓

Exercise 12.1 shows that the sum of the torques about the left end of the rod is zero, just like the sum of the torques about the pivot. This result can be repeated for any other point, and each time you will find that the sum of the torques is zero. The reason is that the rod is not rotating about any point, and so the sum of the torques must be zero about any point. In general we can say:

**For a stationary object, the sum of the torques is zero.**

For a stationary object we can choose any reference point we like to calculate torques. It pays to choose a reference point that simplifies the calculation. As you have seen, we do not need to consider any force that is exerted at the reference point. So, by putting the reference point at the point where a force is exerted, we can eliminate that force from the calculation.



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# how do you process all of that??

- timeliness (before class)

- distribution (not clustered)

On the very left, we see th...

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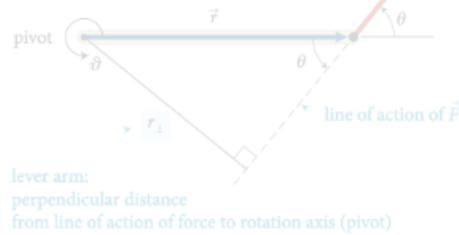
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## rubric-based assessment

(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



- quality (though future could interpret)

How do you process all of that??

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I think you may be able to think about the direction separately. So when finding the magnitude of distance, you can attach a sign to the torque based on the defined parameters of the system. In the following paragraph, they explain how to choose this direction.

This is a great question. To find the direction of the torque, you can think of this in terms of the torque equation. The torque is  $\tau = r \times F$ , with  $r$  being the distance from the pivot to the point where the force acts. We know that force is a vector, and in chapters, and in regards to " $r$ " it can also be thought of as a radial vector. What this means is that this distance from the pivot points from the axis of rotation to the point where the force acts. In as previously mentioned, there is a general convention (the right-hand rule) that is used to determine the direction which happens to be perpendicular to both the radius from the axis and to the force.

Enter your comment or question and press Enter

The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force  $\vec{F}_1$  about the left end of the rod is zero, and so the torque caused by that force about the left end of the rod is zero. If I choose counter-clockwise as the positive direction of rotation,  $\vec{F}_2$  is a force that acts about the left end of the rod that creates a positive torque. The lever arm distance of  $\vec{F}_2$  about the left end of the rod is  $r_2$ . The lever arm distance of  $\vec{F}_3$  about the left end of the rod is  $r_3$ . The sum of the torques about the left end of the rod is  $(F_1 + F_2)r_2 + F_3r_3$ . This is the same result obtained for the torques about the pivot, and so the sum of the torques about the left end is zero. ✓

Exercise 12.1 shows that the sum of the torques about the left end of the rod is zero, just like the sum of the torques about the pivot. You can repeat the calculation for the right end of the rod and find that the sum of the torques is zero. The reason is that the sum of the torques about any point, and so the sum of the torques about any point. In general, the sum of the torques about any point is zero.

For a static equilibrium problem, you must choose a reference point to calculate the torques. As you have seen, we do not need to consider any force that is exerted at the reference point. So, by putting the reference point at the point where a force acts, we can eliminate that force from the calculation.



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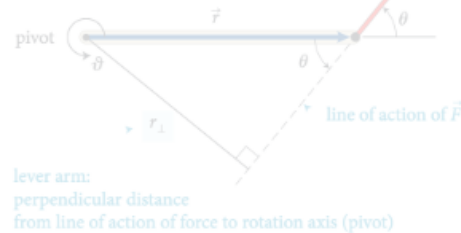
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# fully automated assessment

(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



- specialized machine learning algorithm
- assesses intellectual content
- exceeds intercoder reliability

I don't understand how this combination of factors tells you anything about direction? Aren't magnitude and lever arm distance both scalar quantities? It seems like you would have to know some sort of direction to calculate torque.

Oct 20 12:09 am

I think you may be able to think about the direction separately. So, after multiplying this magnitude and distance, you can attach a sign to the torque based on the defined parameters of the system. The sign convention is arbitrary, but you can explain how to choose it.

Oct 20 12:38 am

This is a great question. To further elaborate on this, we can think of this in terms of the Torque equation. The equation for torque is  $\tau = r \times F$ , with  $r$  being the level arm distance and  $F$  being force. We know that force is a vector vector from previous chapters, and in regards to " $r$ " it can also be thought of as the radial vector. What this means is that this distance from the pivot points from the axis of rotation to the point where the force acts. In as previously mentioned, there is a general convention (the right-hand rule) that is used to determine the direction which happens to be perpendicular to both the radius from the axis and to the force.

Oct 22 8:48 pm

Enter your comment or question and press Enter

The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force  $\vec{F}_1$  to this point is zero, and so the torque caused by that force about the left end of the rod is zero. If I choose counterclockwise as the positive direction of rotation,  $\vec{F}_2$  causes a negative torque about the left end of the rod; the force  $\vec{F}_{pr}$  exerted by the pivot causes a positive torque about the left end of the rod. The lever arm distance of  $\vec{F}_2$  about the left end of the rod is  $r_1 + r_2$ ; that of  $\vec{F}_{pr}$  is  $r_1$ . Because the rod is at rest, the magnitude of the force exerted by the pivot is equal to the sum of the forces  $\vec{F}_1$  and  $\vec{F}_2$ . Taking into account the signs of the torques, we find that the sum of the torques about the left end of the rod is  $r_1(F_1 + F_2) - (r_1 + r_2)F_2 = r_1F_1 - r_2F_2$ . This is the same result we obtained for the torques about the pivot, and so the sum of the torques about any point is zero.

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[REDACTED]		3		

Total number of annotations **16**

Total number of annotations submitted on time **11**

Average quality of top 10 annotations submitted on time **1.80**

2 = demonstrates thorough and thoughtful reading and insightful interpretation of the reading, 1 = demonstrates reading, but no (or only superficial) interpretation of the reading, 0 = does not demonstrate any thoughtful reading or interpretation

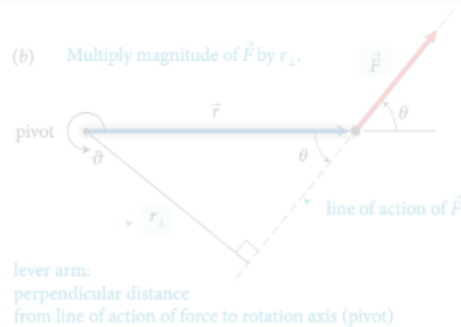
Distribution of annotations **3.8**

0 = clustered, 5 = evenly distributed throughout assignment

Assignment score **1**

scores range from 0 to 3





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# connect pre-class and in-class activities

I don't think you can calculate torque without knowing the direction of the force. Even if you know the magnitude of the force, you need to know the direction of the force to calculate the torque. It seems like we would need to know some sort of direction to calculate torque.

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## Confusion report for Chapter 24

## right hand rule (11 questions)

- JB Can someone in simpler terms explain the right- hand rule? +1
- WJ Is there another way, besides the right hand rule, to find the direction of the magnetic field with a current? 2
- SB Using the right hand rule, I believe the answer is D. Is that correct? 3  
Show more...

## direction magnetic field (8 questions)

- CP Why is it that the magnet field points away from the north pole and towards the south pole? When on the previous page it stated that the direction of the magnetic field is the direction that the north pole of a compass needle points. +2
- AB How can you determine which direction the magnetic field will point towards? +1
- KH So whichever way the north pole faces is the direction of the magnetic field but that doesn't always mean its pointing true north? +1  
Show more...

## earth magnetic field (6 questions)

- CP Does that mean that the compass will be distracted from the Earth's magnetic field and use the magnetic field that the current of the wire gives off? 2
- AK Can someone explain why this type of bacteria knows what direction the earth's magnetic fields are facing? 3
- J Does the circular loop of current have any similarities with the look of the earths magnetic field? They kind of look similar to me. 3  
Show more...

# motivating factors

## Intrinsic:

## • social interaction

(b) Multiply magnitude of  $\vec{F}$  by  $r_{\perp}$ .



lever arm:  
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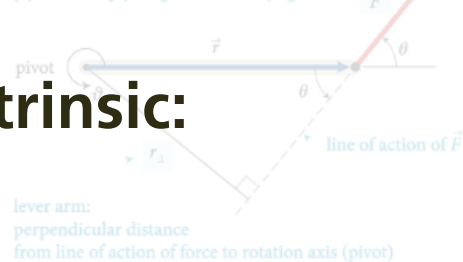


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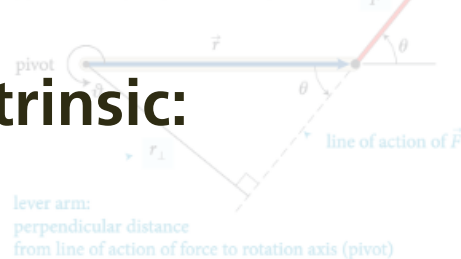
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Extrinsic:

- assessment (fully automated)

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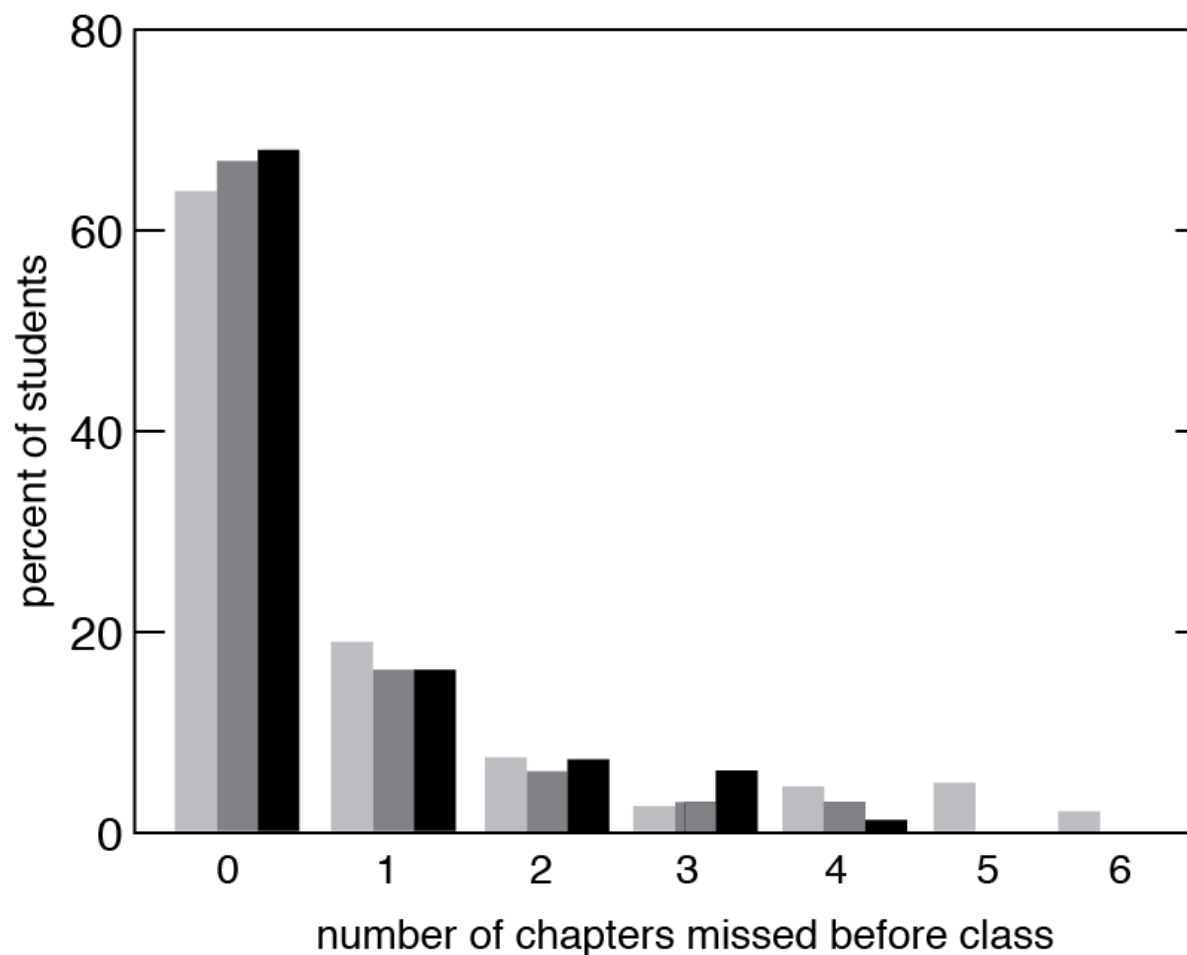
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# research data

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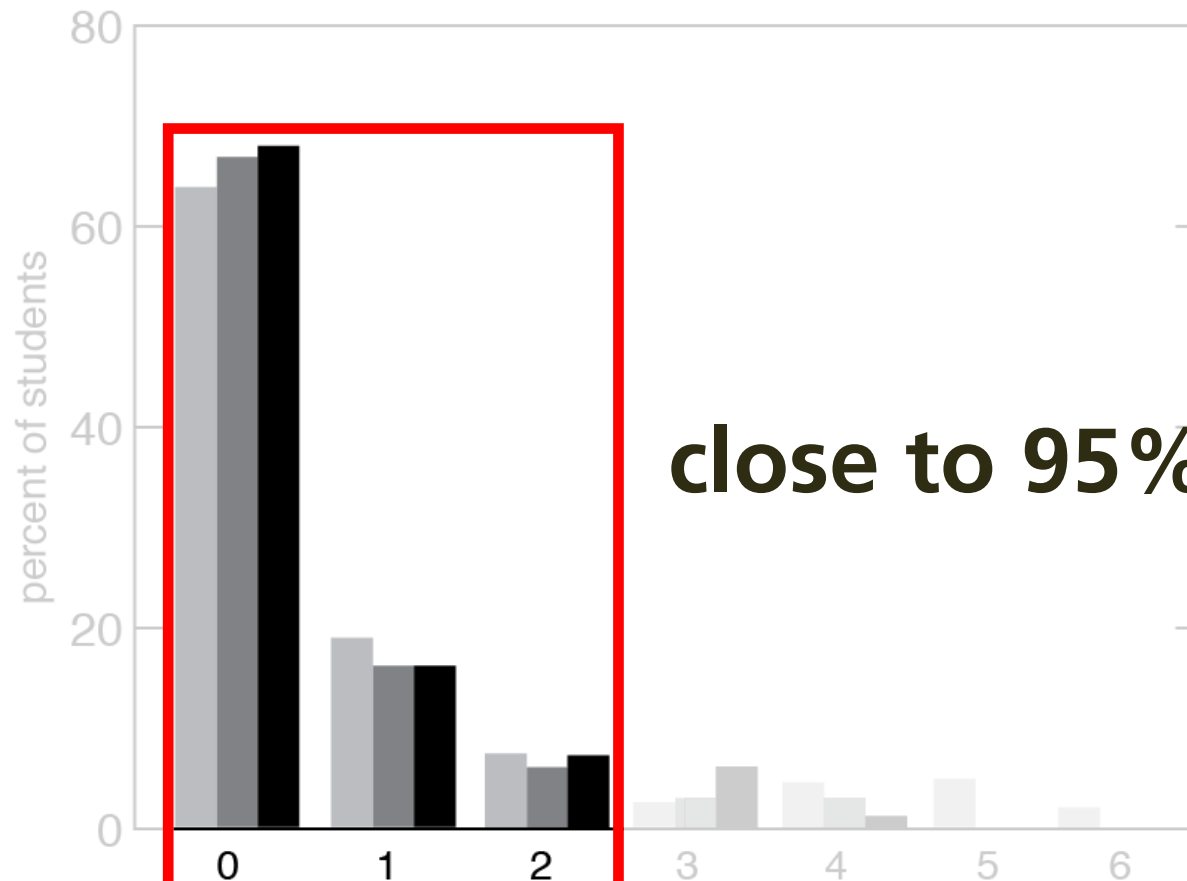
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close to 95%!

number of chapters missed before class

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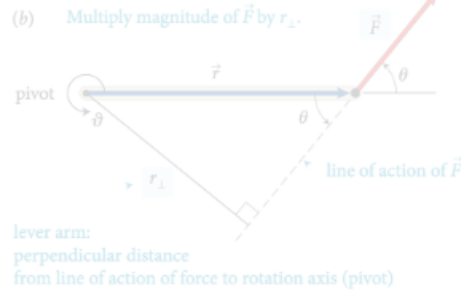
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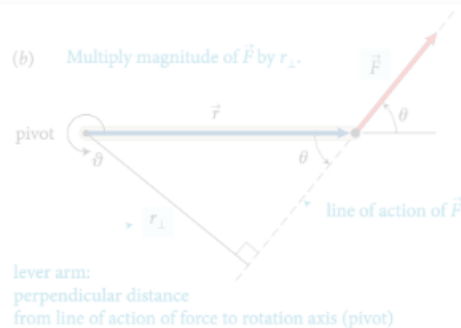
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This is a great question. To further elaborate on this, we can think of this in terms of the Torque equation. The equation for torque is  $\tau = r \times F$ , with  $r$  being the level arm distance and  $F$  being force. We know that force is a vector vector from previous chapters, and in regards to " $r$ " it can also be thought of as the radial vector. What this means is that this distance from the pivot points from the axis of rotation to the point where the force acts. In as previously mentioned, there is a general convention (the right-hand rule) that is used to determine the direction which happens to be perpendicular to both the radius from the axis and to the force. Oct 22 8:48 pm

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action of the force and the axis of rotation. So, the torque caused by a force exerted on an object is the product of the magnitude of the force and its lever arm distance. It can be

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? I don't understand how this combination of factors tells you anything about direction? Aren't magnitude and lever arm distance both scalar quantities? It seems like we would need to know some sort of direction to calculate torque. Oct 20 12:09 am

? I think you may be able to think about the direction separately. So, after multiplying this magnitude and distance, you can attach a sign to the torque based on the defined parameters of the system. In the following paragraph, they start to explain how to choose this direction. Oct 20 12:38 am

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reference point

The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force  $\vec{F}_1$  to this point is zero, and so the torque caused by that force about the left end of the rod is zero. If I choose counterclockwise as the positive direction of rotation,  $\vec{F}_2$  causes a negative torque about the left end of the rod; the force  $\vec{F}_{\text{pr}}$  exerted by the pivot causes a positive torque about the left end of the rod. The lever arm distance of  $\vec{F}_2$  about the left end of the rod is  $r_1 + r_2$ ; that of  $\vec{F}_{\text{pr}}$  is  $r_1$ . Because the rod is at rest, the magnitude of the force exerted by the pivot is equal to the sum of the forces  $\vec{F}_1$  and  $\vec{F}_2$ . Taking into account the signs of the torques, we find that the sum of the torques about the left end of the rod is  $r_1(F_1 + F_2) - (r_1 + r_2)F_2 = r_1F_1 - r_2F_2$ . This is the same result we obtained for the torques about the pivot, and so the sum of the torques about the left end is zero. ✓

For a stationary object, the sum of the torques is zero. For a stationary object we can choose any reference point we like to calculate torques. It pays to choose a reference point that simplifies the calculation. As you have seen, we do not need to consider any force that is exerted at the reference point. So, by putting the reference point at the point of application of a force, we can eliminate that force from the calculation.



**12.2** In the situation depicted in Figure 12.2a, you must continue to exert a force on the seesaw to keep the child off the ground. The force you exert causes a torque on the seesaw, and yet the seesaw's rotational acceleration is zero. How can this be if torques cause objects to accelerate rotationally?

## Example 12.2 Torques on lever

Three forces are exerted on the lever of Figure 12.7. Forces  $\vec{F}_1$  and  $\vec{F}_2$  are equal in magnitude, and the magnitude of  $\vec{F}_3$  is half as great. Force  $\vec{F}_1$  is horizontal,  $\vec{F}_2$  and  $\vec{F}_3$  are vertical, and the lever makes an angle of  $45^\circ$  with the horizontal. Do these forces cause the lever to rotate about the pivot? If so, in which direction?

? On the very left, we see th...

It's interesting that the white ...

? Is the reference frame i... 2

? How does force affect ... 2

I was curious about this, t... 3

? I understand partially w... 3

In this class, we always emp...

? The part before this wa... 2

The extended free-body d... 4

? This just means the net... 3

I don't understand why ... 3

is important to note that... 2

This reminds me of when we ...

Torque is the ability of a forc...

The type of diagram to use d...

? It sounds like it is sayin... 3

? So then do we have a p... 5

Since torque is the cross pro...

The right-hand rule can al... 3

? I don't understand how ... 3

Orientation-based descriptio...

? I don't really understand... 2

? How small is small? As ... 3

? I think it would be slightly ...

? While I believe I underst... 3

? (a) The change in rotationa...

As we saw earlier in the chap...

Objects executing motion ar...

Generally, for rotating bod... 2

? Does torque have the s... 3





**Education is not just about:**

- **transferring information**
- **getting students to do what we do**



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**active engagement/social interaction a must!**



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