

Confessions of a converted lecturer



Presidential Speaker Series
Yale-NUS
Singapore, 22 August 2016



Confessions of a converted lecturer



@eric_mazur

Presidential Speaker Series
Yale-NUS
Singapore, 22 August 2016









What are the following...
1. Personal...
2. The...
3. The...
4. The...
5. The...

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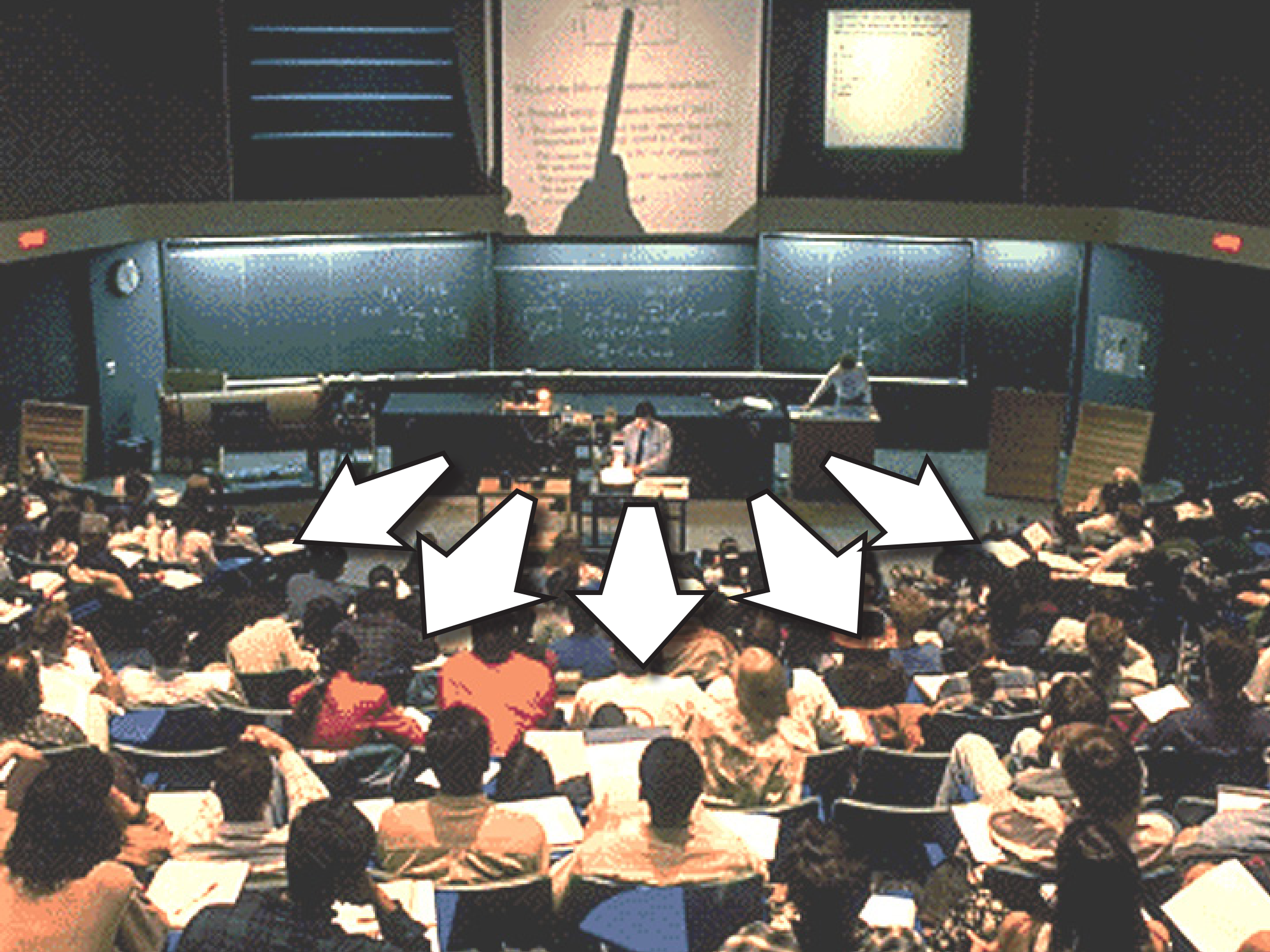
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What are the following...
A...
The...
The...
The...
The...

- 1. ...
- 2. ...
- 3. ...
- 4. ...
- 5. ...





A painting of a face with eyes looking through horizontal window blinds. The text "an illusion..." is overlaid in red.

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)

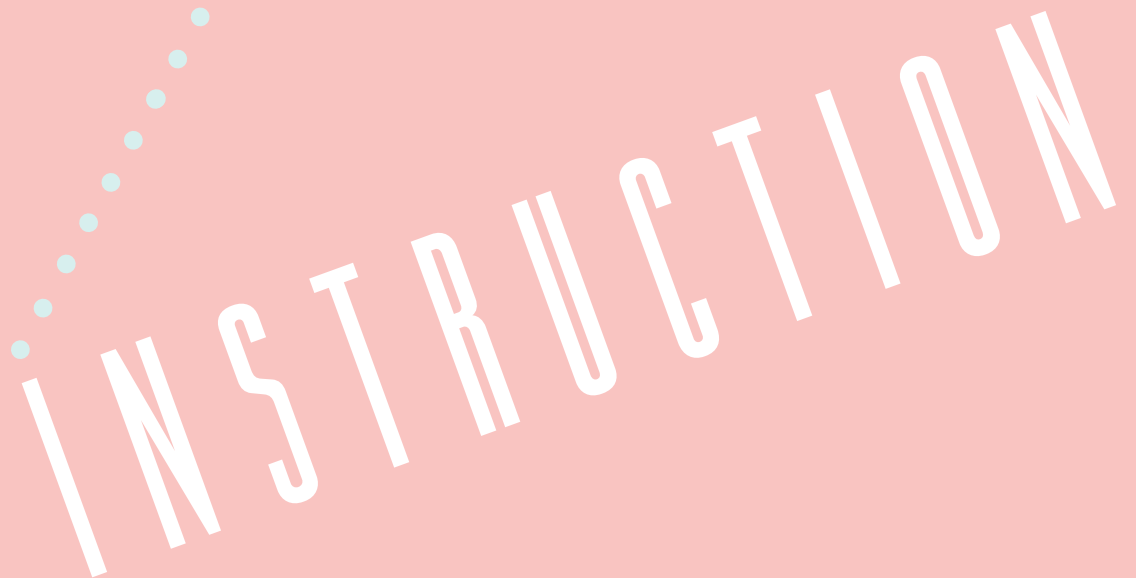
Peer



1. transfer of information (out of class)

2. assimilation of that information (in class)

INSTRUCTION



question

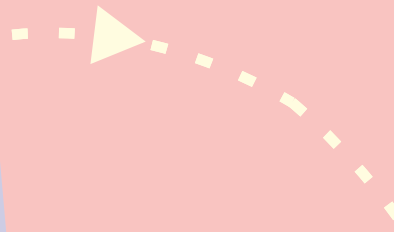
INSTRUCTION

question



think

r



INSTRUCTION

question



think



poll

r

INSTRUCTION

INSTRUCTION

question



think



poll



discuss

INSTRUCTION

question



think



poll



discuss



repoll

repoll

question



think



poll



discuss

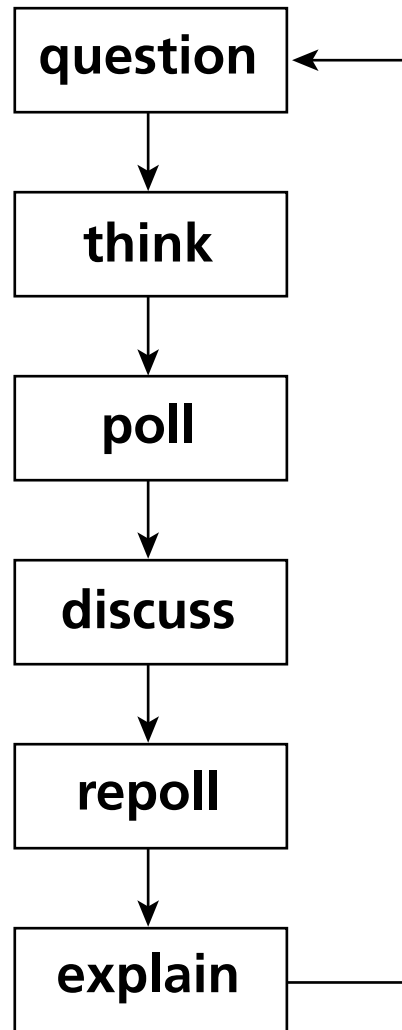


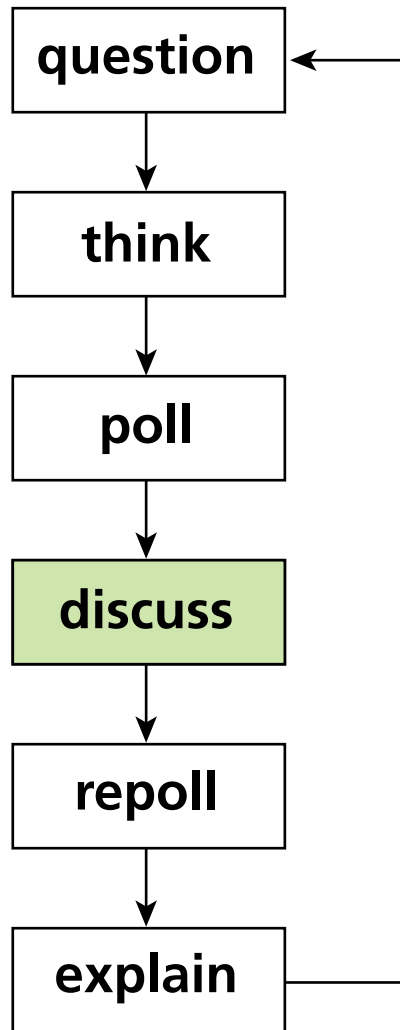
repoll



explain

INSTRUCTION

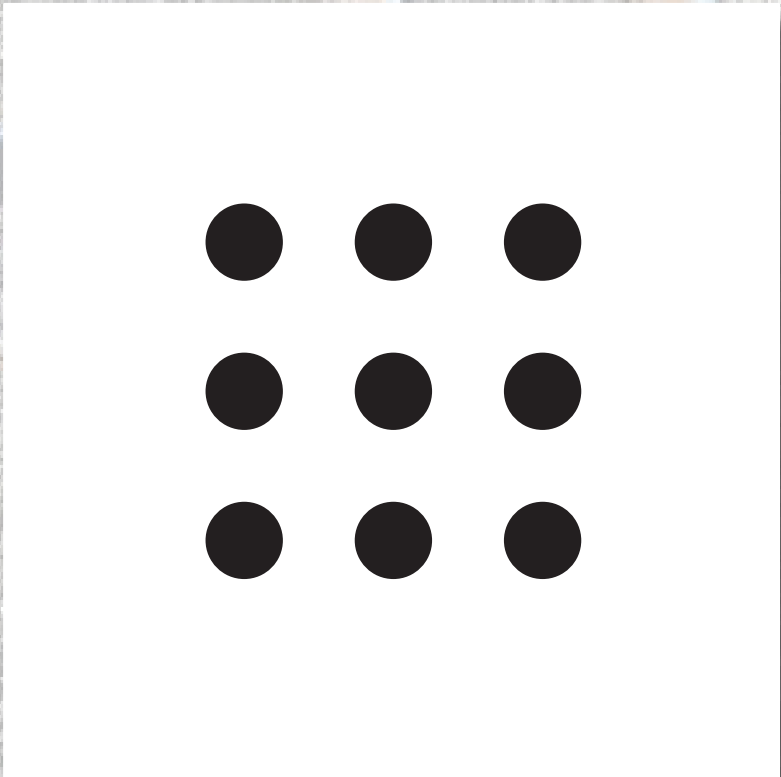
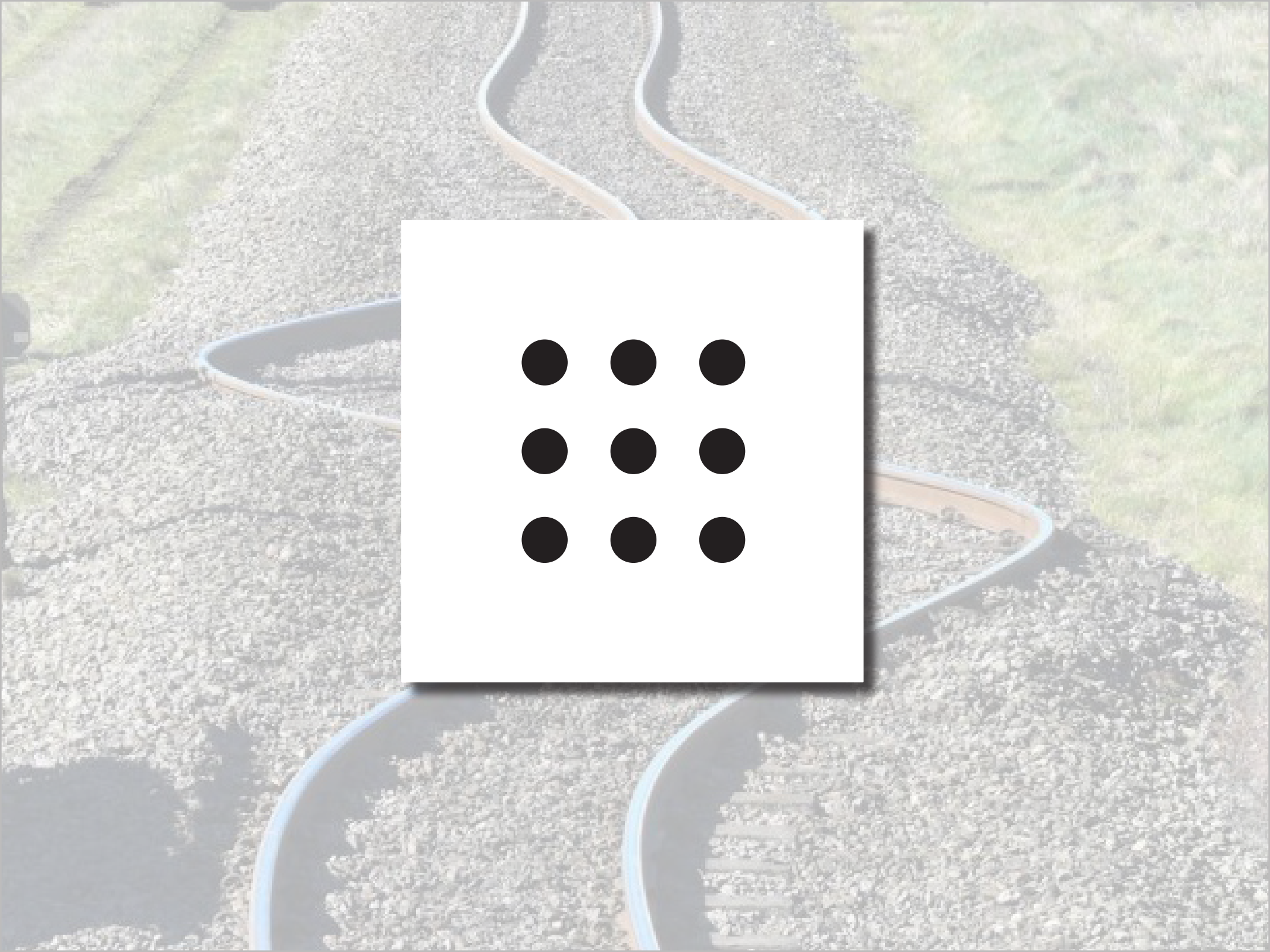


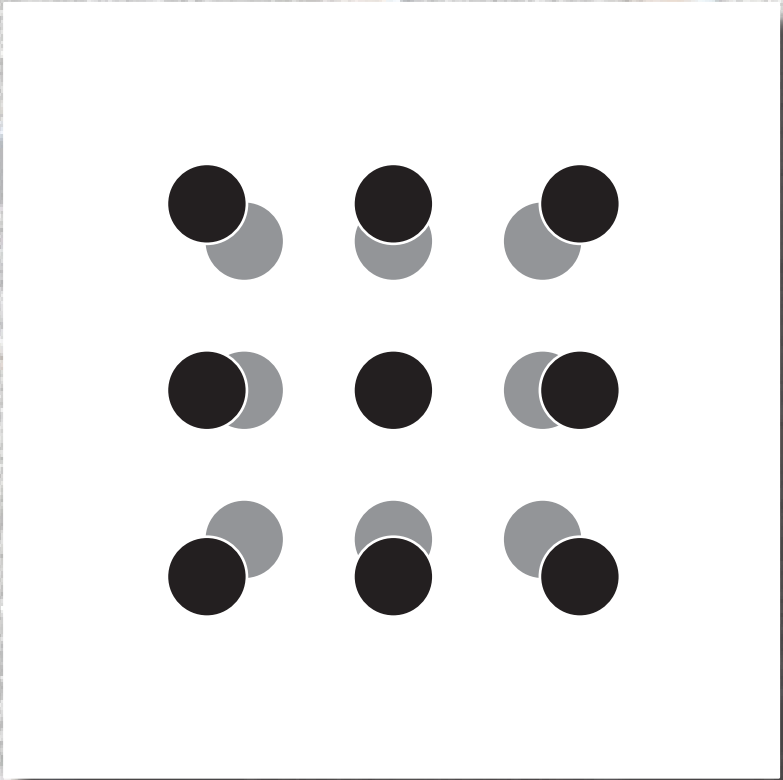




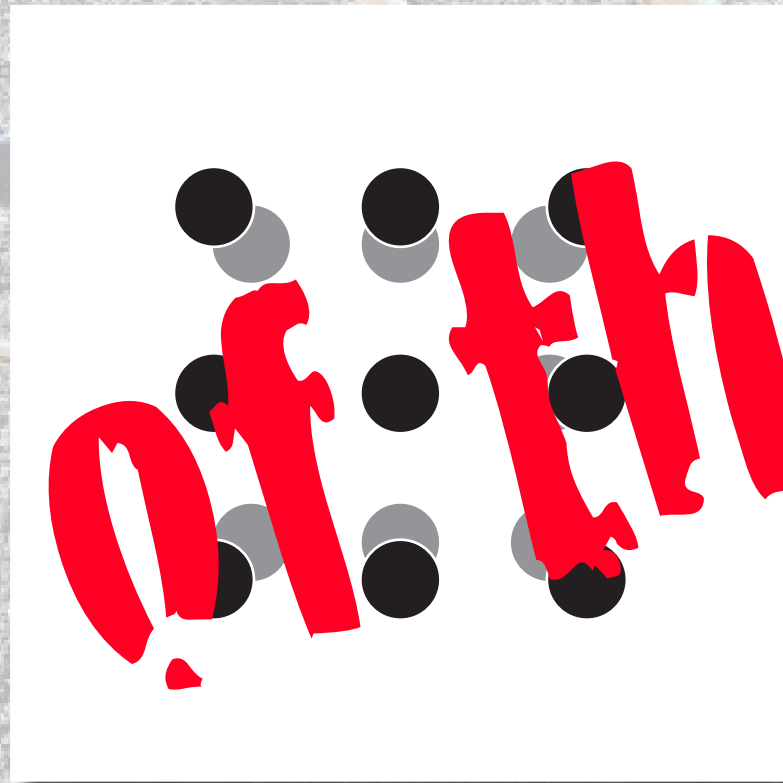
A photograph of a railway track with a wavy, undulating track bed, illustrating thermal expansion. The track is composed of gravel and wooden sleepers. The text "thermal expansion" is overlaid on the image.

thermal expansion

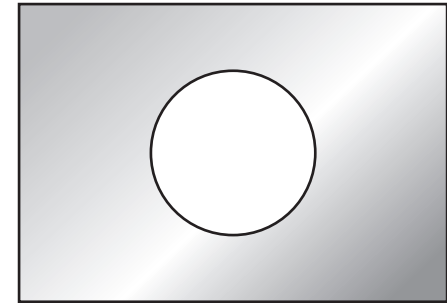




all of them!

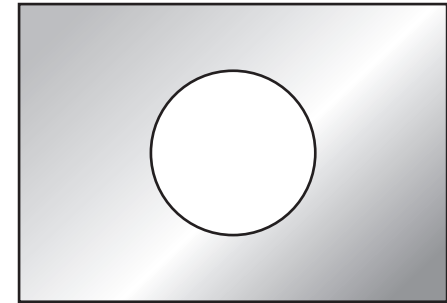


**Consider a rectangular metal plate
with a circular hole in it.**



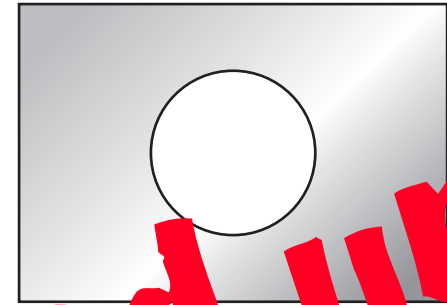
Consider a rectangular metal plate with a circular hole in it.

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.



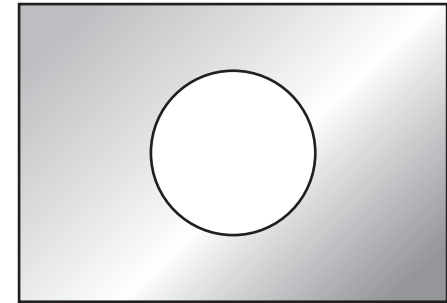
When the plate is uniformly heated, the diameter of the hole

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**

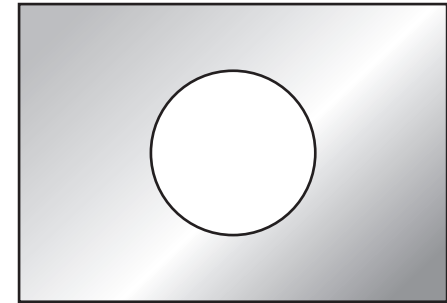
Before I tell you the answer, let's analyze what happened.

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.

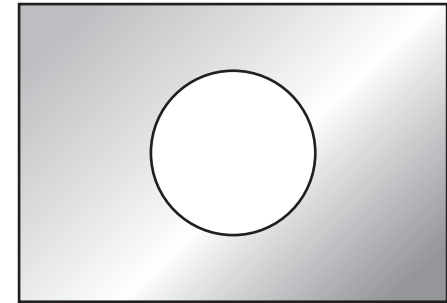
When the plate is uniformly heated, the diameter of the hole



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

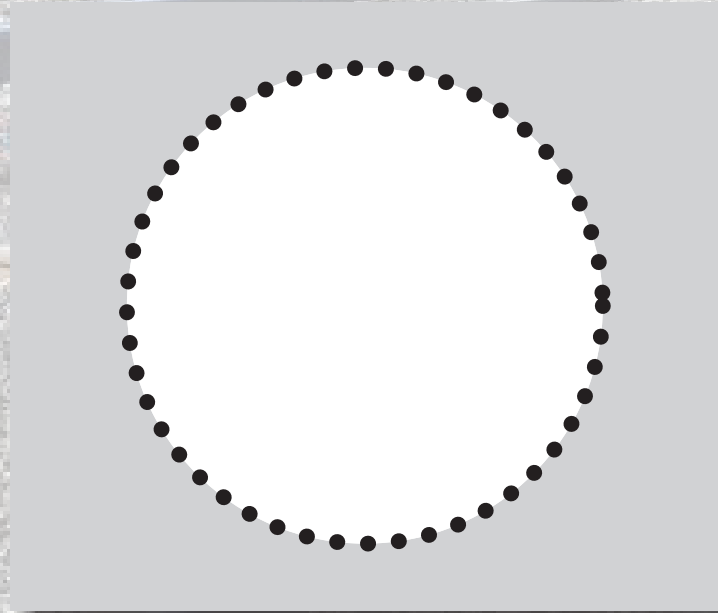
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When the plate is uniformly heated, the diameter of the hole

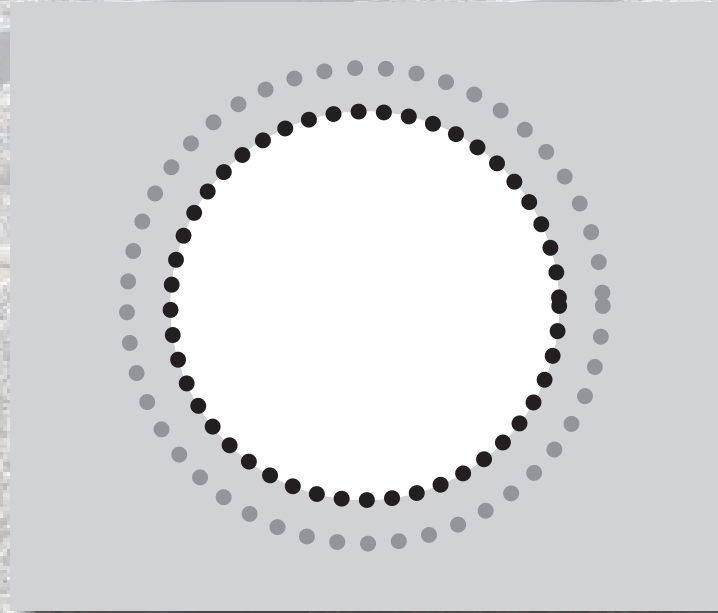


- 1. increases. ✓**
2. stays the same.
3. decreases.

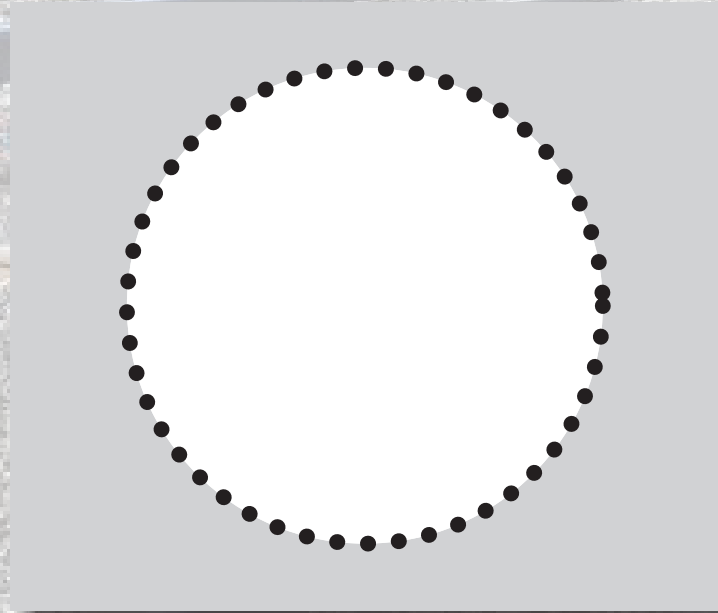
consider atoms at rim of hole



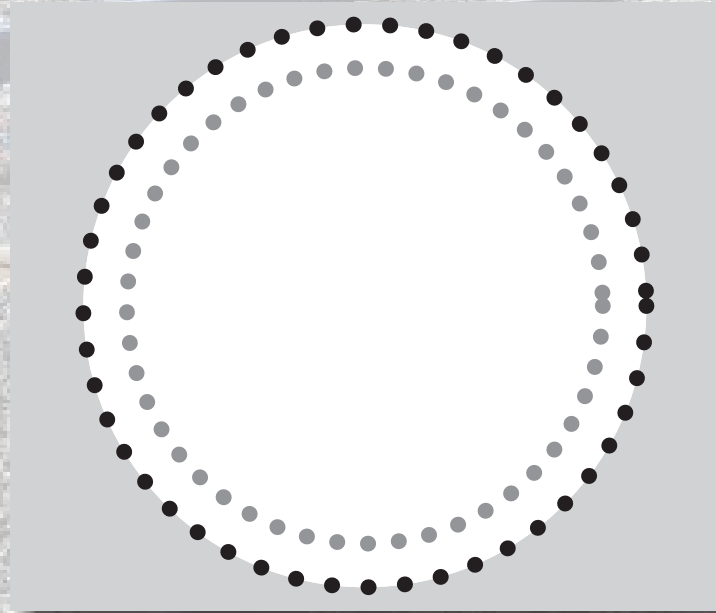
consider atoms at rim of hole



consider atoms at rim of hole



consider atoms at rim of hole



consider atoms at rim of hole

you won't forget this



Peer

back to pi

INSTRUCTION

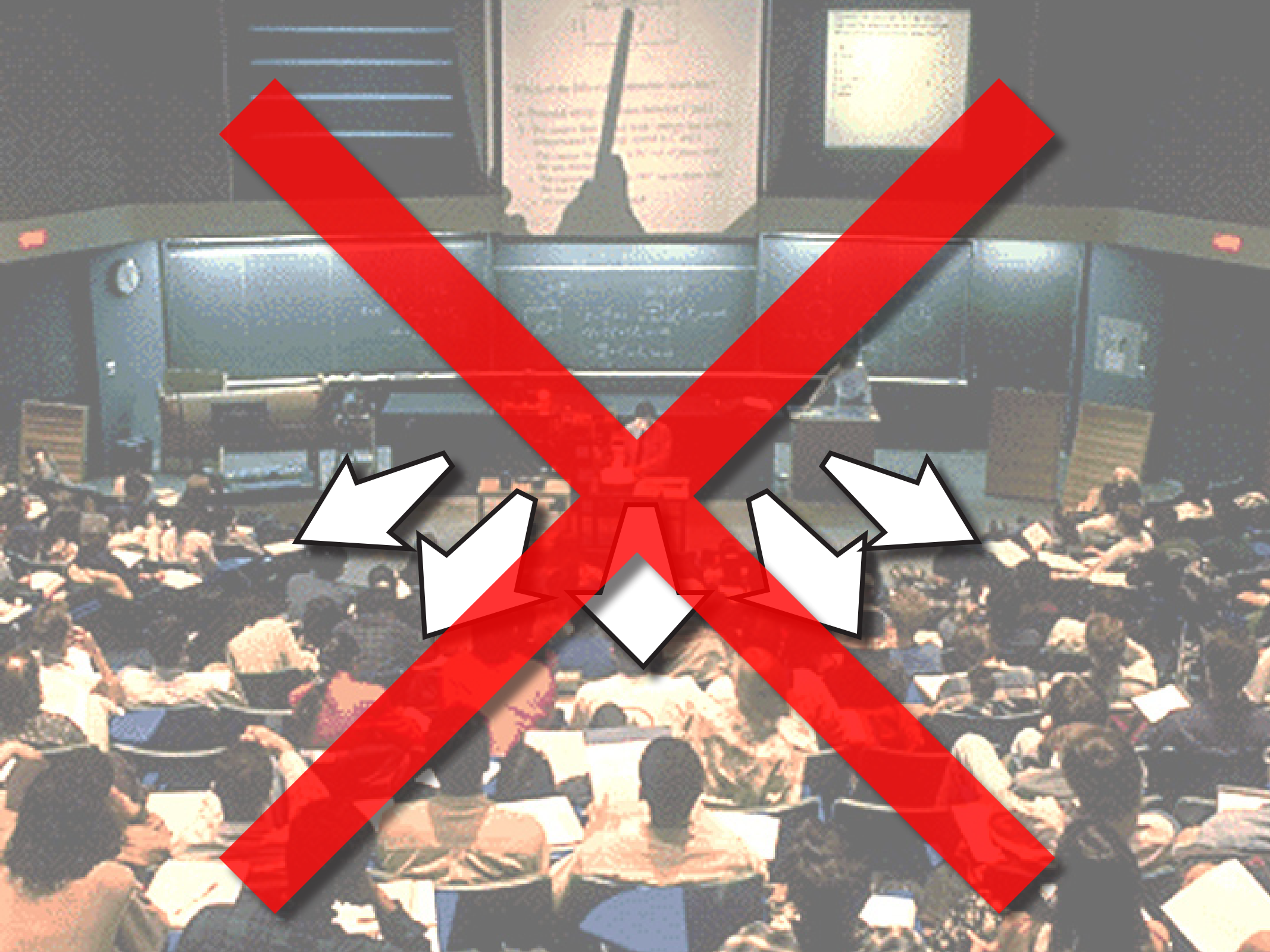
Higher learning & gains

INSTRUCTION

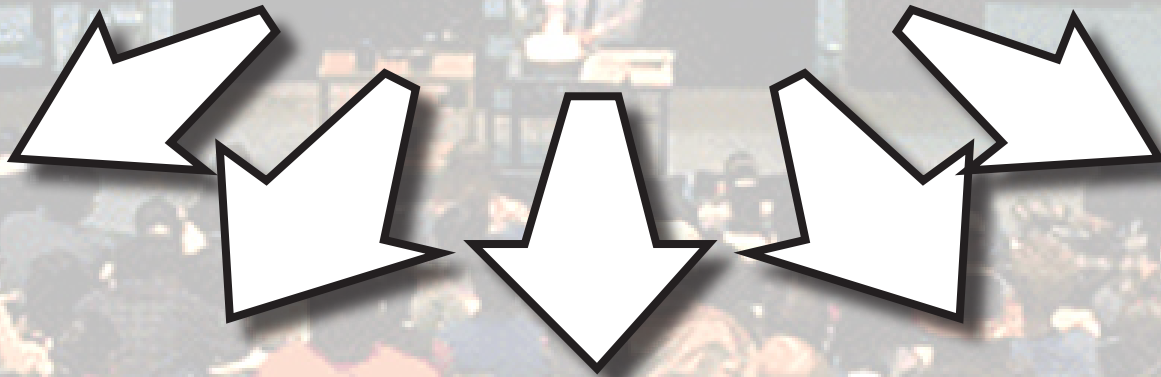
Higher learning gains

Better retention

INSTRUCTION



how to effectively transfer information outside classroom?

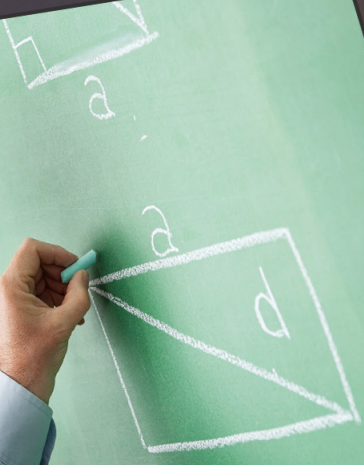




$$S = 2^2$$

$$P = 4 \cdot a$$

$$d = a$$



but...



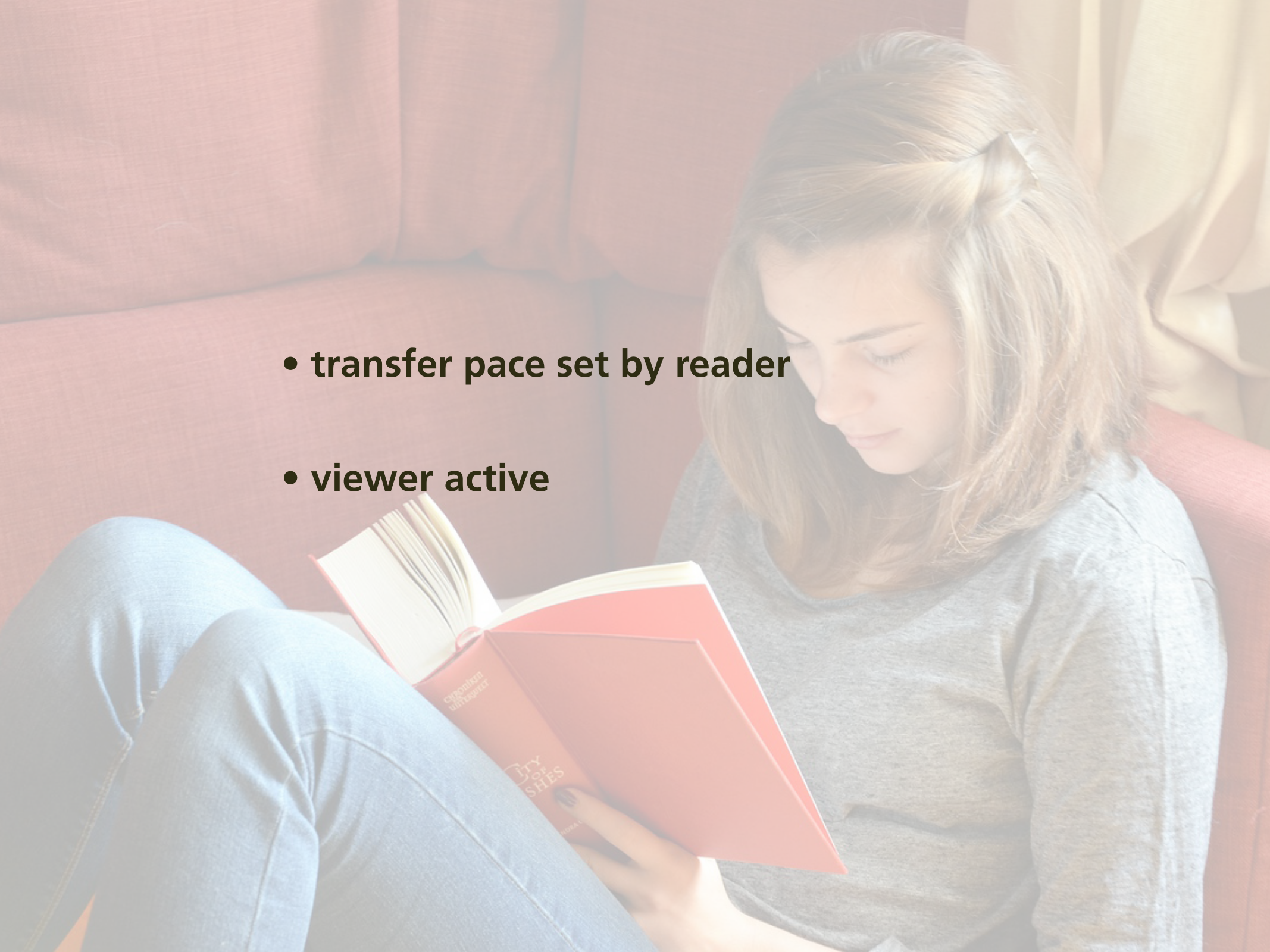
- **transfer pace set by video**
- **viewer passive**
- **viewing/attention tanks as time passes**
- **isolated/individual experience**






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)



Solution

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

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. An interesting 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 hardly decreases as the block slides over the other two surfaces. 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 an air hockey table. The air that is blown through the table 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 as the block slides. The block slides easily over ice. Friction between the two surfaces is so small that it can be neglected. To bring two objects to rest with respect to each other, in this case the wooden block and the ice, 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, where a thin layer of air is blown through holes in the table top, which prevents direct contact. 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 physics lab. Although there is still some friction between the wheels and the tracks and for the track sliding on the surface, the friction is so small that it can be neglected. For example, if the track is horizontal, the carts move along its length with a constant velocity. In other words:

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

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?

log in through social network



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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 decrease 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.



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.



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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 wood, this distance can vary. If the surface is particularly 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 hardly decreases as the block slides over a smooth surface; and it decreases rapidly as the block slides over a rough surface. 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 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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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 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 to a stop. 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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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.



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highlighting text...

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Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The rougher the surface, the more quickly the velocity decreases 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 decrease as the block slides on 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.



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 minimized. 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:

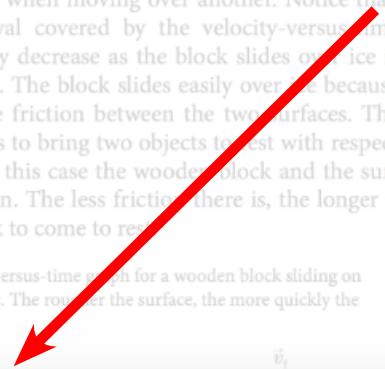
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...opens chat window



Enter your comment or question and press Enter

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4.1 Friction

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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 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 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.

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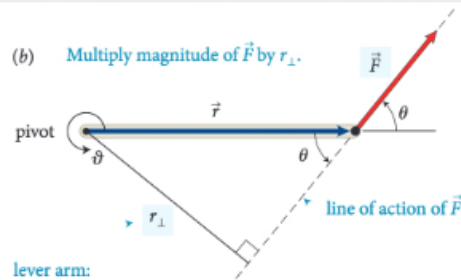
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(b) Multiply magnitude of \vec{F} by r_{\perp} .



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

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_1 and as $r_{\perp}F$.

Like other rotational quantities, torque carries a sign that depends on the choice of direction for increasing ϑ . 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 ϑ 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).

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}^c 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}^c 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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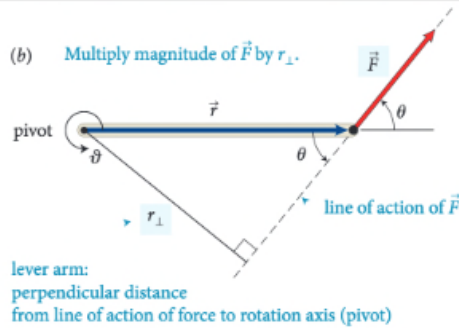
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12.2 In the situation depicted in Figure 12.2a, you must continue to exert a force on the seesaw to keep the child off the ground. The force you exert causes a torque on the seesaw, and yet the seesaw's rotational acceleration is zero. How can this 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}_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° with the horizontal. Do these forces cause the lever to rotate about the pivot? If so, in which direction?



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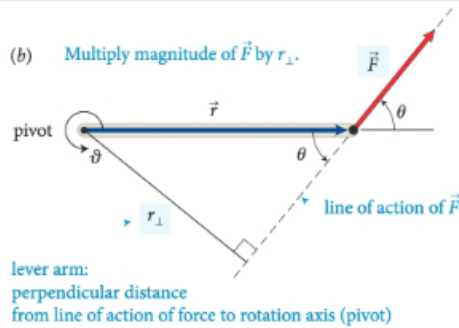


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Brian Lukoff responded to a question in Mazur Chapter 4 Sample that you wanted to know the answer to

21 minutes ago, you asked this question on Perusall:

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

Brian Lukoff just responded to the question by saying:

Right - I think there will always be some friction due to the second law of thermodynamics.

If this helps your understanding, click the button below. If you want to respond, simply reply to this email to post to Perusall.

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Right sidebar with a list of questions and answers:

- On the very left, we see th...
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- about this, t... 3
- partially w... 3
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- we have a p... 5
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- er in the chap... 3
- ing motion ar... 3
- the lever to rotate about the pivot? If so, in which direction? 2
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email notifications

Brian Lukoff responded to a question in Mazur Chapter 4 Sample that you wanted to know the answer to

21 minutes ago, you asked this question on Perusall:

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

Brian Lukoff just responded to the question by saying:

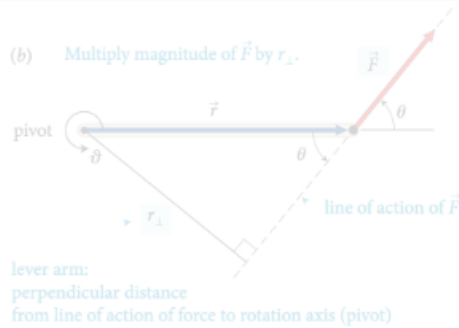
Right - I think there will always be some friction due to the second law of thermodynamics.

If this helps your understanding, click the button below. If you want to respond, simply reply to this comment.

View conversation

This comment helps my understanding

option 3: mark as answered



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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how to get students to participate?

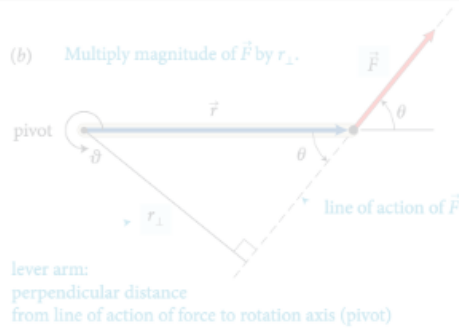
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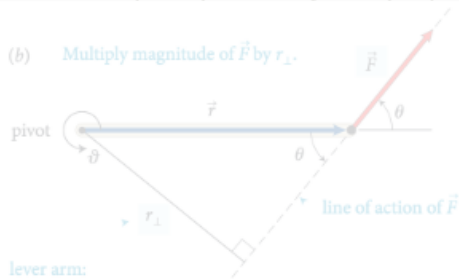
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rubric-based assessment

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

- quality (thoughtful reading & interpretation)

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- quality (thoughtful reading & interpretation)

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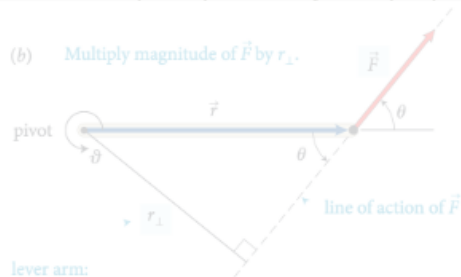
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Three forces are exerted on the lever of Figure 12.7. Forces \vec{F}_1 and \vec{F}_2 are equal in magnitude, and the magnitude of \vec{F}_3 is half as great. Force \vec{F}_1 is horizontal, \vec{F}_2 and \vec{F}_3 are vertical, and the lever makes an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

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- It's interesting that the white ...
- Is the refernece frame i... 2
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- (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

rubric-based assessment

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



- quality (thoughtful reading & interpretation)

over 20,000 annotations!

- timeliness (before class)

- annotated (right-click)

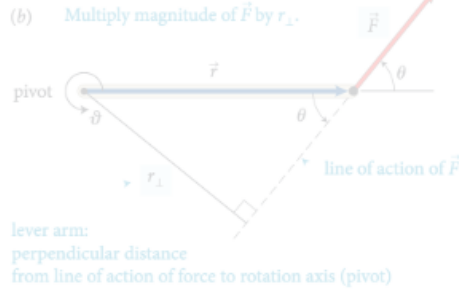
The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force \vec{F}_1 about the left end of the rod is zero, and so the torque caused by this force about the left end of the rod is zero. If I choose the pivot to be the left end of the rod, the force \vec{F}_2 causes a positive torque about the left end of the rod; the force \vec{F}_3 causes a positive torque about the left end of the rod. The net torque about the left end of the rod is the sum of the torques caused by the three forces. We obtain $\tau_{net} = r_1 F_1 + r_2 F_2 + r_3 F_3 = 0$. The result is the same if we choose the pivot to be the right end of the rod.

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° with the horizontal. Do these forces cause the lever to rotate about the pivot? If so, in which direction?

- Only left, we see th...
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- Is it for frame i...
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- As u at this, t...
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rubric-based assessment



- quality (thoughtful reading & interpretation)

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

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. 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 the force \vec{F} is exerted, we can eliminate that force from the calculation.

In general we can say: For a stationary object, the sum of the torques is zero.

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Example 12.2 Torques on lever

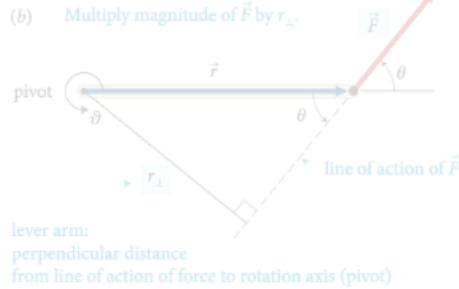
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how do you process all of that??

- quantity (minimum 10)
- timeliness (before class)
- distribution (not clustered)

- On the very left, we see th...
- It's interesting that the white ...
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rubric-based assessment



- quality (though future research on interpretation)

fully automated

do you process all of that??

assessment

- timeliness (before class)

- distribution (not clustered)

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 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 the perpendicular distance from the left end of the rod to the line of action of \vec{F}_2 . 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. This is a general result: for any rigid body, the sum of the torques about any point is the same as the sum of the torques about any other point. In general, the sum of the torques about any point is zero. The reason is that the sum of the torques about any point is the same as the sum of the torques about any other 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 is exerted, we can eliminate that force from the calculation.

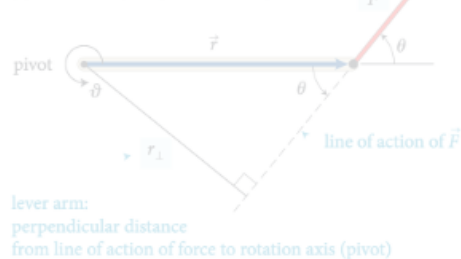
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fully automated assessment

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

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

- 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 just know some sort of direction from the force vector.

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. For example, in the diagram above, you can explain how to choose the sign of the torque.

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.

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.

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 result is that the sum of the torques 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 to calculate the torques. We can choose a reference point that is not on the object. For example, 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?

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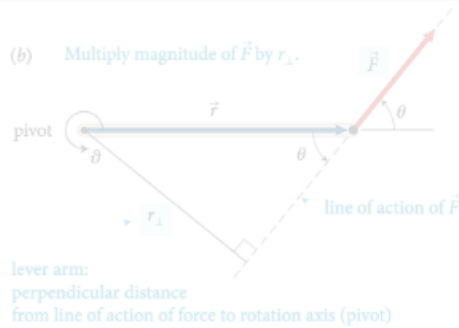
Total number of annotations **16**

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 with just the magnitude of the force and the lever arm distance both scalar quantities? It seems like we would need to know some sort of direction to calculate torque.

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.

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.

Enter your comment or question and press Enter

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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?
- SB Using the right hand rule, I believe the answer is D. Is that correct? 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...

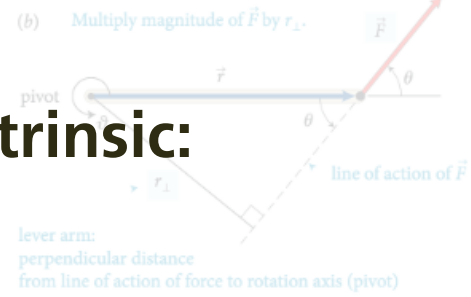
earth magnetic field (6 questions)

- 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?
- AK Can someone explain why this type of bacteria knows what direction the earth's magnetic fields are facing?
- 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. Show more...

motivating factors

Intrinsic:

- social interaction



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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 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. ✓

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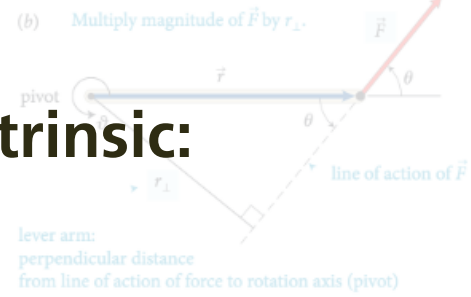
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- Enter your comment or question and press Enter

motivating factors

Intrinsic:

- social interaction
- tie-in to in-class activity



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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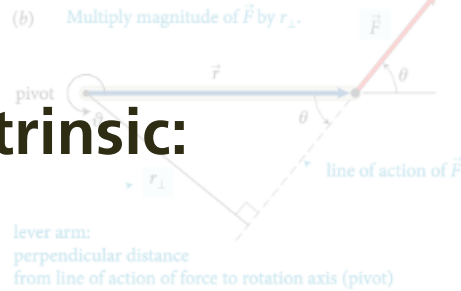
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motivating factors

Intrinsic:



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- tie-in to in-class activity

Extrinsic:

- assessment (fully automated)

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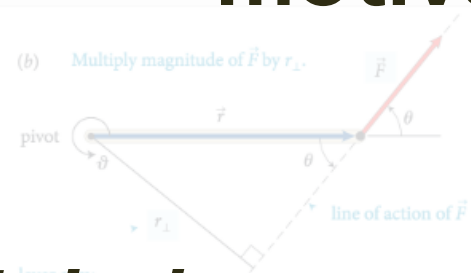
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SB

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motivating factors



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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 right end. You can choose any reference 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. For a stationary object, the sum of the torques is zero.

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Harvard student



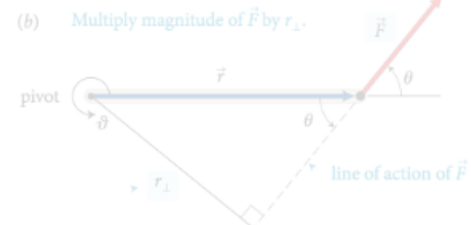
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motivating factors



"It makes the book fun to read..."

All the other students on my floor are disap-

pointed their Prof isn't using Perusall because

they don't read the book."

Ohio State student

Profile picture of a student.

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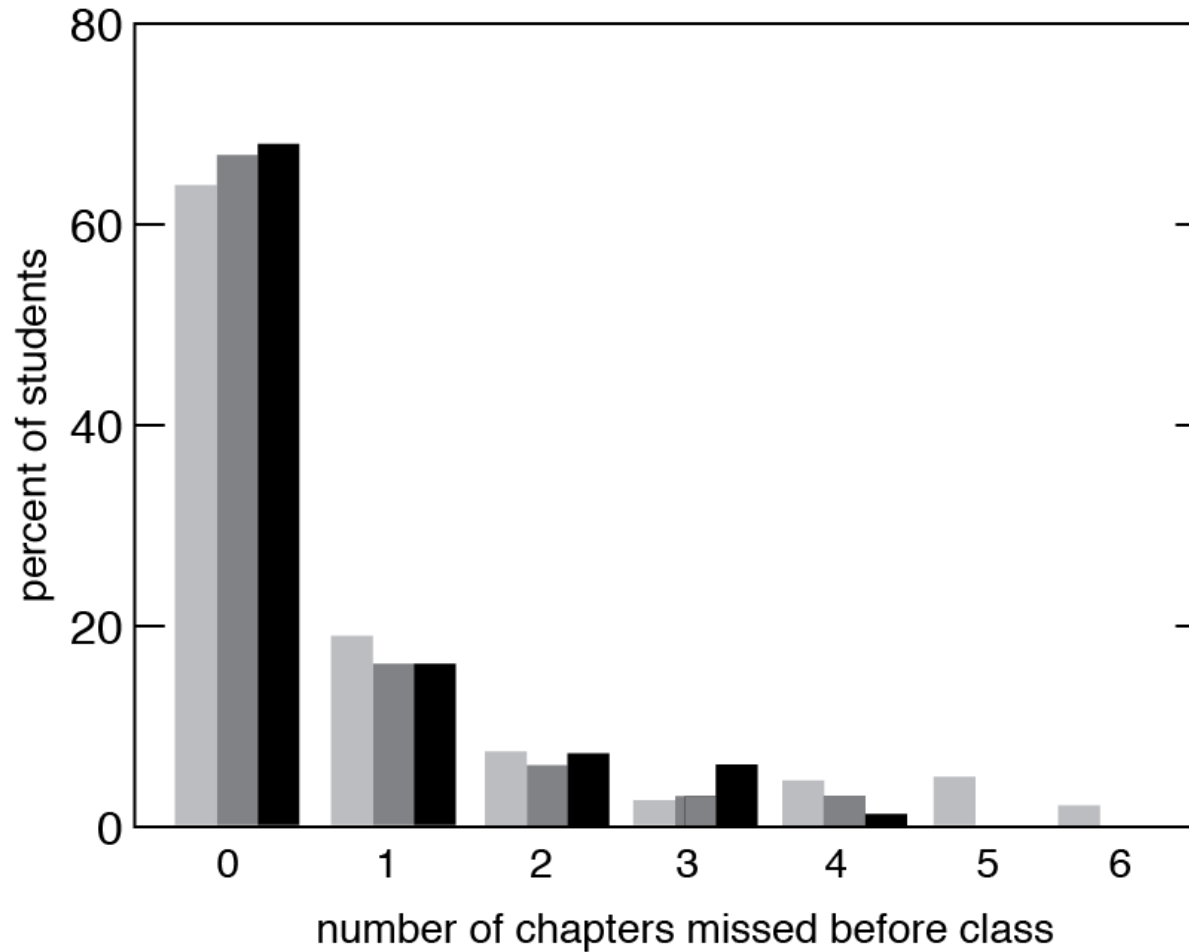
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class test results

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



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



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Example 12.2 Torques on lever

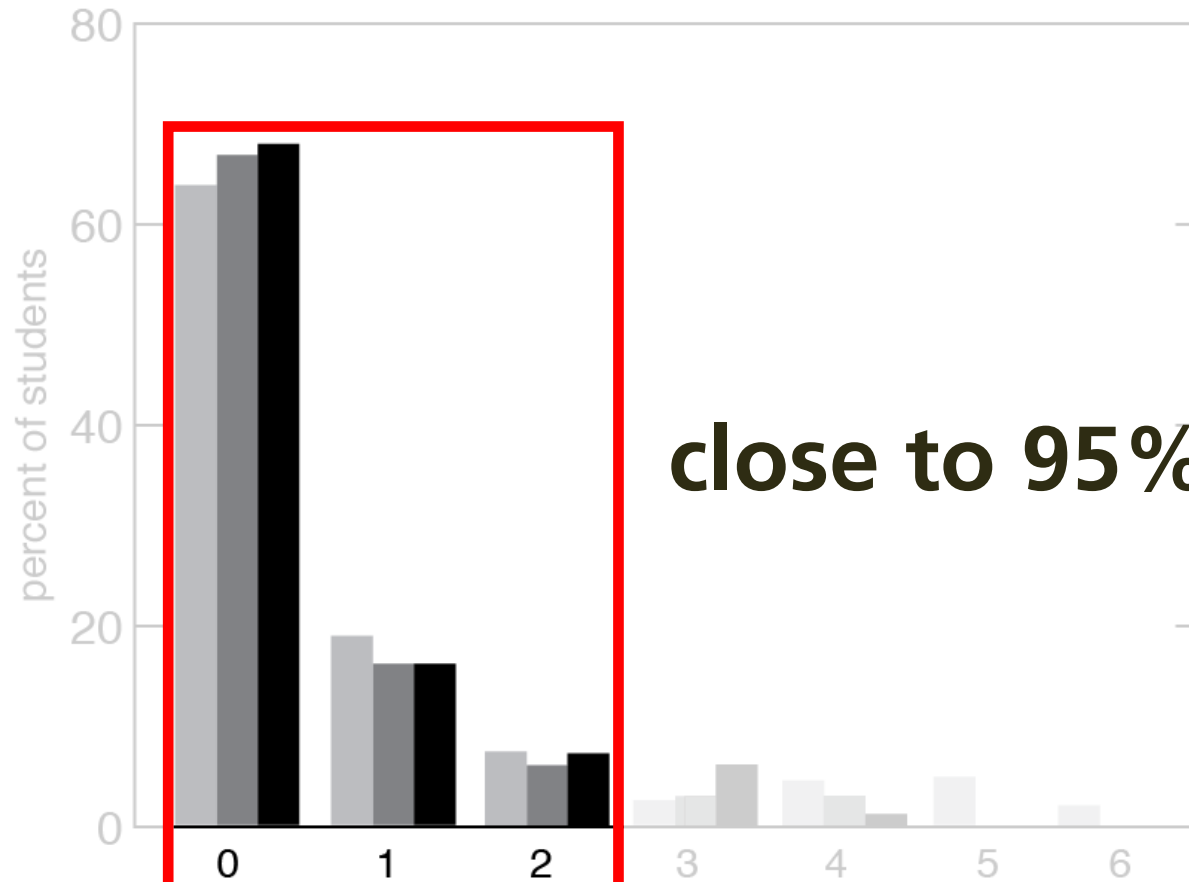
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class test results

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close to 95%!

number of chapters missed before class

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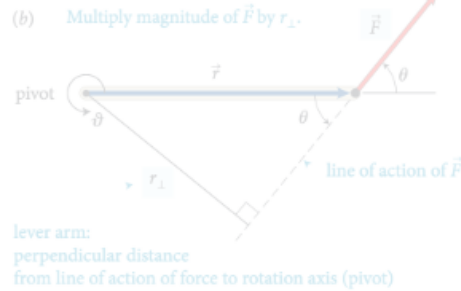
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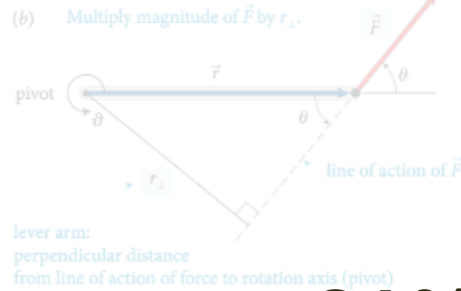
I don't understand how this combination of ... Oct 20 12:09 am

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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

Enter your comment or question and press Enter

additional research data



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

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}^c 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}^c 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 F_1 and F_2 . To account for the signs of the torques due to the forces, we write $r_1(F_1 + F_2) - (r_1 + r_2)F_2 = r_1F_1 - r_2F_2$. 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. ✓

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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

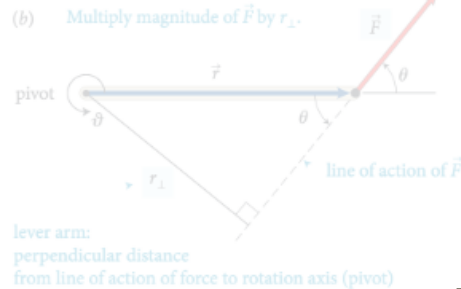
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• Engagement: 81% spend 2–6 hrs/wk reading

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- It's interesting that the white ...
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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
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additional research data



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Exercise 12.1 shows that the sum of the torques about the right end of the rod is also zero. In general, the sum of the torques about the right end of the rod or any other point, on each time you will find that the sum of the torques is zero. In general we can say:

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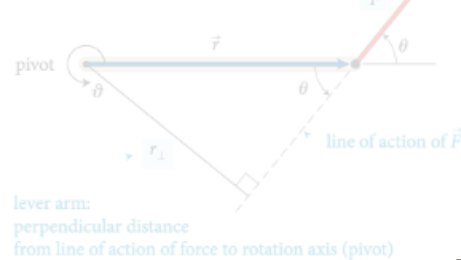
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additional research data

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- **Performance:** significantly higher scores

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



lever arm:
perpendicular distance
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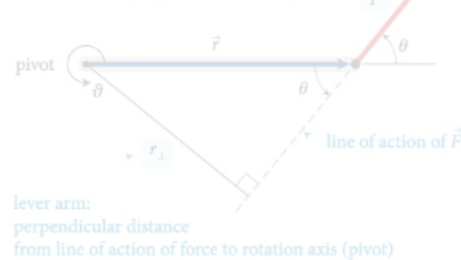
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- virtually 100% completion of assignments
- improved use of class time

CONCEPTS

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).

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

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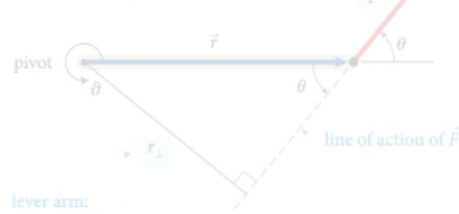


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(b) Multiply magnitude of \vec{F} by r_{\perp} .



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perpendicular distance
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Figure 12.7 shows a seesaw that is not rotating about 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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all at no cost & without additional instructor effort!



Education is not just about:

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

The background of the slide features a close-up, slightly faded image of a person's face, specifically their eyes and nose, looking through horizontal window blinds. The blinds are light-colored, and the person's skin is a warm, yellowish-brown tone. The overall image has a soft, artistic quality.

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active engagement/social interaction a must!

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