

Creating the Ultimate Flipped Classroom



Leadership program for the Brazil STHM Consortium
Harvard University
Cambridge, 22 April 2016



Creating the Ultimate Flipped Classroom



@eric_mazur

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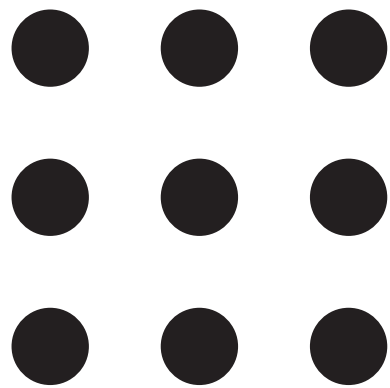


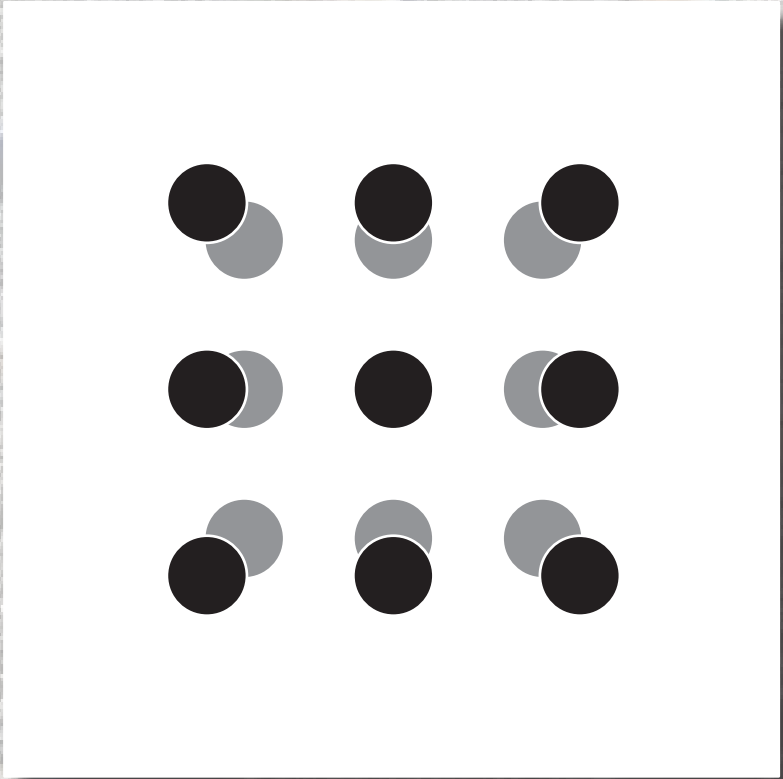




A photograph showing a blue pipe installed on a gravel bed. The pipe is laid out in a zigzag pattern, which is a common technique for thermal expansion. The pipe is supported by small concrete blocks. The background shows a grassy area.

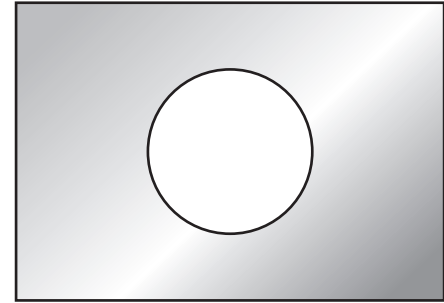
thermal expansion





all of them

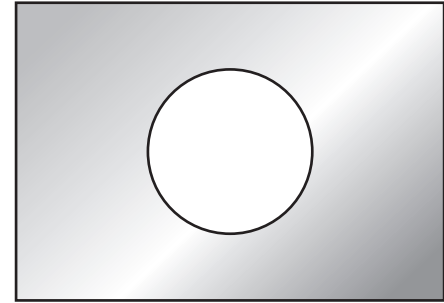
**Consider a rectangular metal plate
with a circular hole in it.**



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!

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.

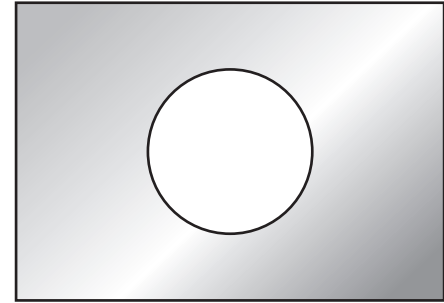
You...

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

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

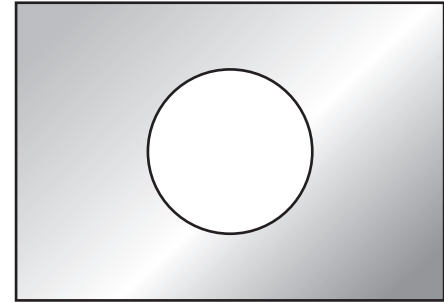
- 1. increases.**
- 2. stays the same.**
- 3. decreases.**



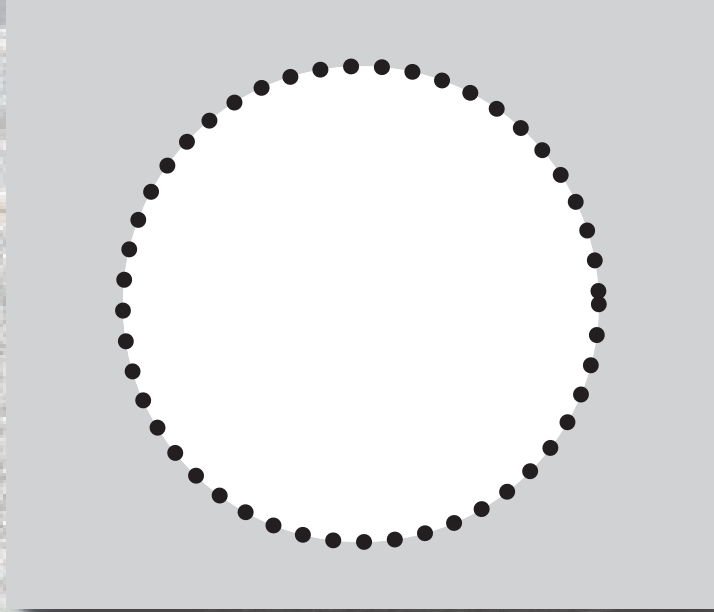
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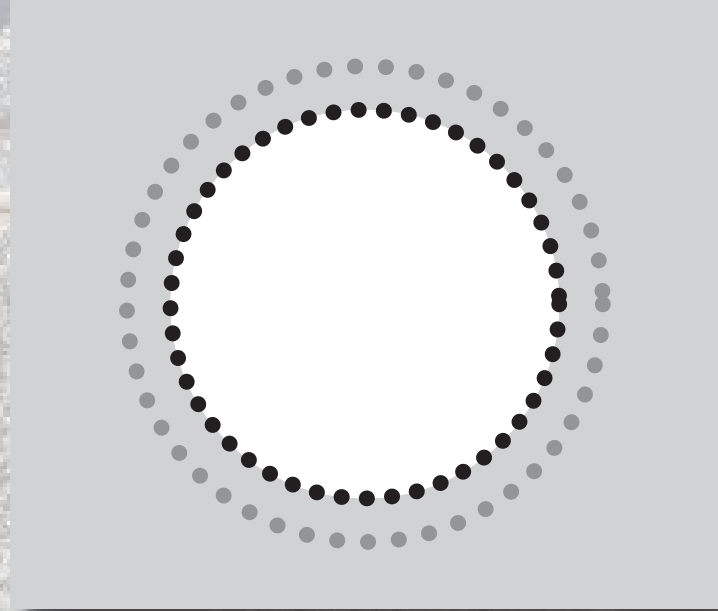
- 1. increases. ✓**
2. stays the same.
3. decreases.



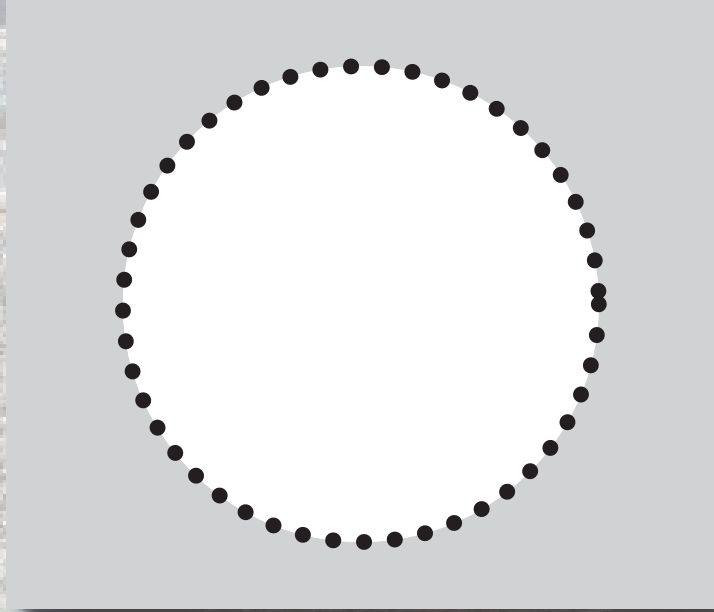
consider atoms at rim of hole



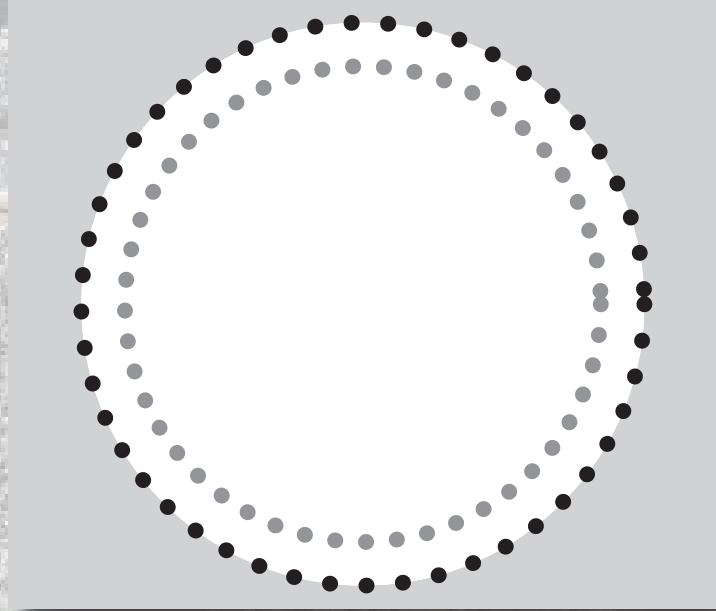
consider atoms at rim of hole



consider atoms at rim of hole



consider atoms at rim of hole



consider atoms at rim of hole

you won't forget this



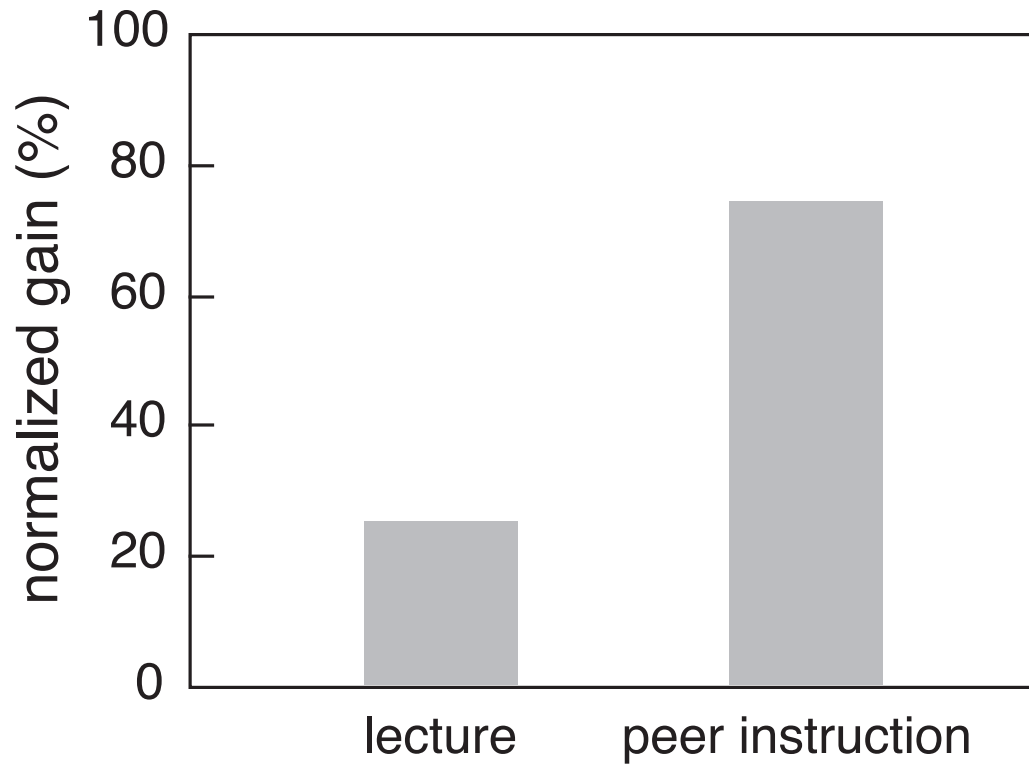
Peer

back to pi

INSTRUCTION

Peer
Higher learning gains

INSTRUCTION



Peer

Higher learning gains

Better retention

INSTRUCTION



CLASS

1st exposure



ROOM

deeper understanding



CLASS

1st exposure



ROOM

deeper understanding



ROOM

1st exposure



CLASS

deeper understanding



1st exposure



deeper understanding



1st exposure



deeper understanding



1st exposure



deeper understanding

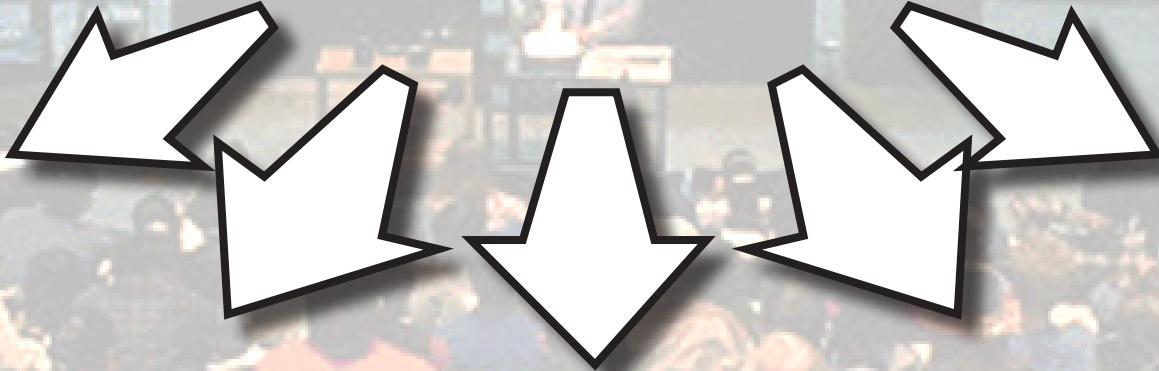


1st exposure



deeper understanding


how to effectively transfer information outside classroom?





but...

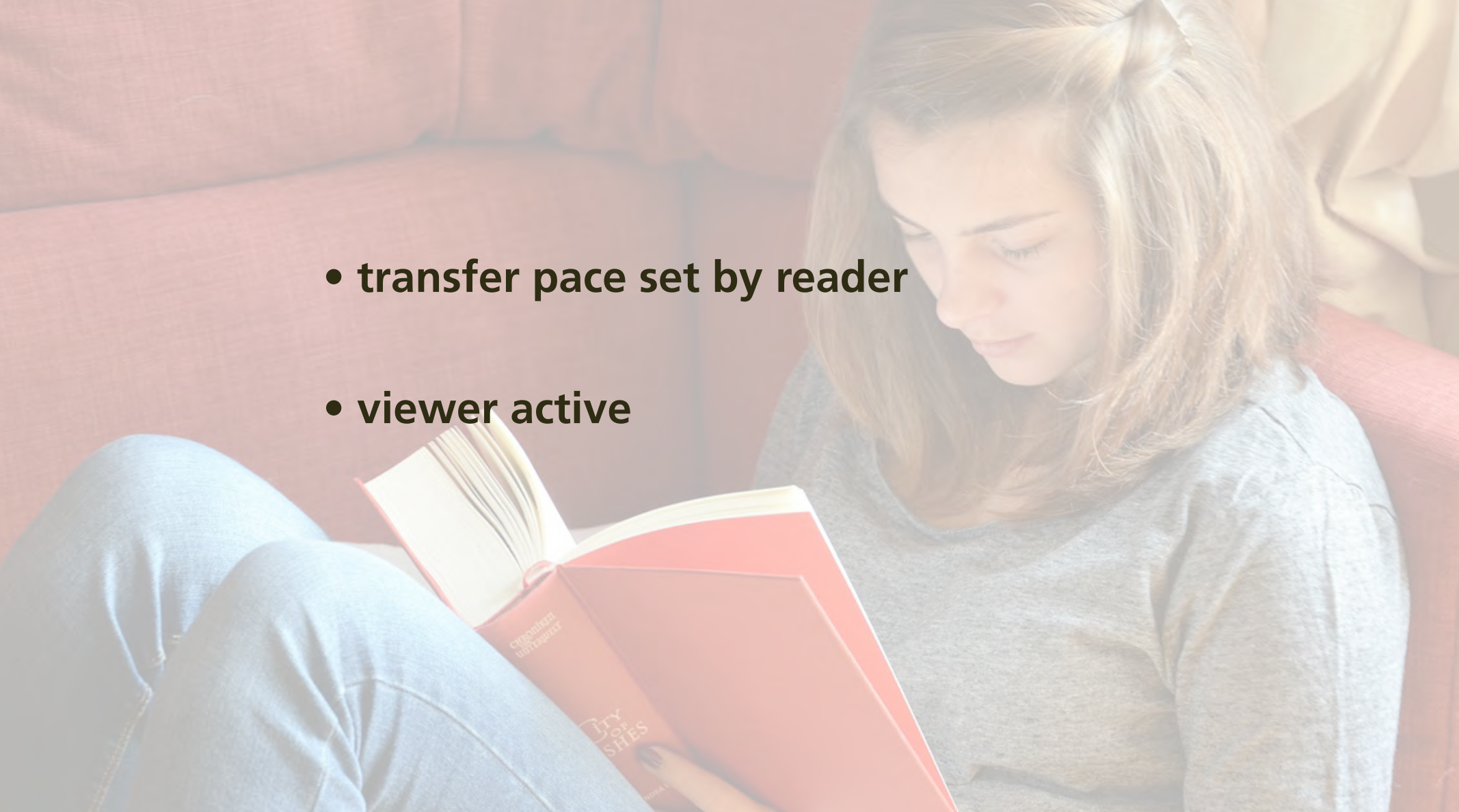


- **transfer pace set by video**
 - **viewer passive**
 - **viewing/attention tanks as time passes**
 - **isolated/individual experience**
- 
- The image shows a person's hands holding a tablet computer. The tablet screen displays a video of a man in a white shirt writing on a green chalkboard. The chalkboard has some mathematical or physics-related content, including a diagram of a rectangle with a diagonal and some equations like
- $P=4a$
- and
- $d=2a$
- . The background of the image is a desk with a green apple, an open book, and a pencil.



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!**

Perusal

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 sliding on a horizontal wooden surface. The block starts with a certain initial velocity, 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 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 4.2 Low-friction track and carts used in the experiments described in this chapter.



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

social learning platform

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4.1 Friction

When you push a block across a wooden surface, it 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 experience: a hockey puck slides easily on ice.

How does the velocity of a block change as it slides over different surfaces? The slower it moves, the more resistance to motion that offers. The velocity decreases as the block slides over a rougher surface. The velocity decrease 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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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.

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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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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 time interval between shove and rest depends on the smoothness of the surfaces. If the surfaces are very 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 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.

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see who is online

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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.



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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.



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?

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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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. In the 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.

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



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



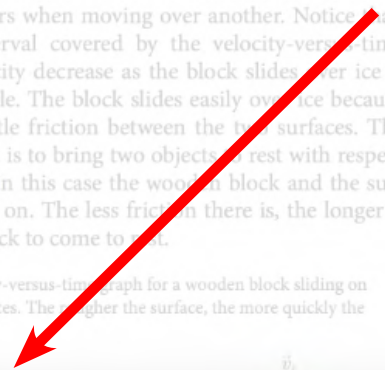
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...opens chat window



Enter your comment or question and press Enter

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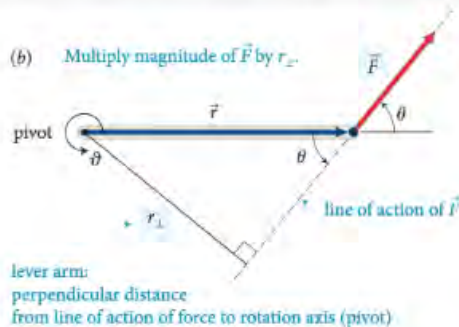
Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.



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?



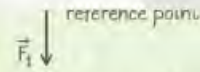
No friction at all seems impossible. Isn't there always some friction in any real case.



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



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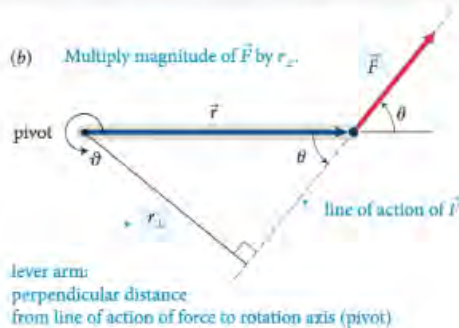
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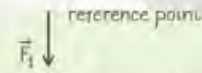
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(b) Multiply magnitude of \vec{F} by r_{\perp} .



lever arm:
perpendicular distance
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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



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 Oct 22 8:48 pm



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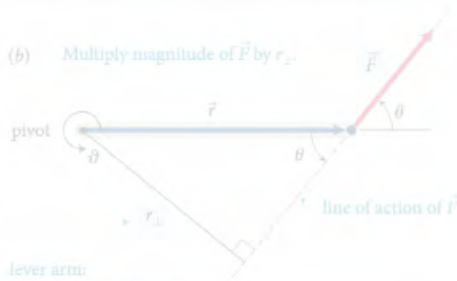
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Oct 22 8:48 pm

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



lever arm:
perpendicular distance
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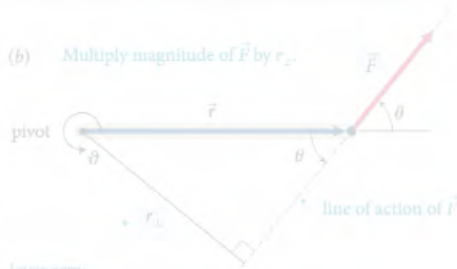
how to get students to participate?

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use combination of

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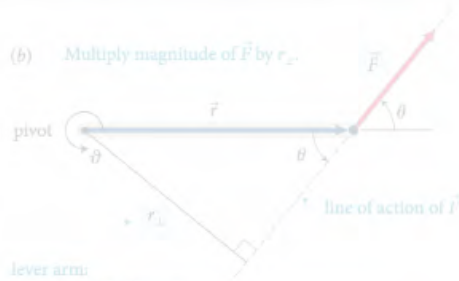
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rubric-based assessment

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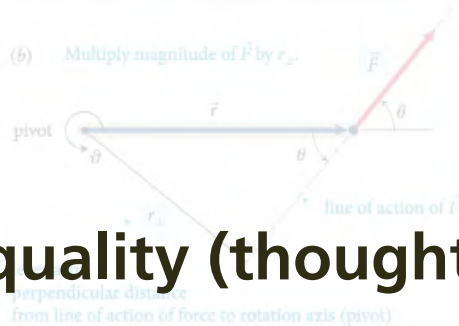
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rubric-based assessment

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- quality (thoughtful reading & interpretation)

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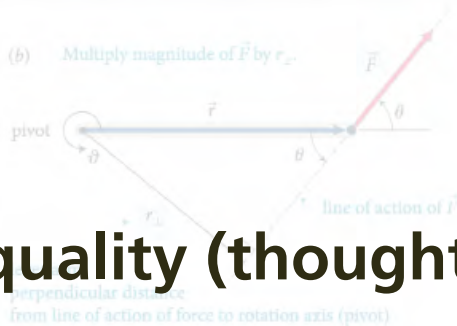
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rubric-based assessment

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- quality (thoughtful reading & interpretation)
- quantity (minimum 10)

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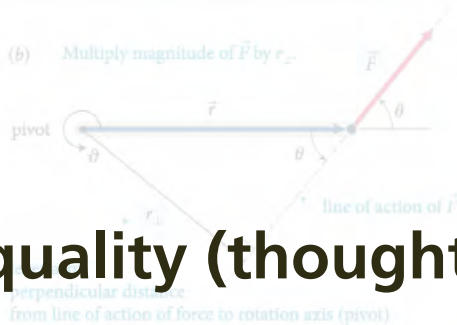
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- quality (thoughtful reading & interpretation)

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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 like we've seen before? I know some sort of direction is involved but I don't know how to choose it.

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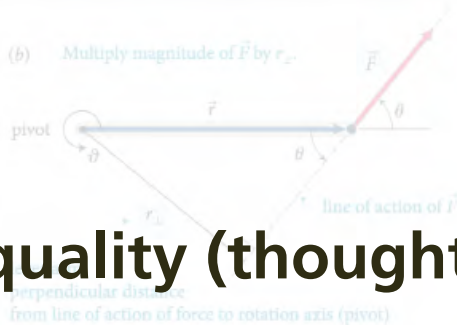
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rubric-based assessment

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- quality (thoughtful reading & interpretation)

- quantity (minimum 10)

- timeliness (before class)

- distribution (not clustered)

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rubric-based assessment

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• quality (thoughtful reading & interpretation)

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

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 Oct 20 2:33

? This is...
 Oct 22 8:48 pm

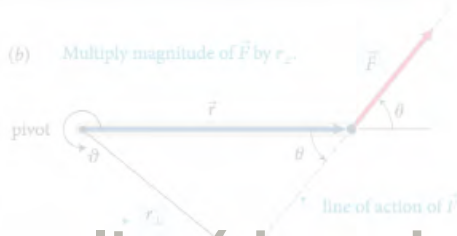
The... must now...
 If I choose...
 Because...
 Taking into account...
 the... about the pivot, and...

Exercise 12...
 For a stationary object we can choose any reference point...
 It pays to choose a reference...
 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.

Over 20,000 annotations!

rubric-based assessment

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



- quality (thoughtful reading & interpretation)

how do you process all of that??

- quantity (minimum 10)

- timeliness (before class)

- distribution (not clustered)

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.

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 first part of the question, 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

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}_{pr} to the left end of the rod 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 . Since the rod is at rest, the net torque about the left end of the rod is zero. This means that the sum of the torques about the left end of the rod is zero. $\tau_1 + \tau_2 = 0$. (This is the same as the sum of the torques 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:

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

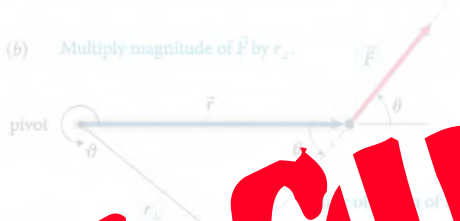
For a stationary object we can choose any reference point we like to calculate torques. It pays to choose a reference point that eliminates the most forces from the calculation. As you have seen, we do not need to consider any force that is exerted at the reference point. So, by putting the reference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

rubric-based assessment

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



fully automated

how do you process all of that??

assessment

- timeliness (not clustered)
- distribution (not clustered)

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

I think you may be able to calculate the magnitude of the torque by multiplying the magnitude of the force and its lever arm distance. It can be calculated by multiplying the magnitude of the force and its lever arm distance.

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

Exercise 12.2 shows that the net torque about the rod and about the pivot is zero. You can verify this by calculating the sum of the torques about the pivot and about any other point, such as the center of mass. The sum of the torques is not zero about any point other than the pivot. In general we can say:

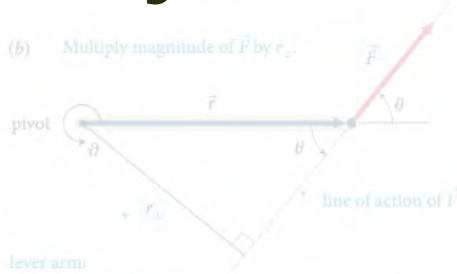
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For a stationary object we can choose any reference point to calculate torques. It pays to choose a reference point that eliminates the most forces from the calculation. As you have seen, we do not need to consider any force that is exerted at the 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, a mass

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)

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

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 F_1 and F_2 . The sum of the torques about the left end 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. The sum of 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: 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.

- specialized machine learning algorithm

- assesses intellectual content

- exceeds intercoder reliability

I don't understand how the direction of the force 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.

I think you may be thinking of torque as a scalar quantity. If you think of torque as a vector, then multiplying its magnitude and direction separately, or, after multiplying its 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

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



lever arm:
perpendicular distance
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connect pre-class and in-class activities

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confusion report

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?

motivating factors

Intrinsic:

- social interaction

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



lever arm:
perpendicular distance
from line of action

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

reference point

\vec{F}_1

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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12.2 In the situation depicted in Figure 12.2a, an object

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

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

Oct 22 8:48 pm

motivating factors

Intrinsic:

- social interaction

- tie-in to in-class activity

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



lever arm:

perpendicular distance from pivot to line of action of force

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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13.2 In the situation depicted in Figure 13.2a, we must

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motivating factors

Intrinsic:

- social interaction

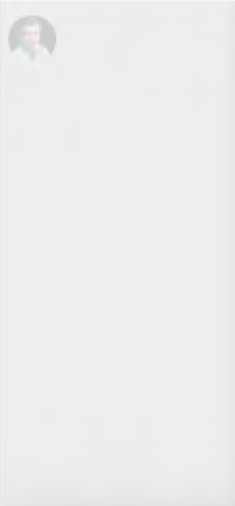
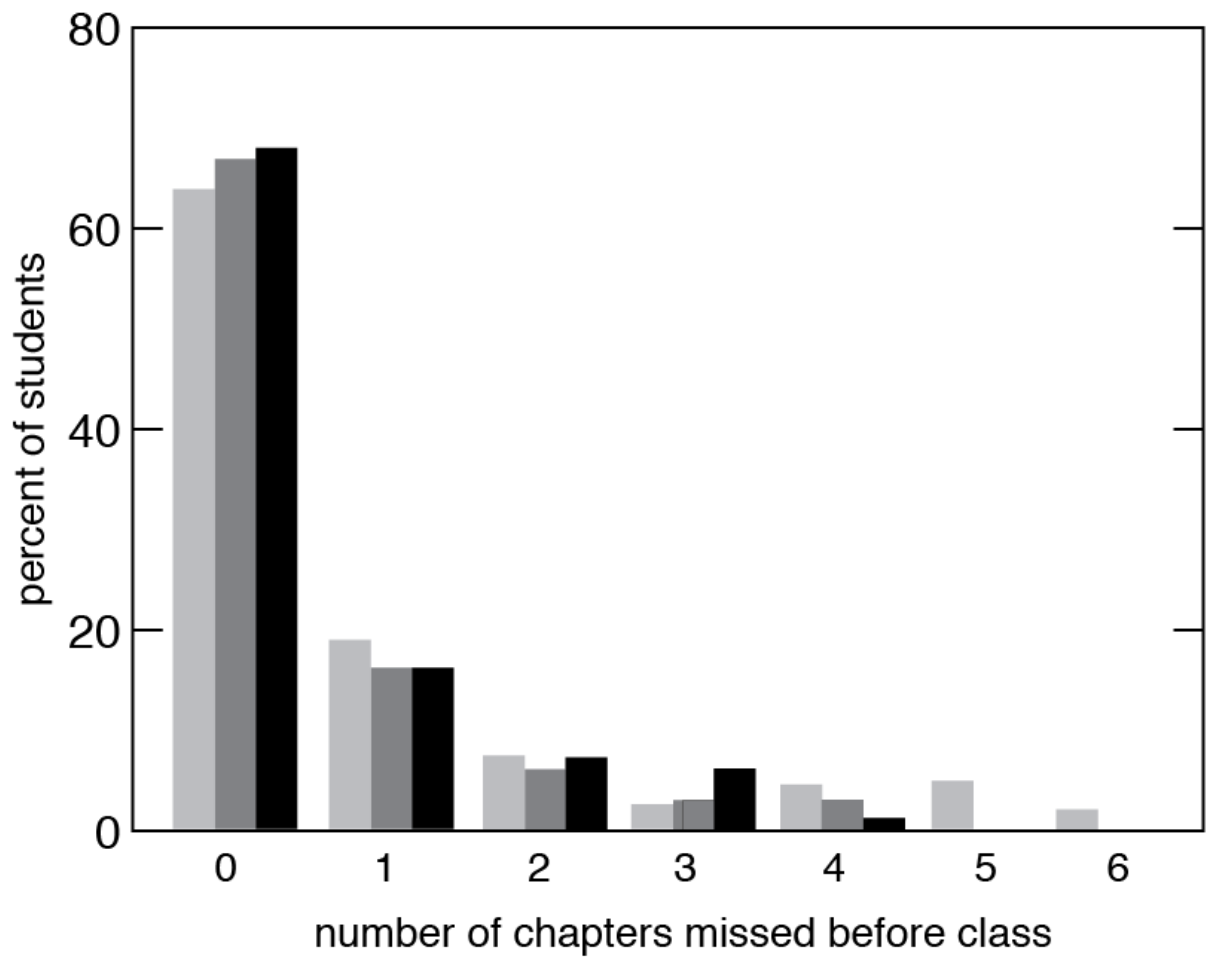
- tie-in to in-class activity

Extrinsic:

- assessment (fully automated)

The screenshot displays the Perusall interface for a physics course. At the top, the course information is "AP50 Fall 2015 » Chapter 12". The main content area is divided into three sections:

- Left Panel:** A forum discussion. A question asks, "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." A response explains that direction is handled by attaching a sign to the torque based on the system's parameters.
- Center Panel:** A physics problem (b) titled "Multiply magnitude of \vec{F} by r_{\perp} ". It includes a diagram of a force vector \vec{F} applied to a rod at an angle θ to the line of action. The lever arm r_{\perp} is shown as the perpendicular distance from the pivot to the line of action. A text box explains: "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..."
- Right Panel:** A textbook page (Page 284) discussing torque. It explains that for a stationary rod, the sum of torques about any point must be zero. It defines the lever arm distance relative to a reference point and shows how forces \vec{F}_1 and \vec{F}_2 contribute to the total torque. A key principle is highlighted: "For a stationary object, the sum of the torques is zero."

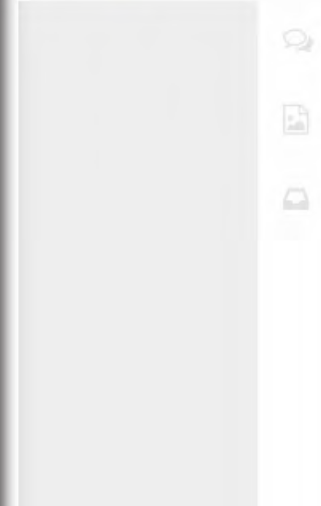


I don't understand how factors tells you any lever arm distance both s know some sort of direct

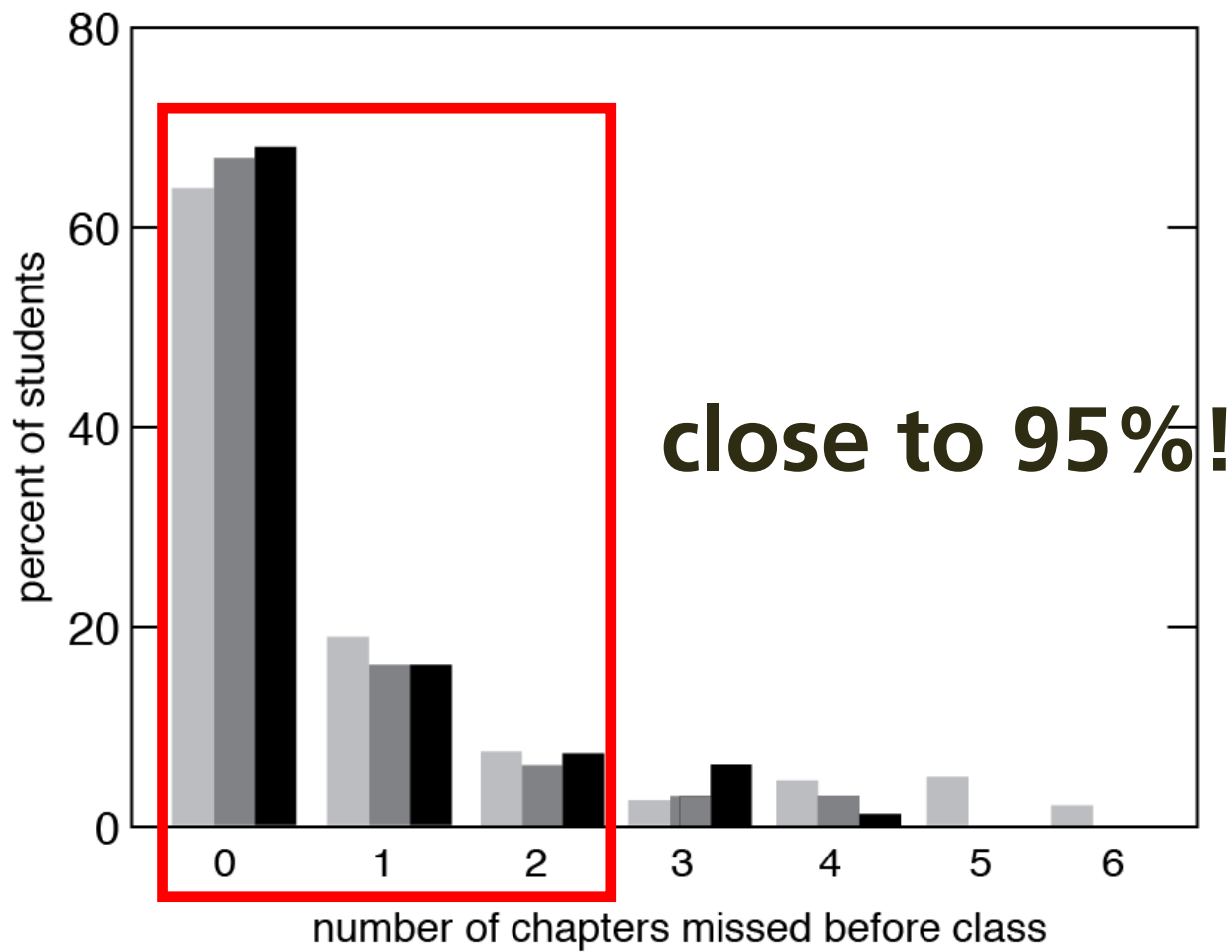
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This is a great quest this, we can think of

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In the situation depicted in Figure 12.2a, the mass



close to 95%!

I don't understand how factors tells you any lever arm distance both s know some sort of direct

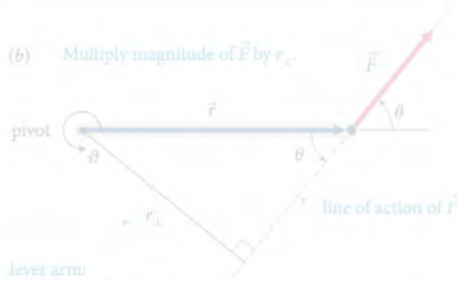
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(b) Multiply magnitude of \vec{F} by r_{\perp} .



lever arm:
perpendicular distance
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every student prepared for every class

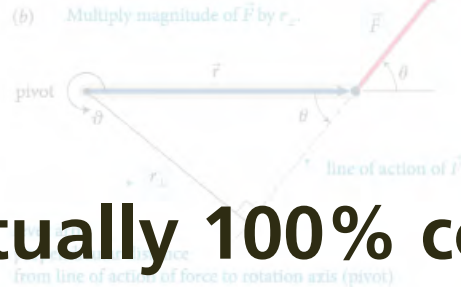
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Benefits

- virtually 100% completion of assignments
- improved use of class time



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}_p , exerted by the pivot causes a positive torque about the left end of the rod. The lever arm 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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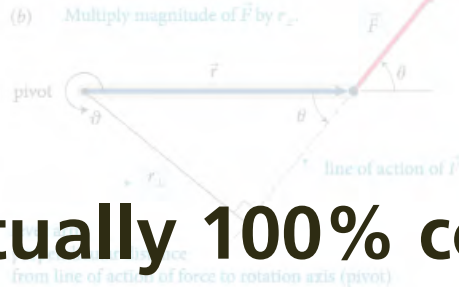
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all at no cost & without additional instructor effort!

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.

I think you may be able to think about this in terms of the cross product. When you take the cross product of two vectors, 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 $\tau = \vec{r} \times \vec{F}$, with \vec{r} being the level arm distance and \vec{F} being force. We know that force is a vector vector from previous



Education is not just about:

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

The background of the slide features a faded, artistic rendering of a classical building facade. It includes two prominent columns on either side, a central archway, and a statue or figure in the center. The overall color palette is muted, with soft blues, greys, and earthy tones.

Education is not just about:

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

active participation/social interaction a must!

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