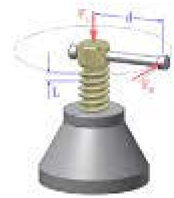
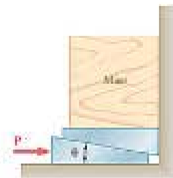
GIVE FEEDBACK

CONTINUE >

Welcome to our final friction chapter, Screws and wedges. These are two engineering applications of friction on an inclined plane.

Remember, we are not talking about screws used in carpentry, but power screws that move loads–like the screw in a lifting jack.

This chapter covers two engineering applications of friction on an inclined plane—power screws and wedges. Screws and wedges can be solved by either mathematical or graphical methods.

Screws are obviously important to engineering. Not the wood screw type, but power screws—the type that are used for moving and lifting loads. This includes screw jacks, power screws in machine tools and linear actuators. The theory is also relevant to static applications, such as determining whether friction will be able to hold a bolt tight.	
Wedges appear in many forms and, like screws, they are based on the theory of friction on an inclined plane. This is a relatively simple concept, except that we now have two inclined planes—one on each side of the wedge. Wedges are particularly suited to the graphical method since they usually form a force triangle (three forces).	

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A screw thread is a helical structure used to convert between rotational and linear movement or force.

A screw is commonly used for a fastener for wood, like this: 	In metals and manufacturing, a screw is a full-threaded bolt, like this: 

GIVE FEEDBACK

CONTINUE >

In engineering mechanics a screw is any threaded rod, particularly if used to clamp or move something—like a screw jack designed to lift a car, for instance.

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In engineering mechanics, the definition we will use for a **screw** is ____.

Click the correct answer.

- a threaded rod used for force and motion
- a fastener used for attaching things into wood
- a bolt threaded all the way to the head
- a type of propellor

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Thread form is the shape of the thread itself. This modifies the load capacity and friction properties.

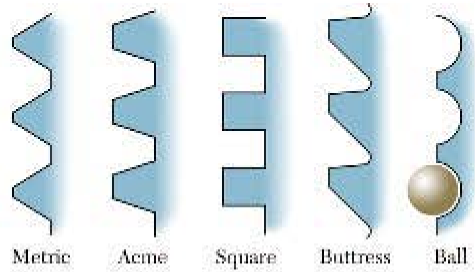
Thread forms compared

The most common thread shape is triangular (e.g. metric), used for bolts.

The ball screw has the lowest friction, and is not self-locking. This is used for linear drives in CNC machines.

The square thread is the most efficient of the plain (non-roller) threads but is difficult to make. It is used for motion and clamping.

Acme is similar to a square thread but is easier to make.



Buttress is the strongest design, but only in one direction, and is seen on some clamps, and moulded threads (especially plastic moulded threads).

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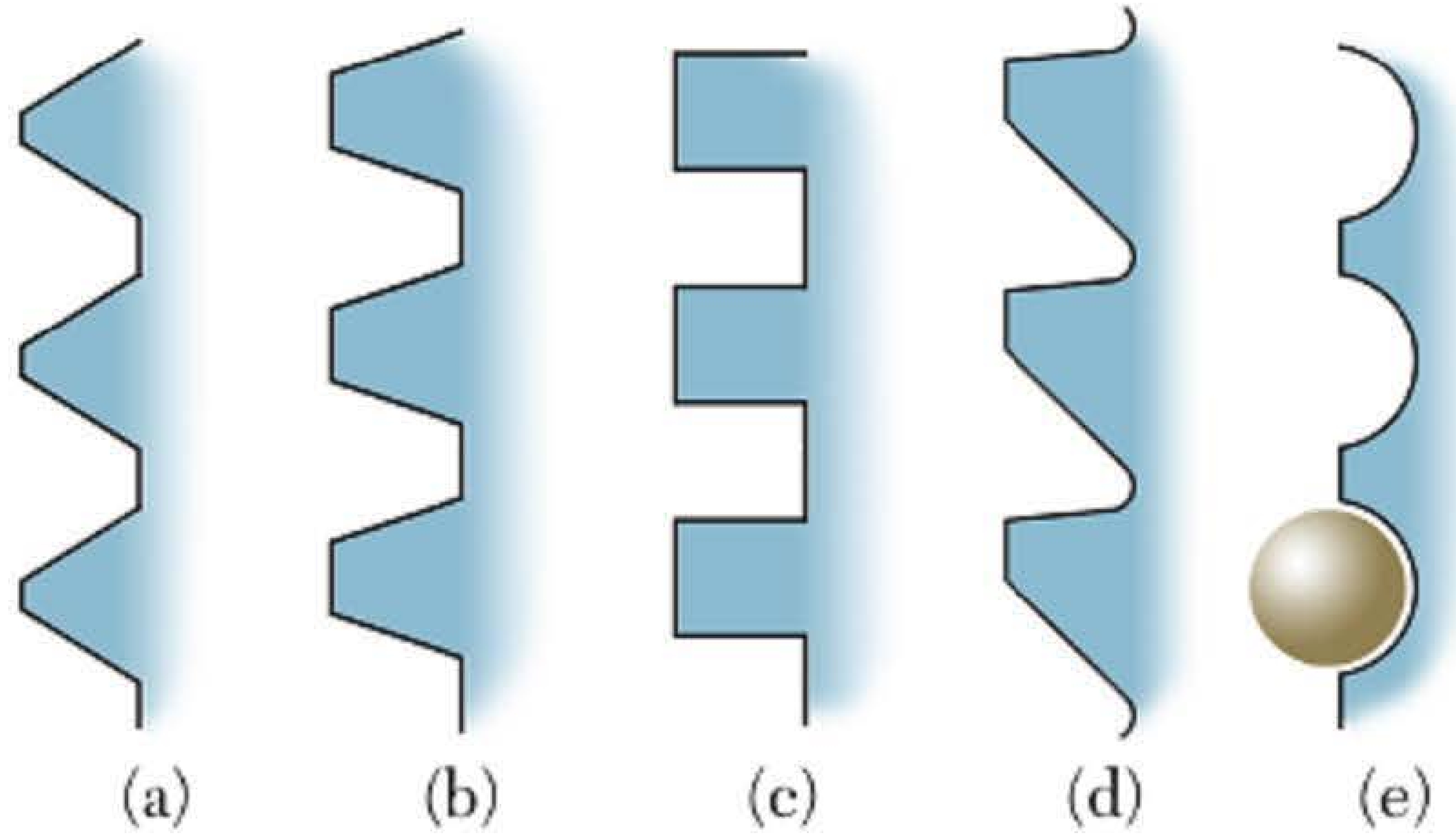
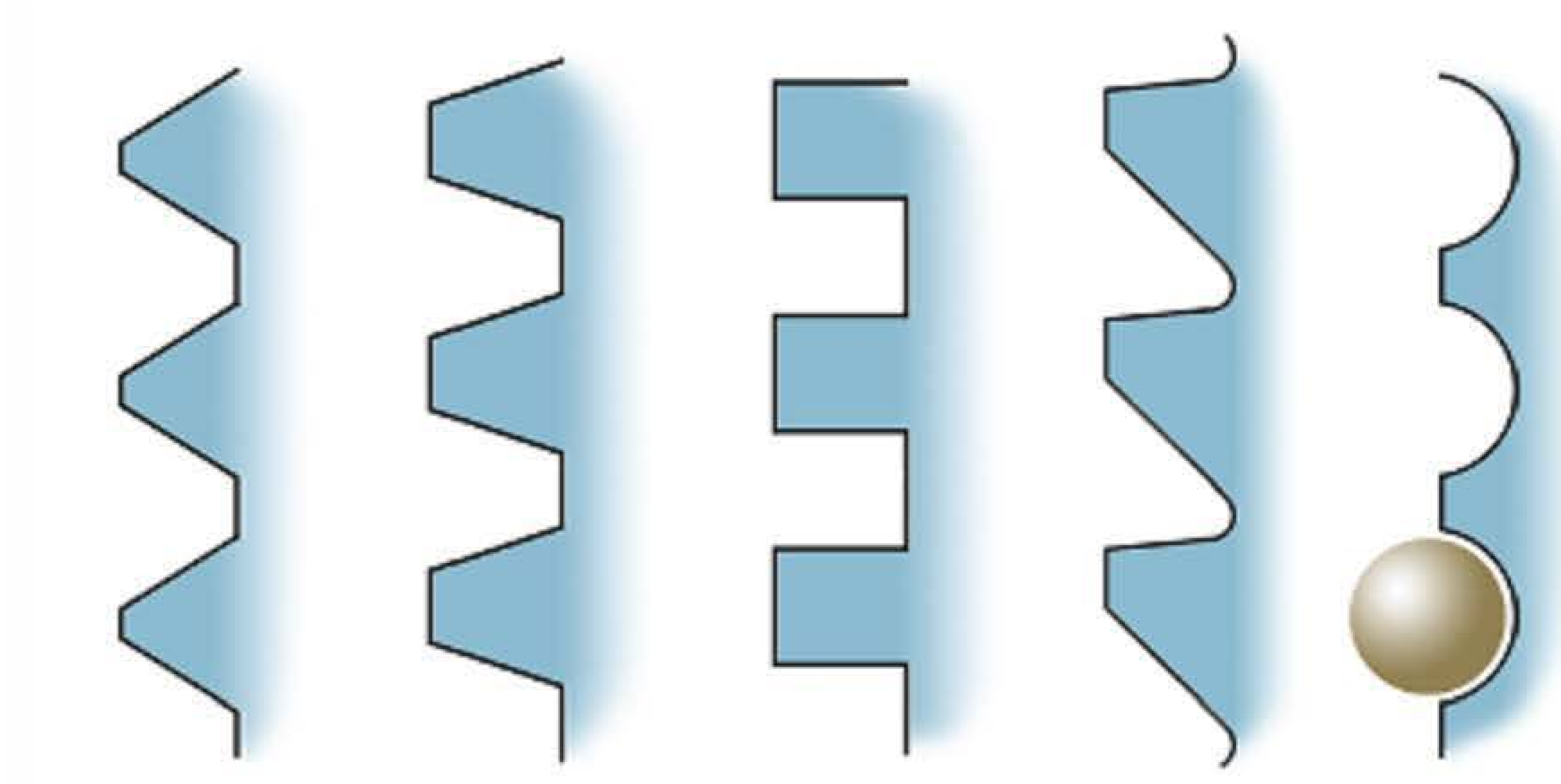


Match attributes of each thread form.

Drag statements on the right to match the left.

Most common in bolts and fasteners	(e)
More easily fabricated power thread	(a)
High load in both directions	(c)
Highest load in one direction	(d)
Lowest friction	(b)



Match the name of each thread form.

Drag statements on the right to match the left.

Metric thread form	(a)
Acme thread form	(b)
Square thread form	(c)
Buttress thread form	(e)
Ball thread form	(d)

Travel attributes of screw threads

Screws are usually right-handed, but a left-handed thread might be used for special situations.

Thread handedness

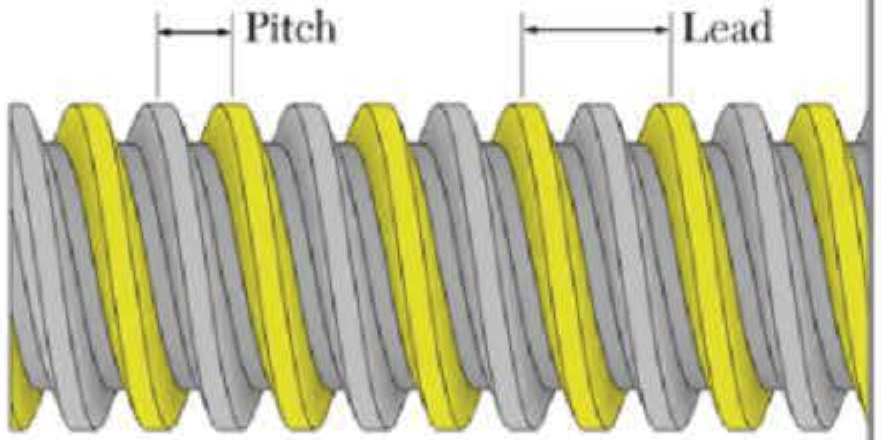
Most screws are right handed. When looking end-on, a clockwise rotation will cause the screw to move away from the viewer. Typically, this means clockwise will tighten it.

A left-handed screw turns anticlockwise for the same effect, and is usually used:

- to prevent loosening (left bicycle pedal, grinding wheels)
- to move in the right direction (turnbuckes, lathe cross-slide)
- to prevent wrong connection (acetylene gas connection in oxy-acetylene welding).

Lead, pitch and starts

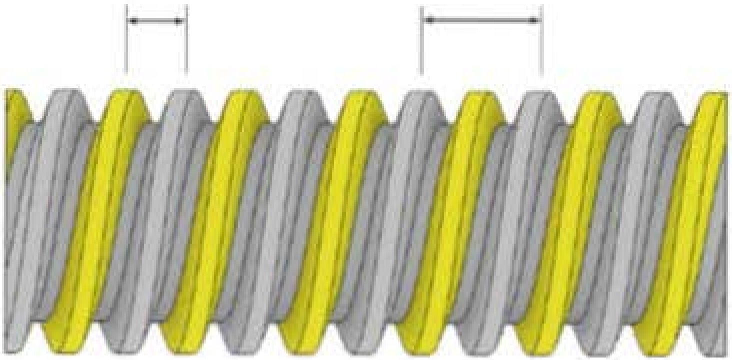
- The lead of a screw is how far it moves in one rotation (Lead = Pitch x Starts)
- Pitch is the distance between successive threads
- Start is the number of pitches per lead.



A two-start right-handed thread

GIVE FEEDBACK

OK

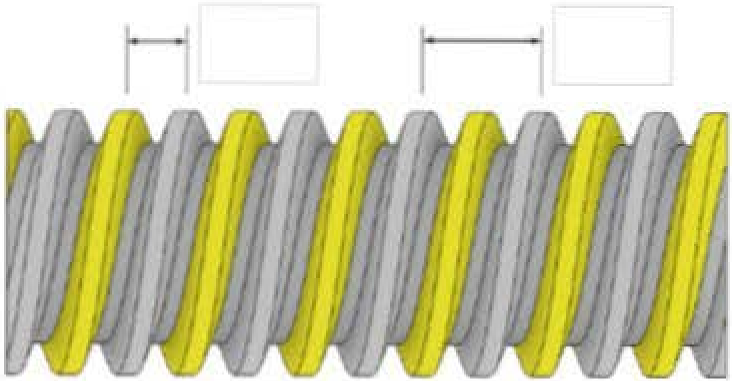


Drag statements on the right to match the left.

The lead of a screw is	the distance travelled in one revolution
The pitch of a screw is	the distance between adjacent threads
The number of starts of a screw is	the number of independent threads

Label the thread attributes in the diagram below.

Lead Right Pitch Left



This is a ______ -handed thread.

This is **not** a ______ -handed thread.

Submit

Do you know the answer?

A 4-start screw must have a lead of 9 mm.

What is the pitch of this screw?

(Give answer to at least 2 decimal place. Include units.)

± ▾ | $\frac{\square}{\square}$ | $1\frac{2}{3}$ | $\square^2$ ▾ | $\sqrt{\square}$ | $(\square)$ ▾ | Clear

≤ ▾ | π | m ▾ | f(x) ▾ | arctan □ | Clear line

? | Undo

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

A 3 start screw has a pitch of 5.

What is the lead of this screw?

(Round off to nearest integer. Include units.)

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Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
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Hint

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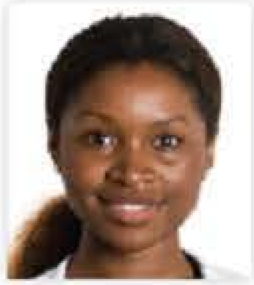


In this chapter we will look at two applications of friction on an inclined plane--screw threads and wedges.

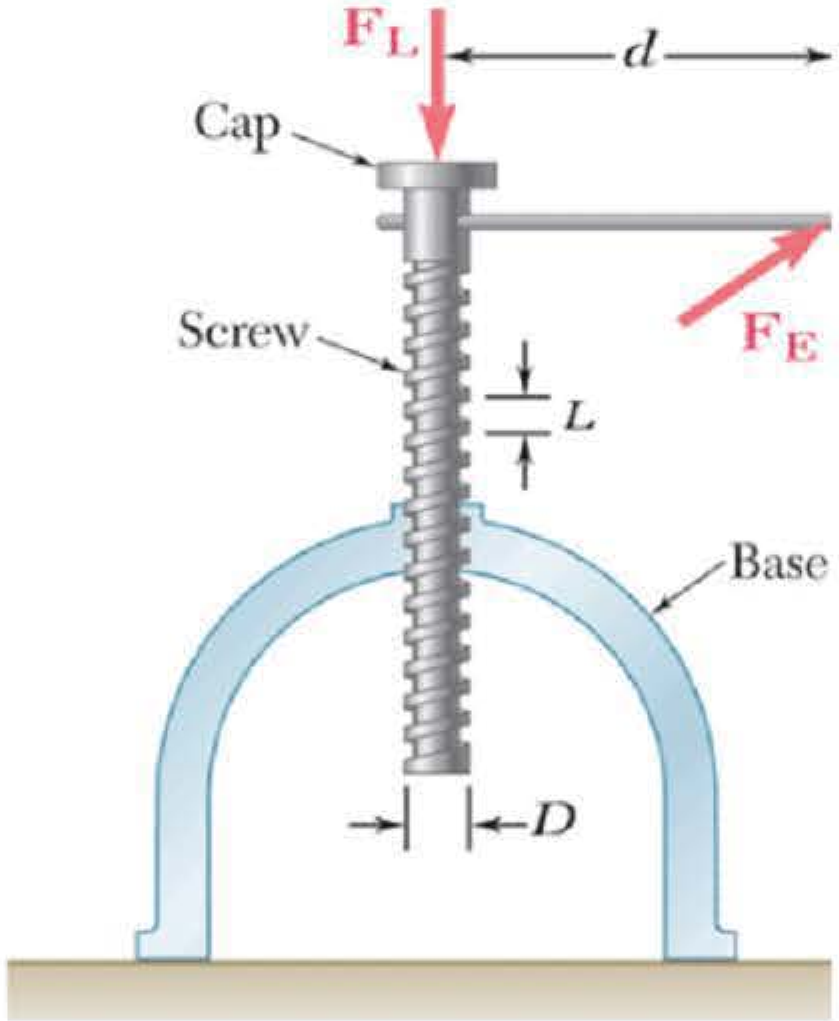
A typical application of a square screw thread

The analysis of forces acting on screw threads is very similar to that of a body sliding along an inclined plane.

To keep it simple, we will look at a single-start square screw thread, which can handle large axial forces.

They are often employed in screw jacks, clamping devices, presses and other mechanisms that convert rotational effort into an axial force.

The square thread is more efficient than the more common V-shaped thread forms, but is more difficult to make.



GIVE FEEDBACK

OK

Which of the following applications is most likely to use a square screw thread?

Check all that apply.

- [ ] Lifting jack
- [ ] Typical automotive bolt
- [ ] Leadscrew on a lathe
- [ ] Typical wood screw

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Advantages of a square thread compared to more common V-type thread forms include ________.

Check all that apply.

- [ ] it is more efficient
- [ ] it can handle higher loads
- [ ] it is easier to make

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

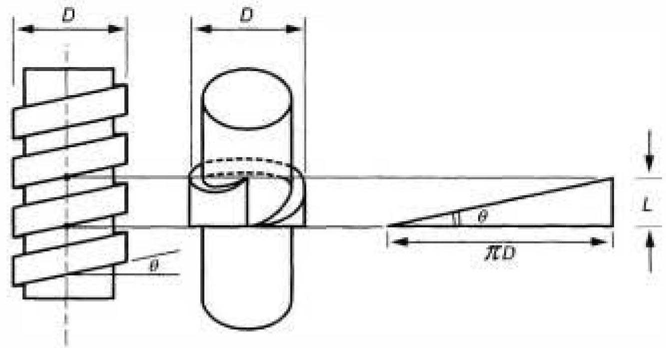
How a screw thread relates to an inclined plane

To apply our knowledge of inclined planes, we can treat a screw thread as an inclined plane wrapped around a cylinder.

A screw thread may be thought of as an inclined plane wrapped around a cylinder, at a mean diameter D.

The base length of the equivalent inclined plane, 'unwrapped' from one turn of the thread, is πD.

A nut travels an axial distance L, called the **lead**, along the axis of the screw for every complete turn of the screw.



GIVE FEEDBACK

OK

The lead of a screw thread is ___________.

Click the correct answer.

- the axial distance moved in one revolution of the screw
- the axial length of the screw (the total distance the nut can move on the screw)
- the circumference of the screw thread itself (the length of one revolution)
- the distance between adjacent threads of the screw

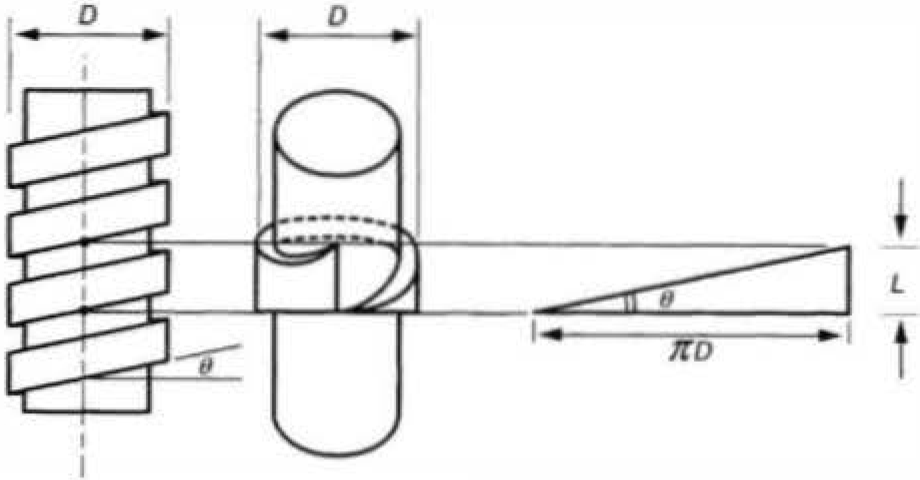
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The angle of the inclined plane of a screw thread is called the helix angle.

Helix angle for a screw thread

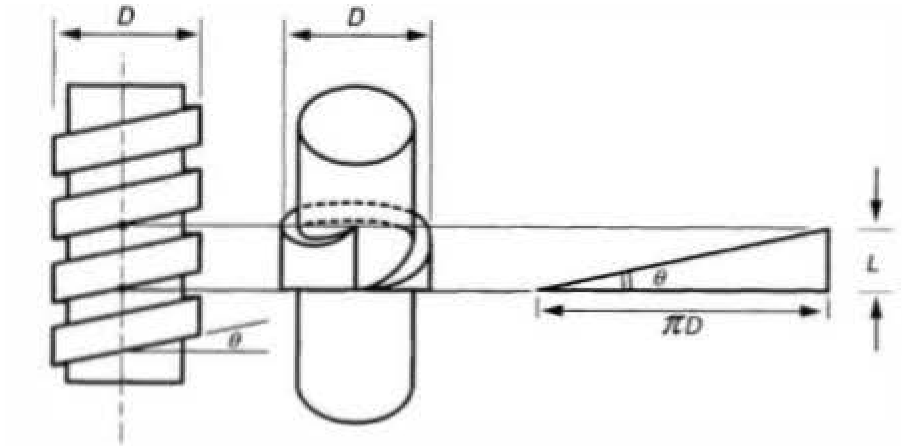
The angle which the actual thread makes with a plane perpendicular to the axis of the screw is called the **helix angle** θ. *(L is the lead of the screw thread. D is the diameter of the screw)*



GIVE FEEDBACK

OK

Match the following attributes of screws.

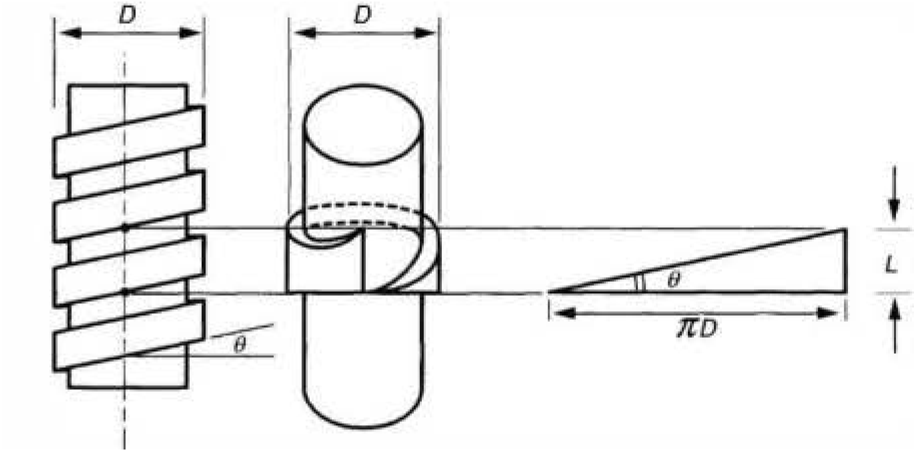


Drag statements on the right to match the left.

Lead of the screw	L
Diameter of the screw	D
Helix angle	θ

Do you know the answer?

Formula for calculating the helix angle



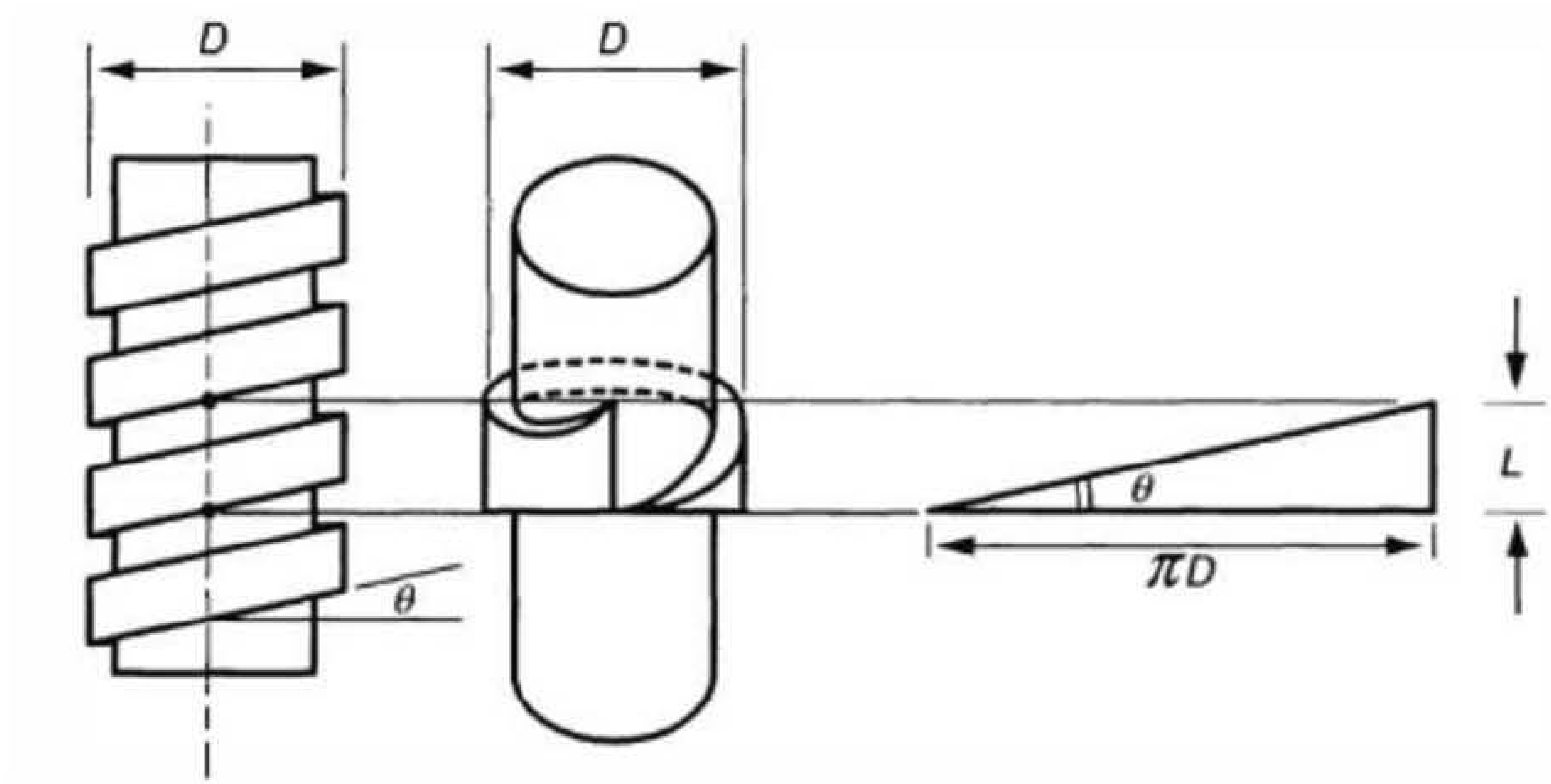
The helix angle θ is the same as the angle of inclination of the equivalent inclined plane. It can be seen from the above diagram that:

$$\tan\theta = \frac{L}{\pi D}$$

GIVE FEEDBACK

OK

The helix angle θ is found by ________.



Click the correct answer.

$\tan\theta = \dfrac{L}{\pi D}$

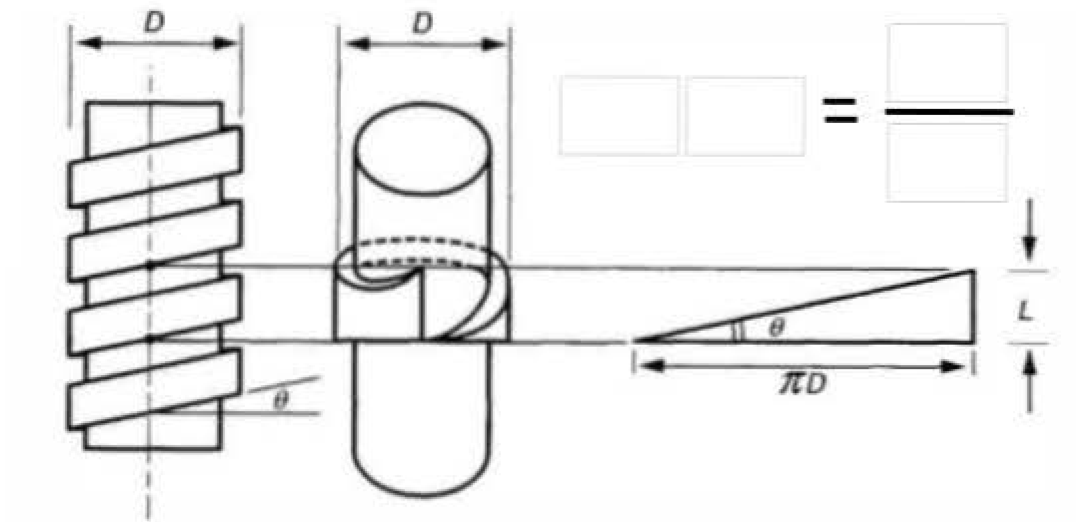
$\sin\theta = \dfrac{L}{\pi D}$

$\theta = \tan\left(\dfrac{L}{\pi D}\right)$

$\tan\theta = \dfrac{\sin\theta}{\cos\theta}$

Label the diagram of an unwrapped screw thread.

πD | θ | tan | L



Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the helix angle--Example

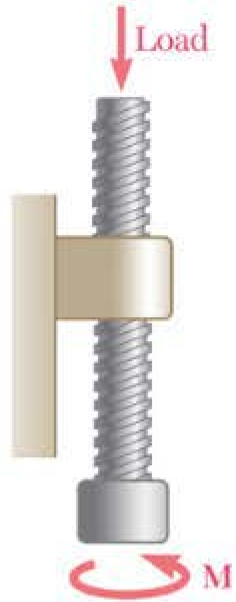
Example

What is the helix angle of a screw thread which has a lead of 10 mm and a mean diameter of 35 mm?

Solution

$$\begin{aligned}\tan\theta &= \frac{L}{\pi D} \\ &= \frac{10}{\pi \times 35} \\ &= 0.09095 \\ \therefore \theta &= \tan^{-1} 0.09095 \\ &= 5.2^\circ\end{aligned}$$

Hence the helix angle is $\theta = 5.2^\circ$.



GIVE FEEDBACK

OK

What is the lead of a screw thread which has a helix angle of 7° and a diameter of 35 mm? *(Use at least 1 decimal place. Include units.)*

± ▾ | $\frac{□}{□}$ | $1\frac{2}{3}$ | $□^2$ ▾ | $\sqrt{□}$ | (□) ▾ | Clear

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≤ ▾ | π | mm | f(x) ▾ | arctan □ | ↵ | ? | Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

What is the helix angle of a screw thread which has a lead of 10 mm and a diameter of 25 mm? *(Use at least 1 decimal place. Do not include units.)*

± ▾ | $\frac{\square}{\square}$ | $\square^2$ ▾ | $\sqrt{\square}$ | $(\square)$ ▾ | Clear

≤ ▾ | π | $\square$ | $f(x)$ ▾ | $\square^\circ$ | $\overline{\square}$ | Clear line

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arctan $\square$ | θ | ↵

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

INSTRUCTIONS

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- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

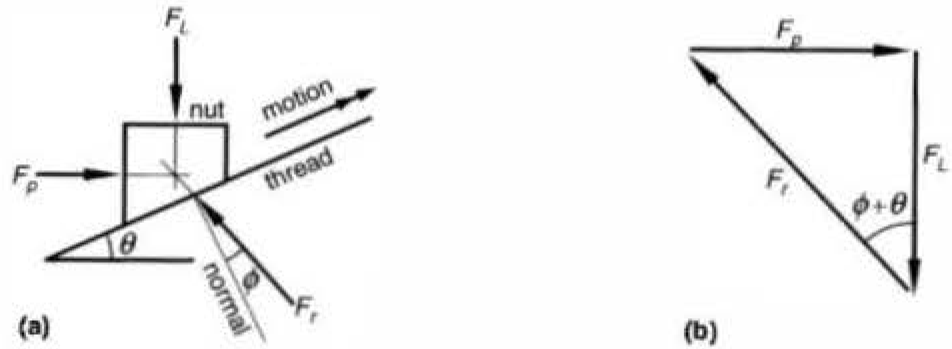
Hint | Each hint will reduce the credit received for this question

We can now derive the formula for the force to push the nut up the screw thread against a load.

Analyse forces acting on the thread of a square-threaded screw

To get the screw of mean diameter D to exert a force F_L along its axis, there must be another force F_P acting on the nut at the mean radius of the thread. Graphical analysis of forces on the incline of the thread shows that:

$$F_P = F_L \tan(\varphi + \theta)$$



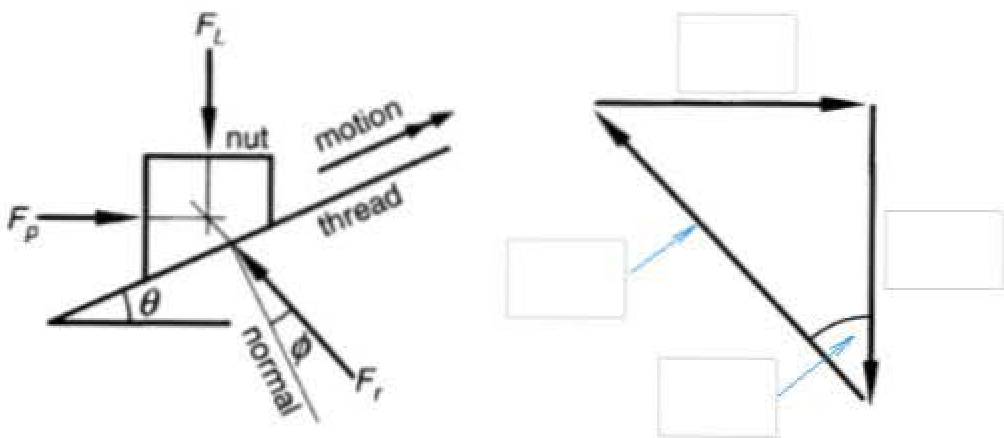
(a) *Forces on the incline of the thread* (b) *Triangle of forces*

GIVE FEEDBACK

OK

Label the free body diagram for a screw thread, where: F_L = load, F_P = applied force, F_r = friction reaction, Φ = angle of friction, θ = helix angle.

F_L	F_r	F_P	$\Phi + \theta$



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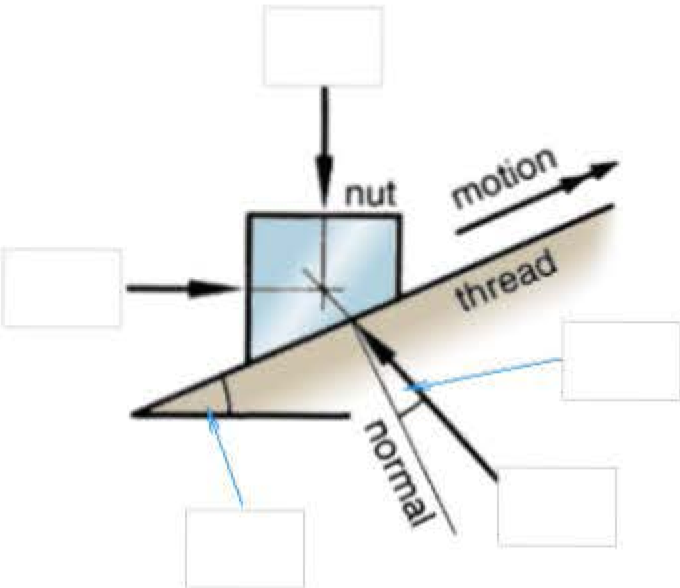
Do you know the answer?

Label the free body diagram for a screw thread where F_L = load, F_P = applied force, F_R = friction reaction, Φ = angle of friction, θ = helix angle.

F_L	F_R	F_P
Φ	θ	



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How to obtain the required turning moment applied to screw

Convert the force at the thread to a turning moment applied to the screw, to raise a load.

Since force F_P is acting at a radial distance $D/2$ from the axis of the screw, the turning moment M which must be applied is:

$$M = F_P \frac{D}{2}$$

and so the formula for the required applied moment M to turn a screw against an axial load is:

$$\boxed{M = \frac{F_L D}{2} \tan(\Phi + \theta)}$$

where Φ is the angle of friction for the thread
θ is the helix angle of the screw
D is the diameter of the screw

GIVE FEEDBACK

OK

According to the formula for the applied moment M to turn a screw against an axial load:

$$M = \frac{F_L D}{2} \tan(\Phi + \theta)$$

The moment required to turn the screw will need to be higher if ___________.

Check all that apply.

- [ ] the axial load is increased
- [ ] the diameter is decreased
- [ ] the helix angle is increased
- [ ] the angle of friction is decreased

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Select the correct equation to determine the **moment** required to turn a screw to lift a load.

Click the correct answer.

$$M = \frac{2\pi}{F_L D}\tan(\varphi + \theta)$$

$$M = \frac{F_L D}{2\pi}\tan(\varphi + \theta)$$

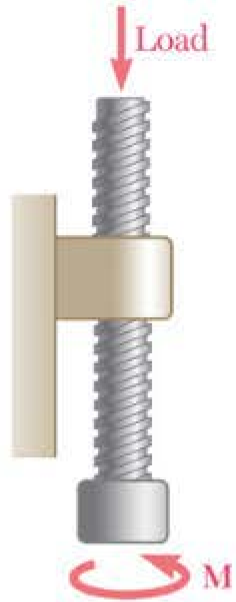
$$M = \frac{F_L D}{2}\tan(\varphi + \theta)$$

$$M = \frac{F_L}{2D}\tan(2\theta)$$

Calculate the required moment to turn a screw against a load--Example

Example

The previous example had a screw thread with 10 mm lead and 35 mm diameter, which gave a helix angle of $\theta = 5.2°$. If this screw has a coefficient of friction of 0.2, what **moment** is needed in order to exert an axial force of 540 N?



Solution

Angle of friction: $\varphi = \tan^{-1}\mu = \tan^{-1}0.2 = 11.31°$

Substitute into the formula for the applied moment:

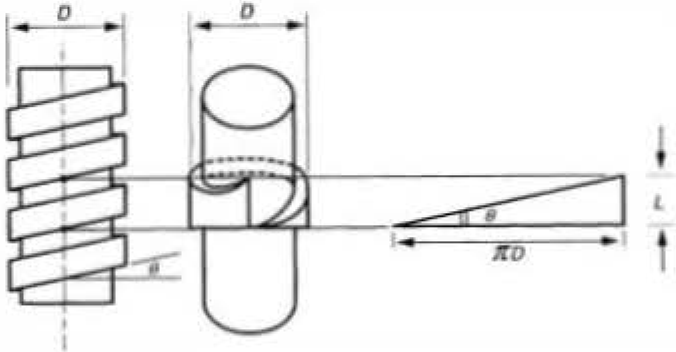
$$M = \frac{F_L D}{2}\tan(\varphi + \theta)$$

$$= \frac{540\ \mathrm{N} \times 0.035\ \mathrm{m}}{2}\tan(11.31° + 5.2°)$$

$$= 2.8\ \mathrm{N.m}$$

GIVE FEEDBACK

OK



A screw thread has a lead of 7 mm, a diameter of 35 mm and a coefficient of friction of 0.25. If the load creates an axial force of 6000 N, what moment (in Nm) is needed to turn the screw? *(Use at least 1 decimal place. Do not type units.)*

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
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Hint

Each hint will reduce the credit received for this question

A screw thread also has an angle of repose, when the screw is self-locking.

Self-locking screws

Recall the angle of repose, when $\Phi = \theta$. If the angle of friction Φ is greater than the angle of inclination θ, the body will not slide down.

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For a screw thread, the angle of repose is the limit at which the screw remains self-locking.

If the angle of friction Φ is greater than the helix angle of the thread, i.e. $\varphi > \theta$, and there is no moment M applied, the screw will remain self-locking.

Increasing the load will not make the screw undo itself by spinning down. It will continue to support the load F_L by friction alone. This is why fine threads resist loosening.

GIVE FEEDBACK

OK

What are the self-locking characteristics of a screw when there is no turning moment applied (i.e. will the screw turn by the axial force of the load)?

Which statement is true?

Click the correct answer.

- If $\varphi > \theta$ the screw will remain self-locking
- If $\varphi < \theta$ the screw will remain self-locking
- If $\varphi < 0$ the screw will remain self-locking
- If $\theta > 0$ the screw will remain self-locking

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the design factors that effect the self-locking characteristics of a thread.

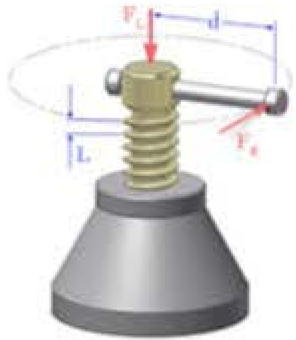
Drag statements on the right to match the left.

More likely to be self-locking	Higher friction
Less likely to be self-locking	Larger lead
More likely to be self-locking	Finer thread
Less likely to be self-locking	Smaller diameter

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which statement is true about self-locking of this screw assembly?



Click the correct answer.

- Friction between the screw and the load F_L will increase the chance of self-locking
- Friction between the screw and the theaded base will decrease the chance of self-locking
- A longer lever arm will reduce self-locking
- A longer depth of screw thread within the base will increase self-locking

Do you know the answer?

Determine whether a screw is self-locking--Example

A screw is self-locking when the angle of friction (Φ) is greater than the helix angle (θ).

Example

A screw thread has 10 mm lead and 35 mm diameter, which gave a helix angle of $\theta = 5.2°$. If this screw has a coefficient of friction of 0.2, and an axial force of 540 N, is this a self-locking screw?

GIVE FEEDBACK

CONTINUE >

Determine whether a screw is self-locking--Example

A screw is self-locking when the angle of friction (Φ) is greater than the helix angle (θ).

Example

A screw thread has 10 mm lead and 35 mm diameter, which gave a helix angle of $\theta = 5.2°$. If this screw has a coefficient of friction of 0.2, and an axial force of 540 N, is this a self-locking screw?

Solution

The angle of friction is $\varphi = \tan^{-1} 0.2 = 11.31°$ and the helix angle is $\theta = 5.2°$. Clearly, the angle of friction is greater than the helix angle. Therefore the screw is self-locking.

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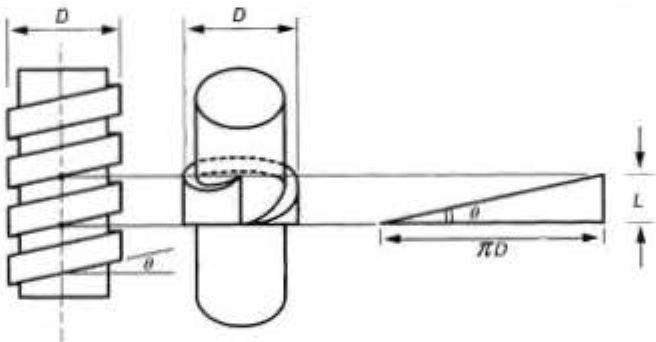

A screw thread has a diameter of 35 mm, a coefficient of friction of 0.25 and an axial force of 6000 N. What is the maximum lead of the screw before it is at risk of undoing itself? Note: There may be unnecessary information given in this question.

(Round off to nearest Integer. Include units.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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- If you choose to show steps, write one on each line.
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Hint

Each hint will reduce the credit received for this question

Which of the following statements about self-locking screws are correct?
(Reducing self-locking means the screw is more likely to undo.)

Check all that apply.

- [ ] A larger axial load reduces self-locking
- [ ] A larger lead reduces self-locking
- [ ] A larger diameter reduces self-locking
- [ ] A larger helix angle reduces self-locking
- [ ] A larger angle of friction reduces self-locking

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculating the required moment to lower a load on a screw

How to obtain the required reverse moment to loosen a self-locking screw

It can be shown that the reverse moment M' required to **loosen** or **lower** a self-locking screw which is supporting a load F_L is given by a very similar expression:

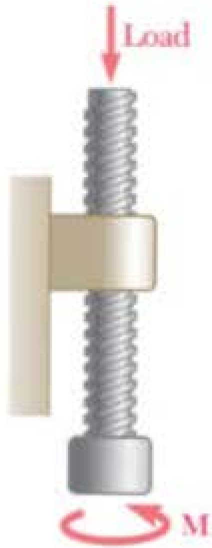
$$M' = \frac{F_L D}{2} \tan(\varphi - \theta)$$

where:

φ is the angle of friction for the thread

θ is the helix angle of the screw

In this example of a right-handed thread raising a load, a clockwise moment applied to the socket will raise the load. Anticlockwise will lower it.



GIVE FEEDBACK

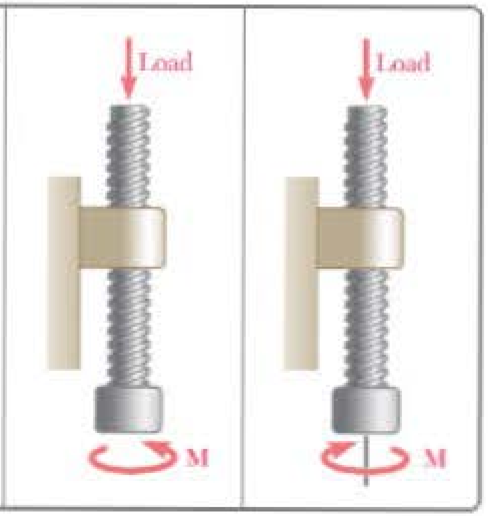
OK

Which of the following statements about the raising OR lowering of the load are correct?

Assume:

Φ = Angle of friction

θ = Helix angle of screw



Click the correct answer.

- If $\Phi = \theta$, then the moment to **raise** the load is zero
- If $\Phi = \theta$, then the moment to **lower** the load is zero
- If $\Phi = 0$, then the moment to **raise** the load is zero
- If $\theta = 0$, then the moment to **raise** the load is zero

Do you know the answer?

The turning moment required to drive a screw that supports a load.
Assume clockwise will raise the load and anticlockwise will lower it.

Drag statements on the right to match the left.

Clockwise moment to turn the screw to **raise** the load	$= \frac{F_L D}{2} \tan(\varphi + \theta)$
Anticlockwise moment to turn the screw to **lower** the load	$M = \frac{F_L D}{2} \tan(\varphi - \theta)$
The screw will not turn if the clockwise moment is	$M < \frac{F_L D}{2} \tan(\varphi + \theta)$
The screw will not turn if the anticlockwise moment is	$M < \frac{F_L D}{2} \tan(\varphi - \theta)$

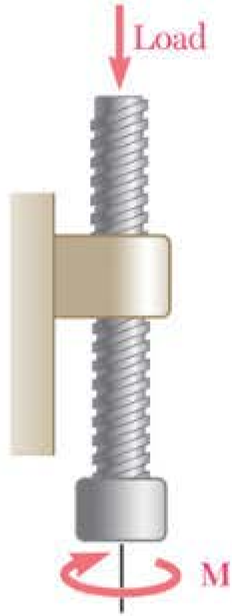
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the required reverse moment to loosen a self-locking screw--Example

Example

Consider a screw thread with 10 mm lead and 35 mm diameter, which gives a helix angle of $\theta = 5.2°$. With a coefficient of friction of 0.2, what moment is needed in order to **loosen** it under an axial force of 540 N?



Solution

Substitute into the formula:

$$M' = \frac{F_L D}{2} \tan(\varphi - \theta)$$

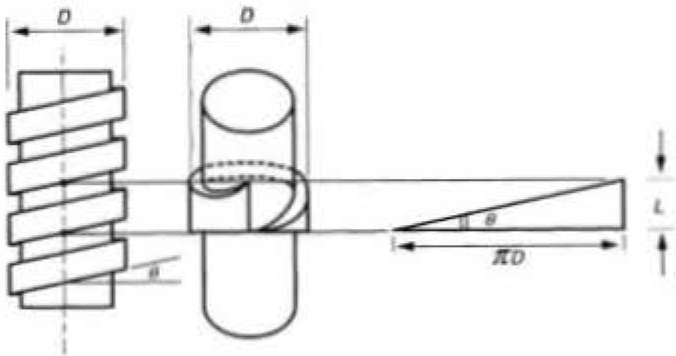
$$= \frac{540\ \text{N} \times 0.035\ \text{m}}{2} \tan(11.31° - 5.2°)$$

$$= 1.01\ \text{N.m}$$

Hence the reverse moment required is 1.01 N.m.

GIVE FEEDBACK

OK



A screw thread has a lead of 7 mm, a diameter of 35 mm and a coefficient of friction of 0.25. If the load creates an axial force of 6000 N, what moment (in Nm) is needed to undo the screw? *(Use at least 1 decimal place. Do not type units.)*

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

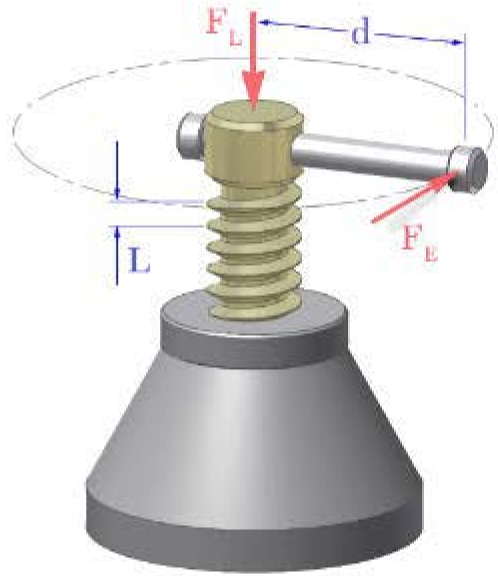
The screw jack we will study here is simply a screw with a handle on it.

Simple screw jacks

A simple screw jack is a portable device for raising a heavy mass through a short distance.

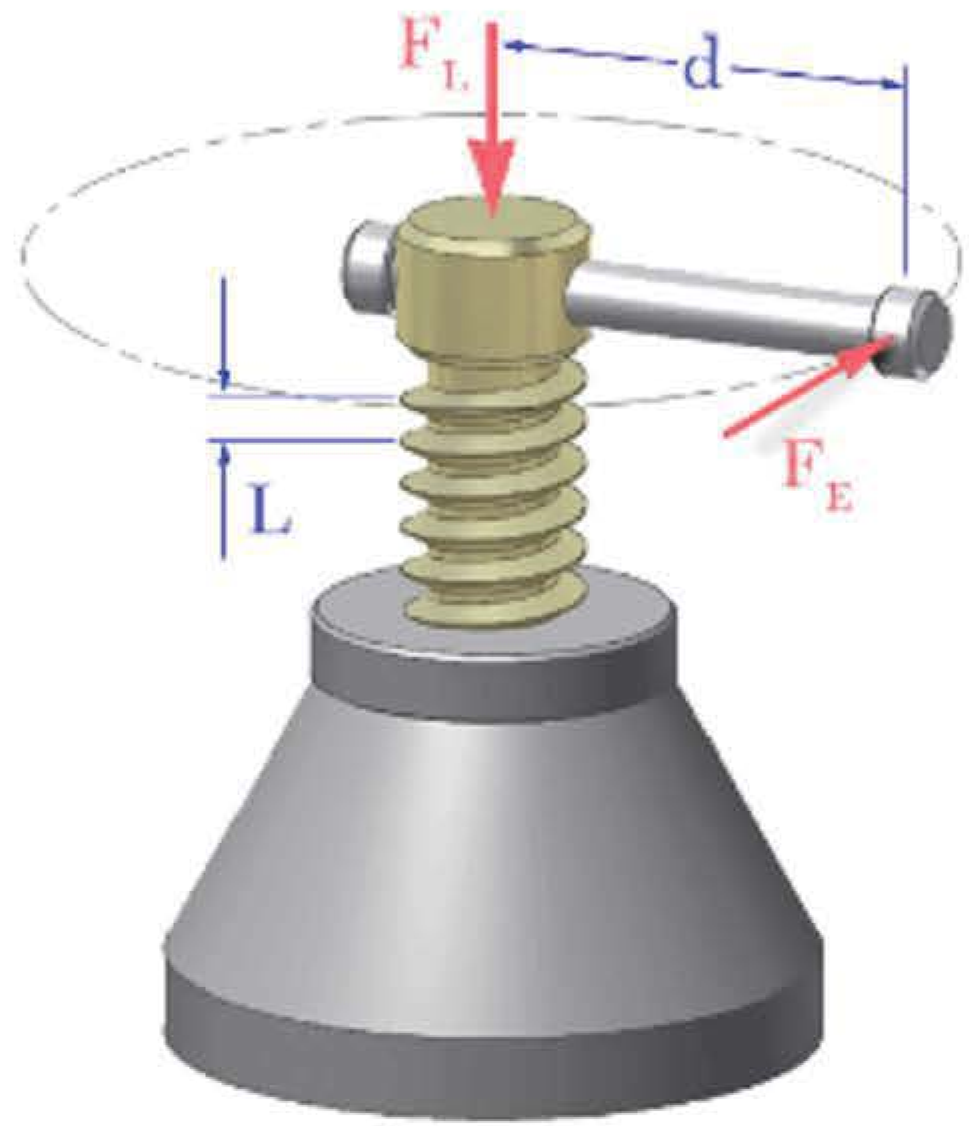
It consists of a vertical screw in a threaded base, turned by a handle.

Force F_E applied to the lever arm is working against the much higher load force F_L.



GIVE FEEDBACK

OK

Match the symbols used for a simple screw jack with their descriptions.	

Drag statements on the right to match the left.

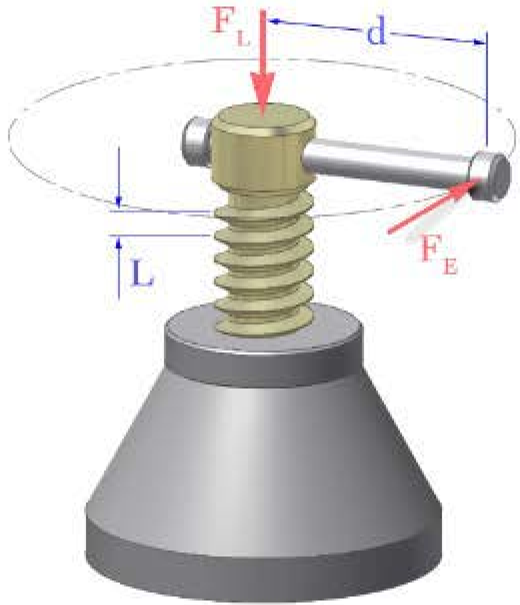
The load	F_L
The effort	d
The lever arm	F_E
The lead	L

Derive the formula to calculate the effort required for a simple screw jack

A simple screw jack is designed to raise a heavy mass through a short distance. The vertical screw is turned in a threaded base by an effort applied to the lever arm.

This allows a small effort F_E to raise a large load F_L. The effort applied for one revolution $(2\pi d)$ raises the load by one lead (L) of the screw.

Note: Only a very simple lever arm arrangement is considered here. Any difference in the ratio advantage due to a hand-operated crank-and-gear mechanism, found in many mechanical screw jacks, has to be taken into account where appropriate.



Define the screw jack	Calculate the effort F_E	Calculate F_E for load in kg

GIVE FEEDBACK

OK

Derive the formula to calculate the effort required for a simple screw jack

The required turning moment M is produced by the effort force F_E applied at a distance **d** from the centreline, so that:

$$M = F_E \cdot d$$

Since the required moment is related to the load F_L by:

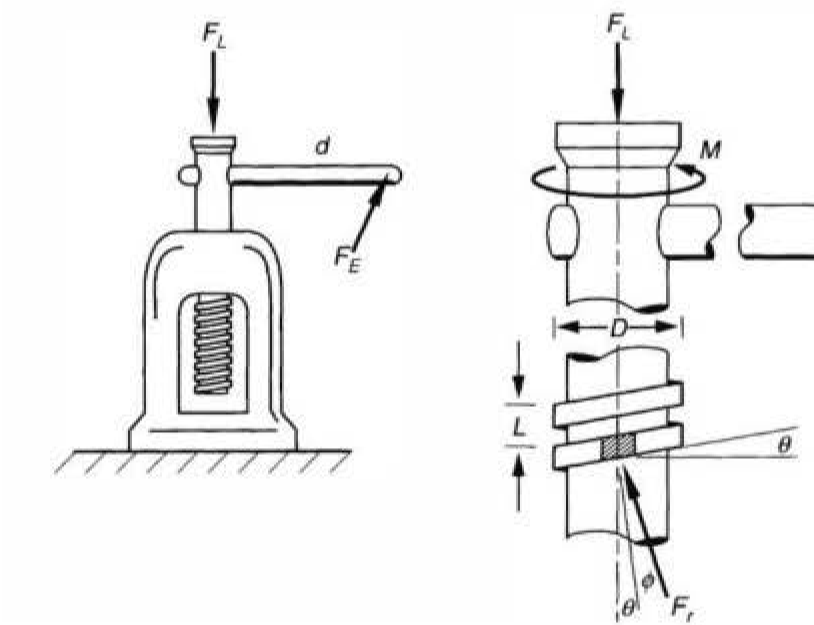
$$M = \frac{F_L D}{2} \cdot \tan(\Phi + \theta)$$

We can combine these two expressions to give:

$$F_E d = \frac{F_L D}{2} \cdot \tan(\Phi + \theta)$$

So the effort is:

$$F_E = \frac{F_L D}{2d} \cdot \tan(\Phi + \theta)$$



Define the screw jack	Calculate the effort F_E	Calculate F_E for load in kg

GIVE FEEDBACK

OK

Derive the formula to calculate the effort required for a simple screw jack

Since the load on a screw jack is usually given as mass (m), the expression can be modified by substituting:

$$F_L = F_w = m\,g$$

So the applied effort on the lever arm is:

$$F_E = \frac{m\,g\,D}{2\,d} \cdot \tan(\Phi + \theta)$$

Where:

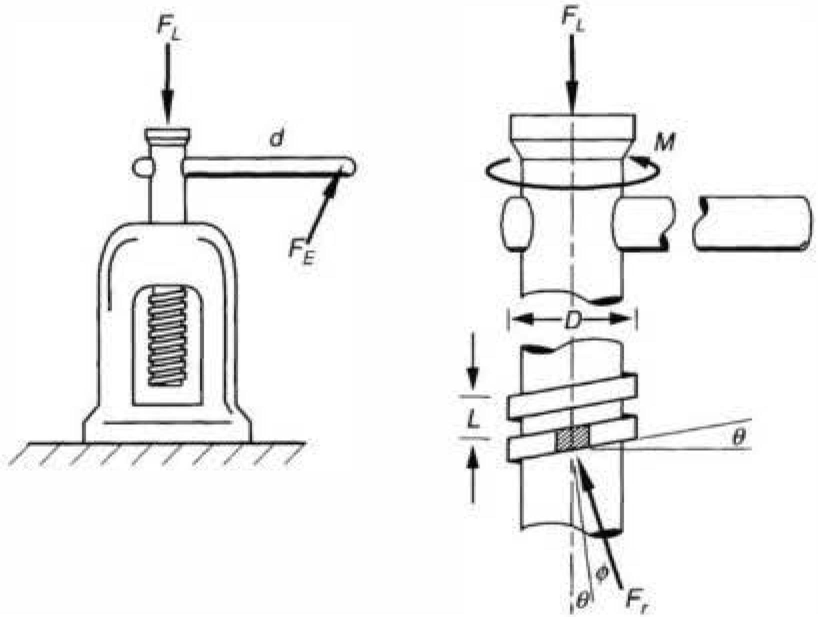
m = mass of load (kg)

D = diameter of screw

d = lever arm length (mm)

Φ = angle of friction of screwthread

θ = helix angle



Define the screw jack	Calculate the effort F_E	Calculate F_E for load in kg

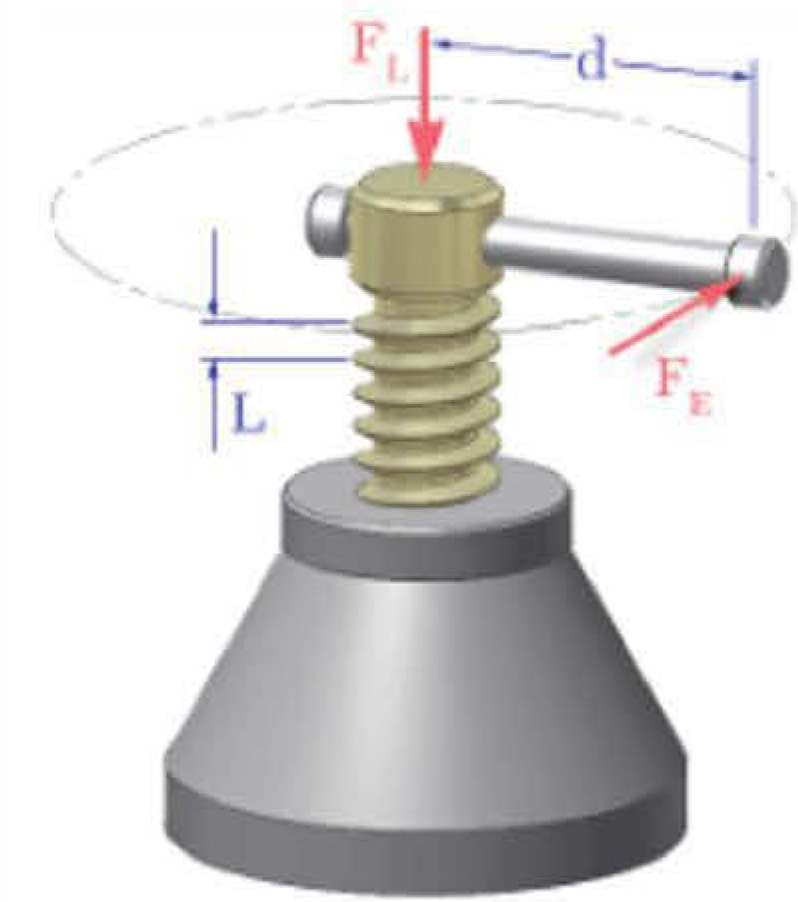
GIVE FEEDBACK

OK

The applied effort on the lever arm to raise the load is:

$$F_E = \frac{m\,g\,D}{2d} \cdot \tan(\Phi + \theta)$$

Match the variables with their descriptions.



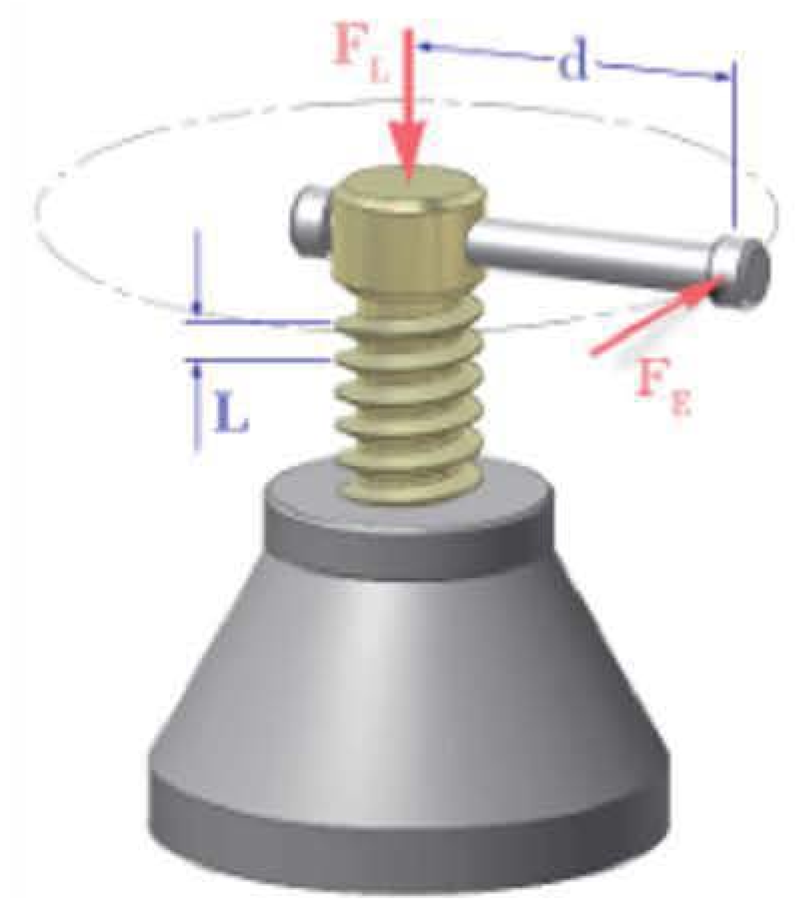
Drag statements on the right to match the left.

Mass being raised	D
Diameter of screw	θ
Lever arm length	φ
Angle of friction of screw	m
Helix angle of screw	d

The applied effort on the lever arm to raise the load is:

$$F_E = \frac{m\,g\,D}{2d} \cdot \tan\,(\Phi + \theta)$$

Match the following changes and their effect on the lever force F_E.



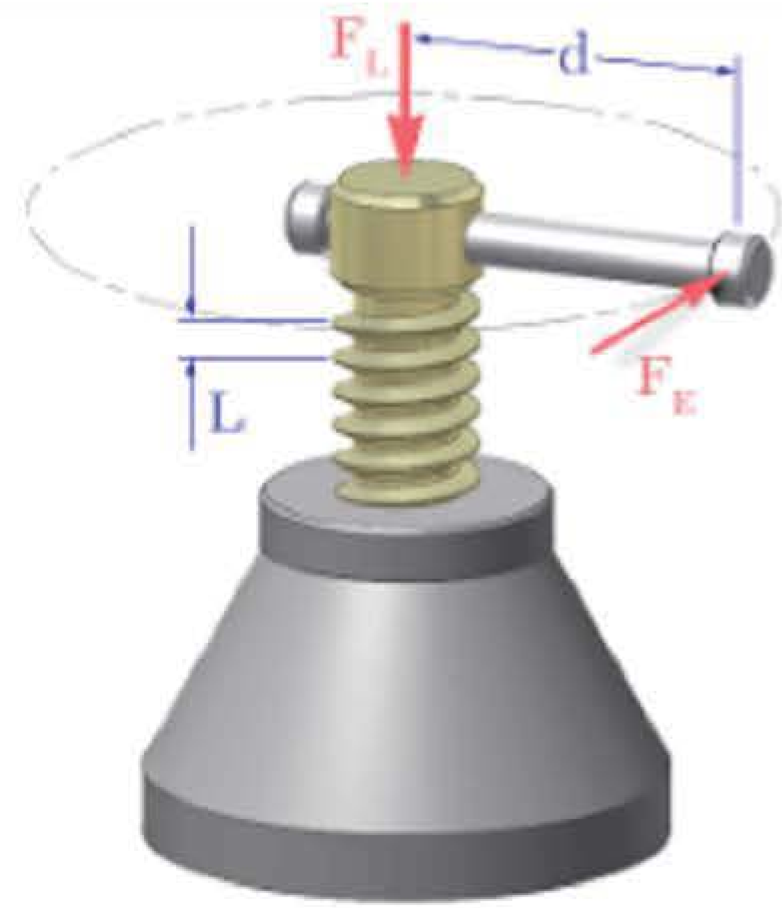
Drag statements on the right to match the left.

Lever force will increase	Angle of friction Φ is increased
Lever force will decrease	Load m is increased
Lever force will increase	Lead is decreased
Lever force will decrease	Lever arm d is increased
Lever force will increase	Screw diameter D is increased

The applied effort on the lever arm to raise the load is:

$$F_E = \frac{m\,g\,D}{2d} \cdot \tan\left(\Phi + \theta\right)$$

Match the variables with their units.



Drag statements on the right to match the left.

kg	D
m	m
m	Φ
degrees	d
degrees	φ

Example

Determine the horizontal force F_E, perpendicular to the 500 mm long handle of a simple screw jack, necessary to start lifting a 500 kg load. The square-threaded screw has a lead of 7 mm and a mean diameter of 80 mm. The coefficient of static friction for the screw is 0.15.

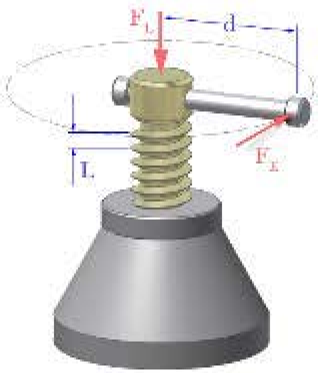
GIVE FEEDBACK

CONTINUE >

Solution

Angle of friction:	Helix angle:	Therefore, the **effort required** F_E at the end of the arm is:
$\varphi = \tan^{-1}\mu$ $= \tan^{-1} 0.15$ $= 8.53°$	$\theta = \tan^{-1}\frac{L}{\pi D}$ $= \tan^{-1}\frac{7}{\pi \times 80}$ $= 1.6°$	$F_E = \frac{m\,g\,D}{2\,d}\tan(\varphi + \theta)$ $= \frac{500\text{ kg} \times 9.81\text{ N/kg} \times 0.08\text{ m}}{2 \times 0.5\text{ m}}\tan(8.53° + 1.6°)$ $= 70.1\text{ N}$

< BACK GIVE FEEDBACK OK



A screw thread has a lead of 7 mm, a diameter of 35 mm and a coefficient of friction of 0.25. If the load is 600 kg and the lever arm is 500mm, what force (in N) is needed to turn the screw? *(Use at least 1 decimal place. Include units.)*

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Clear line
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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

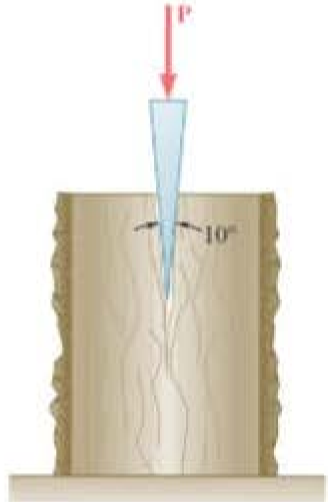
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint Each hint will reduce the credit received for this question

Another application of the inclined plane–the wedge. It is really just two inclined planes back-to-back.

What is a wedge?

A **wedge** is a piece of hard material with two principal faces meeting at a sharply acute angle.

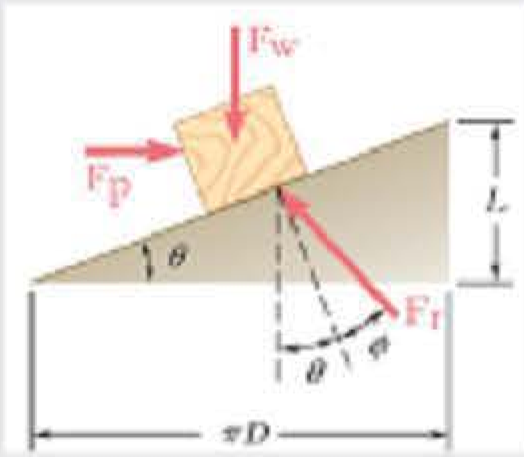


GIVE FEEDBACK

OK

Select all diagrams that are examples of a wedge.

Check all that apply.

- [ ] 

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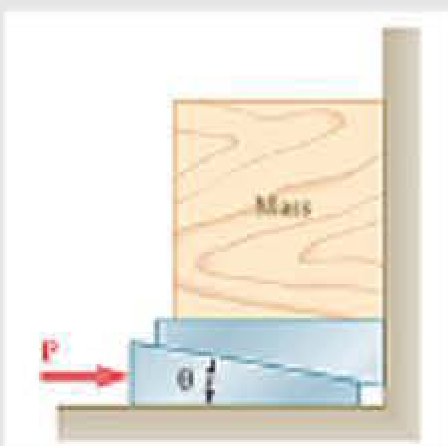
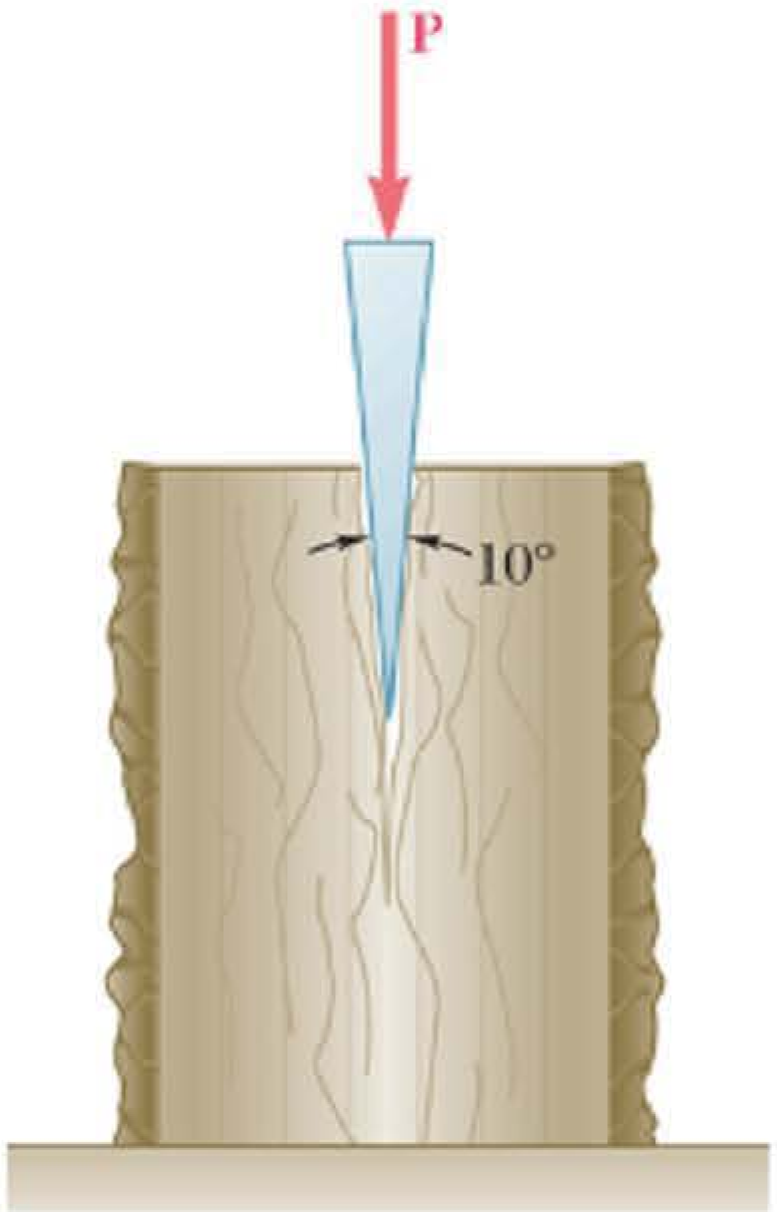
- [ ] 

- [ ] 

Ignore the weight of the wedge.
Assume the wood is tightly binding on the wedge (not split through)
Find the minium friction to keep the wedge from popping out.
Or, in terms of the angle of friction φ:

Find the minimum angle of friction to keep the wedge in place.



Click the correct answer.

- 10°
- It cannot be measured
- 5°
- 20°

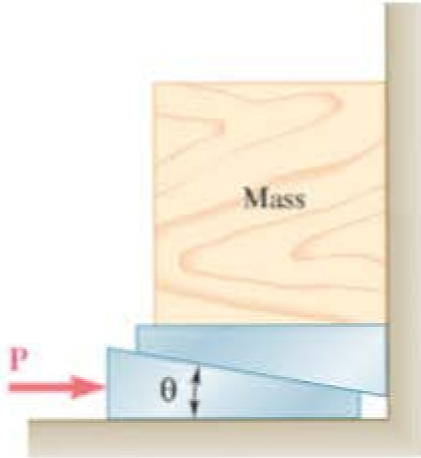
Wedges do more than split wood. The action of a wedge is used to amplify force, provide fine position adjustments and jam things together.

The application of wedges

Wedges are often used to make small adjustments to the position of heavy objects by applying a considerably smaller force P to the wedge.

Wedges are also used as machine parts wherever small movements of a component in one direction is associated with large forces in a perpendicular direction.

Because wedges usually have a small angle they tend to be self-locking. In other words they will remain in place and not slip out under the load.

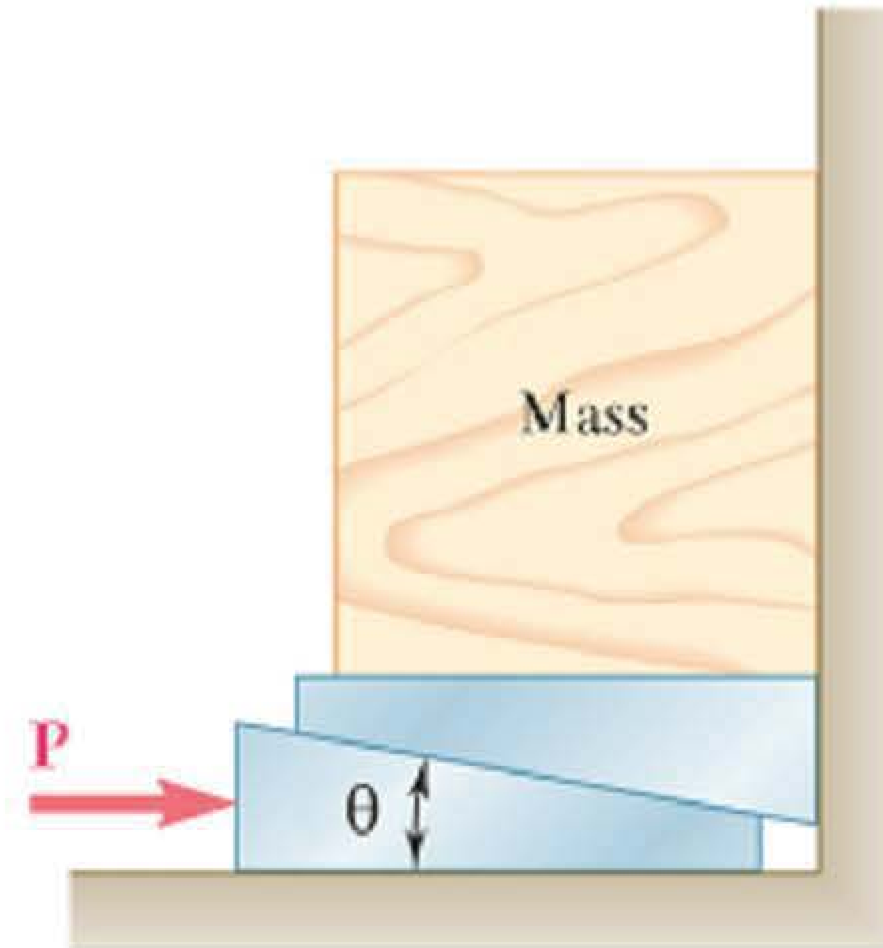


GIVE FEEDBACK

OK

Assume the force P is at the point of impending motion.

Select all correct statements below.



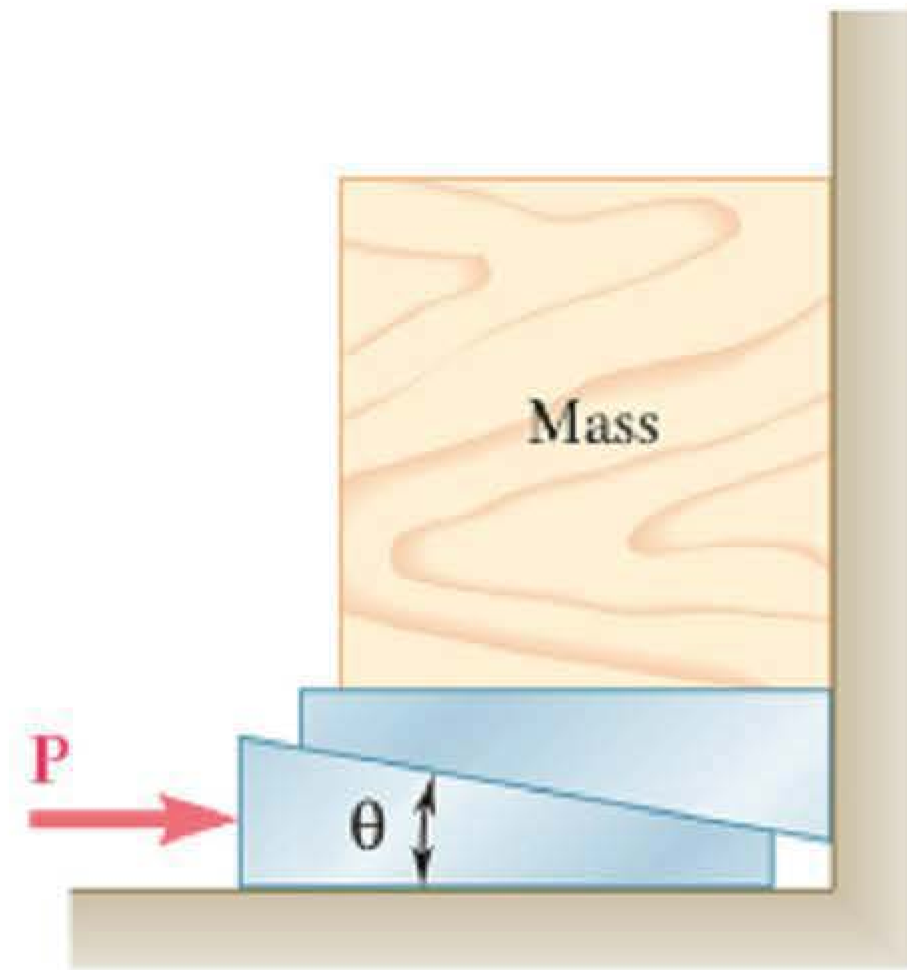
Check all that apply.

- [ ] A higher mass increases the chance of the wedge slipping out
- [ ] A smaller mass will increase P
- [ ] A higher coefficient of friction will increase P
- [ ] A smaller wedge angle θ will reduce P
- [ ] A smaller wedge angle θ will reduce the chance of the wedge slipping out

Wedges are often used to make small adjustments to the position of heavy objects.

For the wedge arrangment shown, assume typical value of friction and wedge angle. (i.e. friction is high enough to hold the wedge in place, but also low enough that inserting the wedge takes less force than the weight of the mass)

Select the correct statements.



Check all that apply.

- [ ] A small force P will generate a large force on the mass
- [ ] A large movement by force P will generate a small movement of the mass
- [ ] A large force P will generate a small force on the mass
- [ ] A small movement by force P will generate a large movement of the mass
- [ ] The smaller the angle θ, the smaller the force P

Solving a wedge problem is no different to solving an inclined plane problem. We just need to be extra careful with the direction of friction.

The method of analysing friction forces on wedges

As with all problems in statics, we must start with a free body diagram (FBD). There will usually be more than one FBD beause the wedge will move something. (See? That makes two bodies already!)

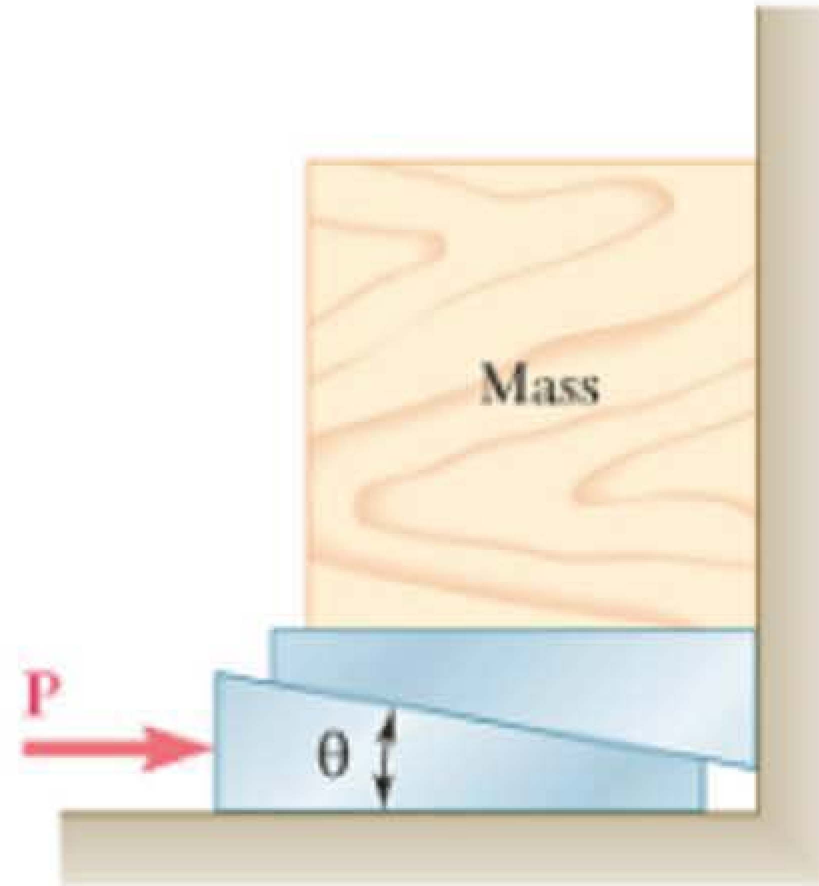
- Choose the starting body and draw the FBD. The starting body will usually have a force applied.
- Direction of friction reaction force. Be careful here. Friction always resists motion (or impending motion). Make sure you are thinking the FBD way—show forces according to what they do TO THE BODY.
- Draw the force triangle. Take the angles from the FBD and construct the force polygon (triangle).
- Solve this triangle for the unknown lengths or angles (usually lengths, if we know friction).

Use this information to move to an adjacent body and repeat this process.

GIVE FEEDBACK

OK

Arrange the following steps into the correct order for the solution of a wedge problem.



↑↓ **Place these in the proper order.**

- Look for a body with a known force and maximum two unknowns
- Solve the force triangle for the unknown lengths or angles (usually lengths, if we know friction)
- Get the angle of friction reaction force/s by checking impending motion. Show forces as what they do to the body
- Draw the force triangle. Take the angles from the FBD and construct the force polygon (triangle)

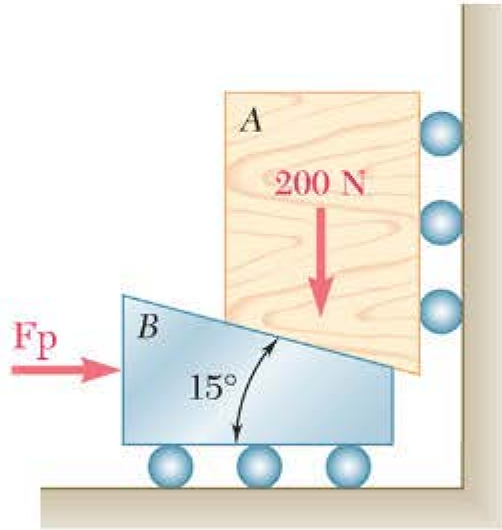
Calculate forces on a simplified wedge--Example

The following example illustrates a method of solving problems involving wedges.

Example

A 200N block is raised by forcing a 15 ° wedge under it as shown. The coefficient of static friction is 0.22 at all sliding contact surfaces. Determine the minimum value of force F_P w to move the block upwards.

There are two moving objects in this problem: the block and the wedge. Both require a FBD.



Define the wedge problem	FBD of mass	Direction of friction reactions	Force Polygon for Block A	Force Polygon for Block B

GIVE FEEDBACK

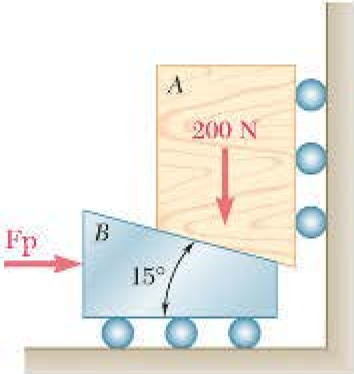
OK

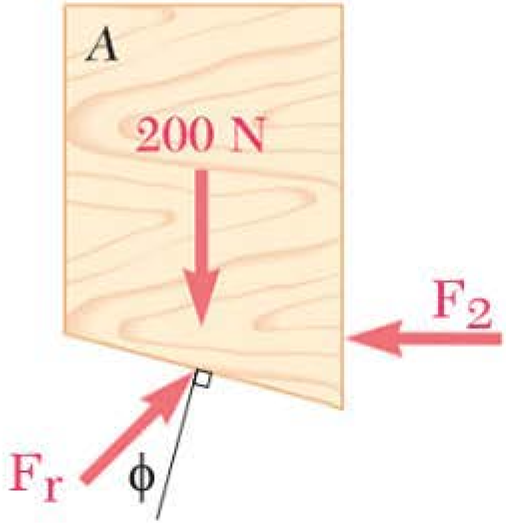
Calculate forces on a simplified wedge--Example

Solution

We start with the object with known force, the weight F_w of 200N.

$$\Phi = \tan^{-1}\mu$$
$$= \tan^{-1} 0.22$$
$$= 12.4°$$





Free-body diagram of block

Define the wedge problem	FBD of mass	Direction of friction reactions	Force Polygon for Block A	Force Polygon for Block B

GIVE FEEDBACK

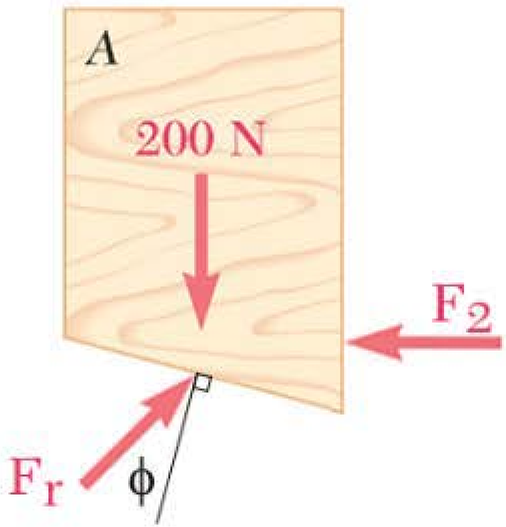
OK

Calculate forces on a simplified wedge--Example

Note carefully the directions of reaction forces at the surfaces subjected to friction.

Friction force opposes the **impending motion** of the block in relation to the contacting friction surface. When the block moves, it goes upwards relative to the wall, and to the right relative to the wedge.

But the wall has no friction so this force is horizontal. The inclined surface does have friction which is applied at the angle of friction Φ.



Free-body diagram

Define the wedge problem	FBD of mass	Direction of friction reactions	Force Polygon for Block A	Force Polygon for Block B

GIVE FEEDBACK

OK

Calculate forces on a simplified wedge--Example

The friction reaction force is inclined at:

$$90 - \Phi - \theta = 90 - 12.4 - 15 = 62.6°$$

We now know the angle of every force:

$F_w = 200\ \text{N} @ 270°$

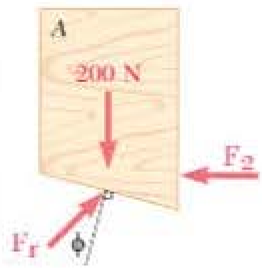
$F_r = ?\ \text{kN} @ 62.6°$

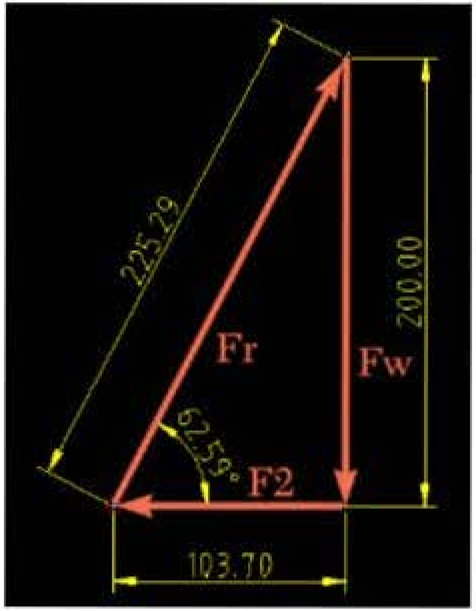
$F_2 = ?\ \text{kN} @ 180°$

This are two unknowns, which is solvable.

Draw the force triangle.

$$F_r = \frac{F_w}{\sin 62.6} = 225\ N$$





Triangle of forces using CAD

Calculate forces on a simplified wedge--Example

Now draw FBD of the wedge.

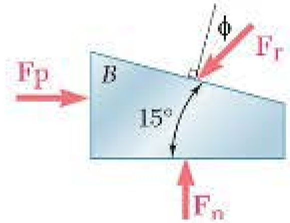
Force F_w is now in reverse, or $180 + 62.6 = 242.6°$

So;

$F_r = 225.6 \text{ N} @ 242.6°$

$F_p = ? \text{ kN} @ 0°$

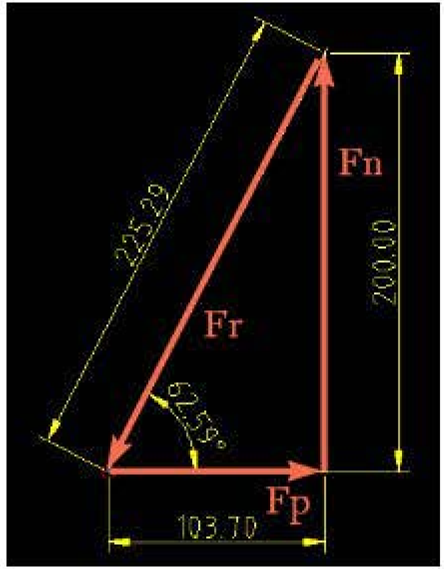
$F_2 = ? \text{ kN} @ 90°$



Now, this force triangle is identical to the block except that the forces are in reverse.

So $F_p = \dfrac{200}{\tan 62.6} = 103.7 \text{ N}$

The force to push wedge is 103.7N

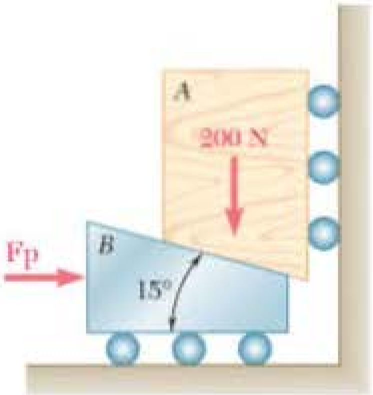


Triangle of forces in CAD

Define the wedge problem | FBD of mass | Direction of friction reactions | Force Polygon for Block A | Force Polygon for Block B

GIVE FEEDBACK

OK



A wedge, with an inclined face at 15°, is used to raise the 200 N weight of block A. If the coefficient of friction between the two blocks is 0.25, what is the angle of friction force Fr applied to the wooden block A? *(Write the angle in 360 degree format, using at least 1 decimal place. Do not include units)*

Clear

Clear line

Undo

Click and type your answer here

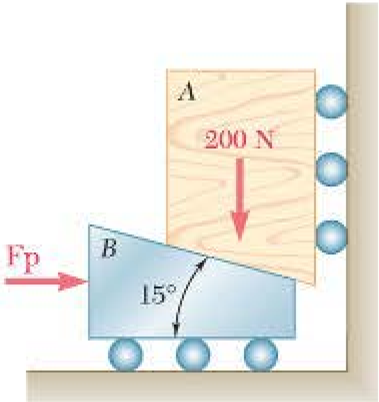
CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question



A wedge has an inclined face at 15° and is used to raise the 200 N weight of block A. If the coefficient of friction between the two blocks is 0.25, what is the magnitude force Fp applied to block B? *(Use at least 1 decimal place. Do not type units.)*

Clear

Clear line

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Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

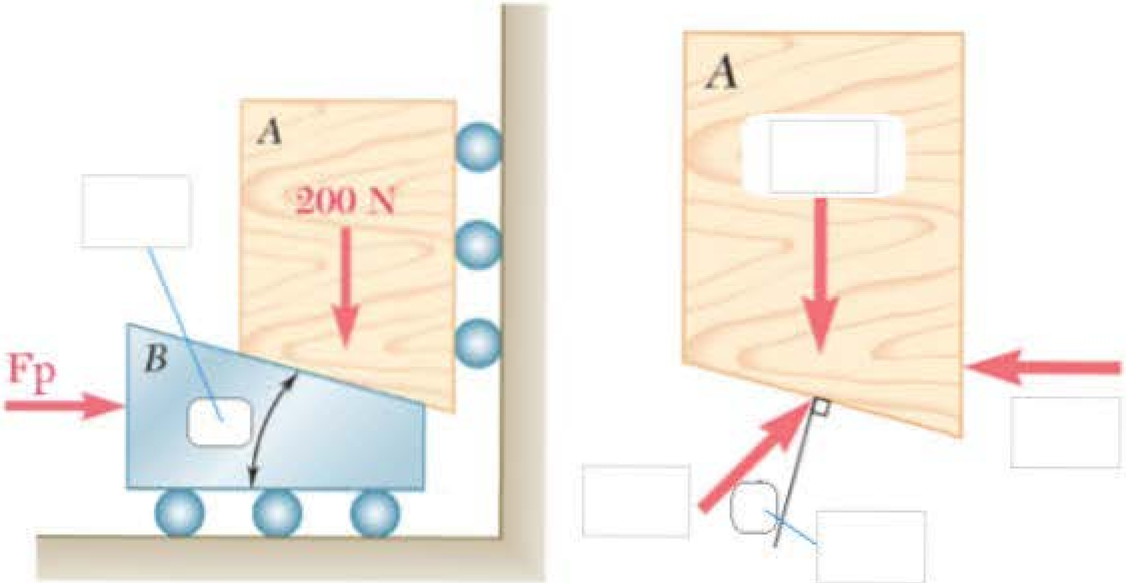
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Label the diagram at left and the FBD of the block (right).

F_r	Φ	F_2	θ	F_w



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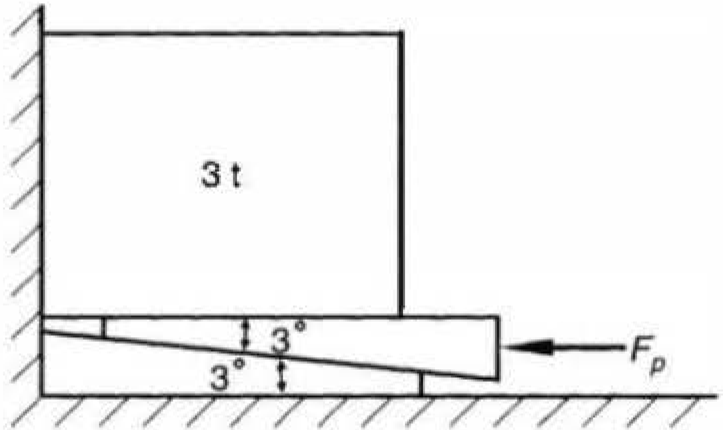
Calculate forces on a wedge using the sine rule method--Example

The following example illustrates a method of solving problems involving wedges. You will recognise this method as a semigraphical approach, using the sine rule for solving the triangle of forces.

Example

A 3 tonne block is raised by forcing a $3°$ wedge under it as shown. The coefficient of static friction is 0.27 at all surfaces in contact. Determine the minimum value of force F_P which must be applied to the wedge to move the block upwards.

There are two moving objects in this problem: the block and the wedge. Both require a FBD.



Define the wedge problem	FBD of mass	Direction of friction reactions	Angles of forces in FBD	Solve force triangle	FBD of Wedge

GIVE FEEDBACK

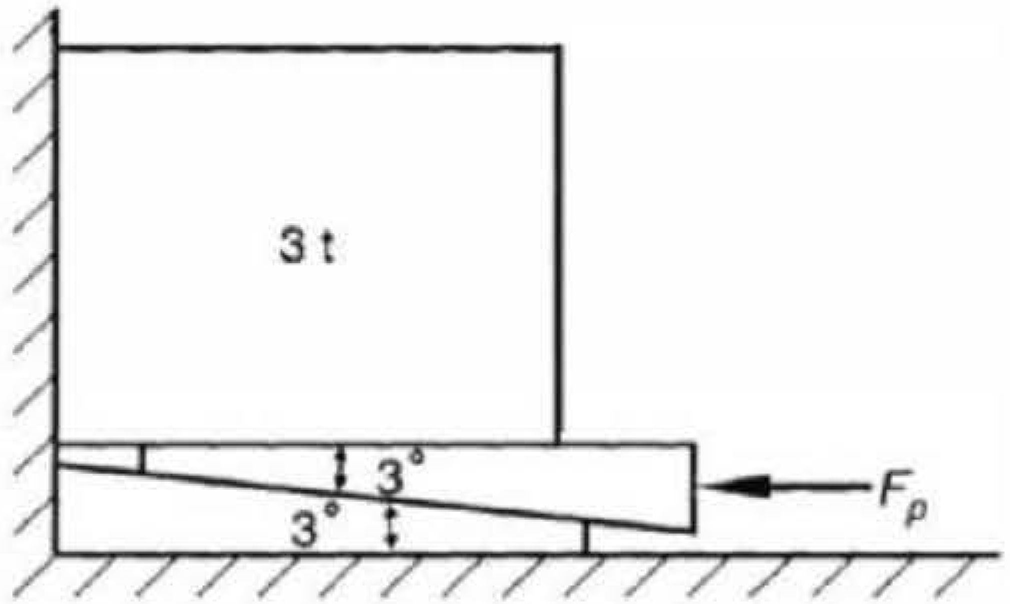
OK

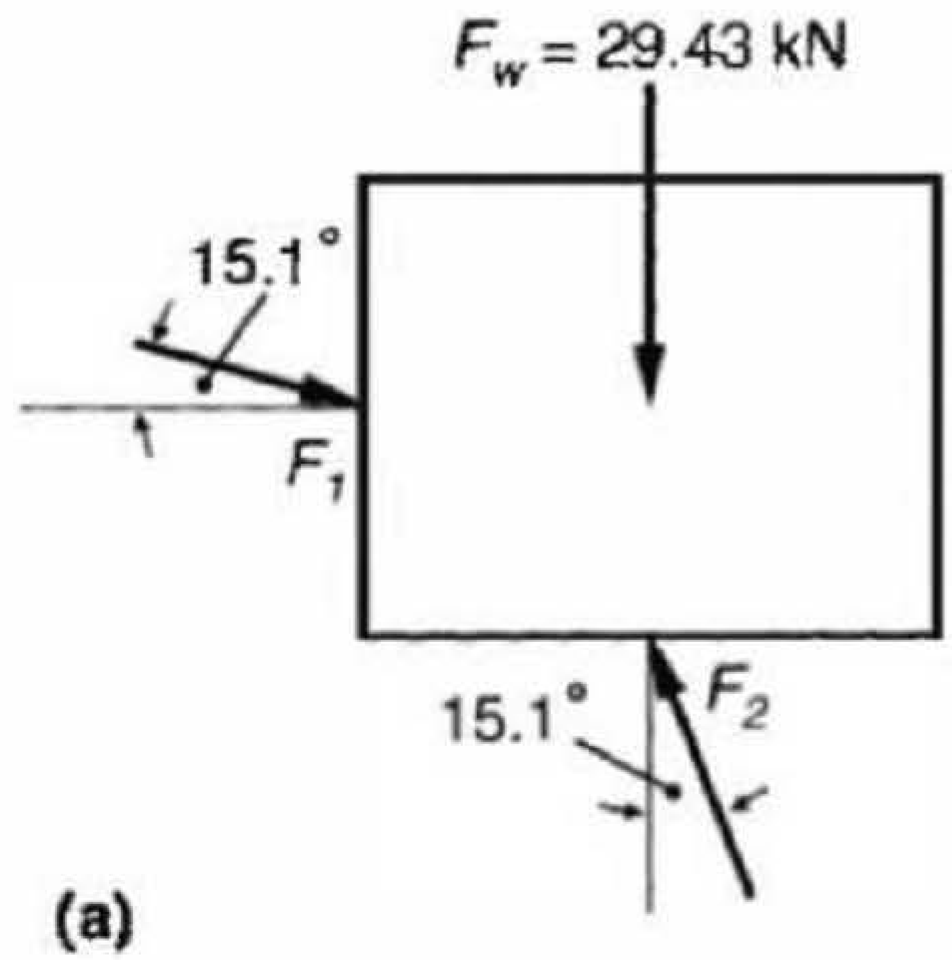
Calculate forces on a wedge using the sine rule method--Example

Solution

We start with the object with known force F_w (weight).

$$
\begin{aligned}
F_w &= m\,g \\
&= 3{,}000\ \text{kg} \times 9.81\ \text{N/kg} \\
&= 29{,}430\ \text{N}
\end{aligned}
$$





(a) *Free-body diagram*

Define the wedge problem	FBD of mass	Direction of friction reactions	Angles of forces in FBD	Solve force triangle	FBD of Wedge

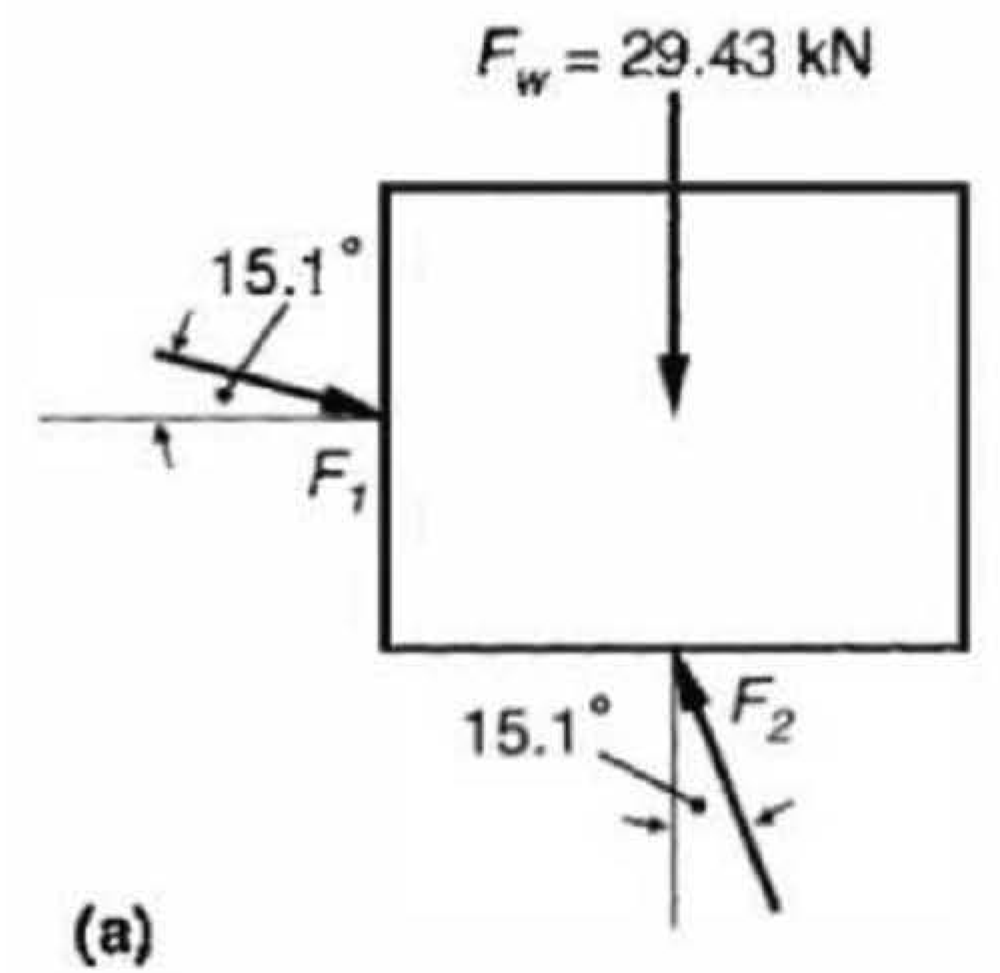
GIVE FEEDBACK

OK

Calculate forces on a wedge using the sine rule method--Example

Note carefully the directions of reaction forces at the surfaces subjected to friction. Friction force opposes the **impending motion** of the block in relation to the contacting surfaces. When the block moves, it goes upwards relative to the wall, and to the right* relative to the wedge.

** In the horizontal direction the wedge is the one that moves—to the left. But from the perspective of the block, we can treat the surface contact as if the wedge was stationary and the block moves forward. It is the relative motion of the block against the wedge that matters, which is from left to right.*



Free-body diagram

Define the wedge problem	FBD of mass	Direction of friction reactions	Angles of forces in FBD	Solve force triangle	FBD of Wedge

GIVE FEEDBACK

OK

Calculate forces on a wedge using the sine rule method--Example

Friction opposes motion, and this determines the direction of the resultant forces F_1 and F_2. These are pushing at the angle of friction:

$$\varphi = \tan^{-1}\mu$$
$$= \tan^{-1}0.27$$
$$= 15.1°$$

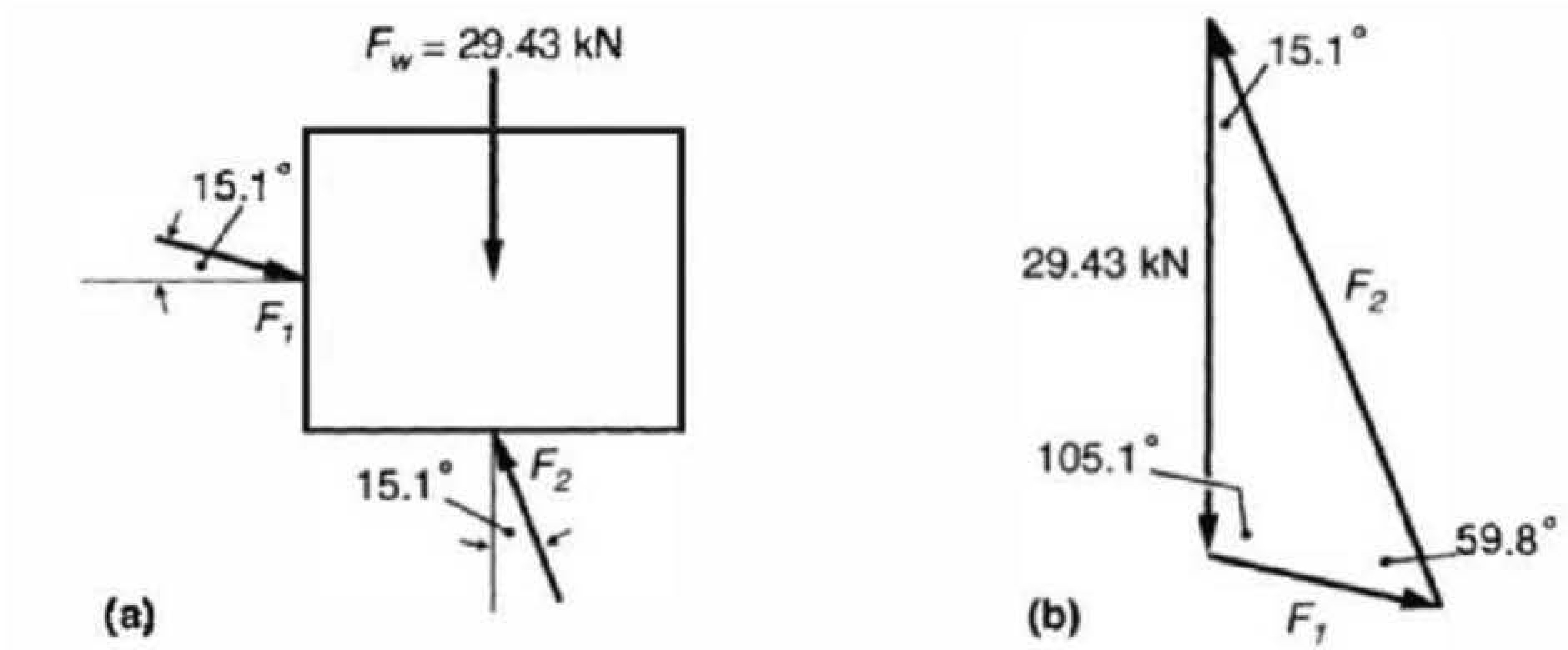
We now know the angle of every force:

$F_w = 29.43\,\text{kN} @ 270°$

$F_1 = ?\,\text{kN} @ 344.9°$

$F_2 = ?\,\text{kN} @ 105.1°$

The corresponding triangle of forces is then drawn as shown in Fig (b).



(a) *Free-body diagram* (b) *Triangle of forces*

Define the wedge problem	FBD of mass	Direction of friction reactions	Angles of forces in FBD	Solve force triangle	FBD of Wedge

GIVE FEEDBACK

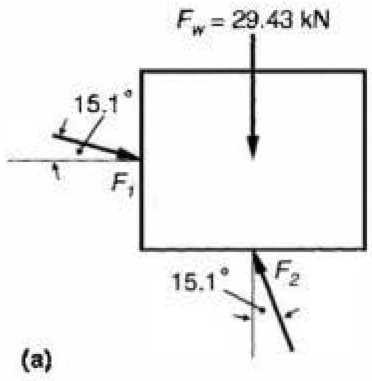
OK

Calculate forces on a wedge using the sine rule method--Example

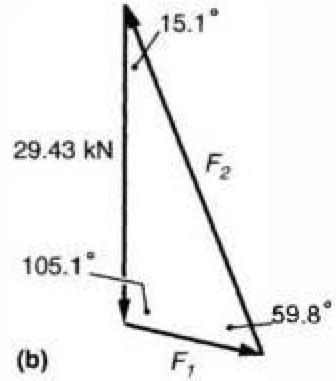
We can now use the sine rule to solve for force F_2:

$$\frac{29.43}{\sin 59.8°} = \frac{F_2}{\sin 105.1°}$$
$$\therefore F_2 = 32.88 \text{ kN}$$

This is the force that the wedge applies to the **block**.



(a) *Free-body diagram*



(b) *Triangle of forces*

Define the wedge problem	FBD of mass	Direction of friction reactions	Angles of forces in FBD	Solve force triangle	FBD of Wedge

GIVE FEEDBACK

OK

Calculate forces on a wedge using the sine rule method--Example

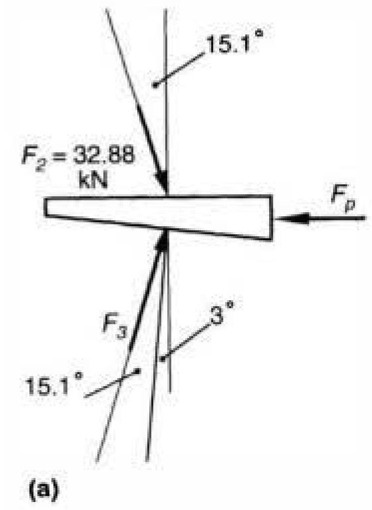
Now we are ready to draw the FBD of the **wedge**.

It has the equal and opposite reaction to force F_2 (= 32.88 kN), as well as the unknown reaction force F_3. Note very carefully the directions of these forces in relation to the wedge.

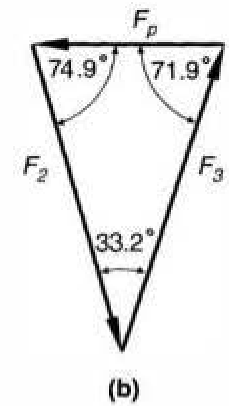
The triangle of forces is drawn. Solving the triangle by the sine rule gives:

$$\frac{32.88}{\sin 71.9°} = \frac{F_p}{\sin 33.2°}$$
$$\therefore F_p = 18.9 \text{ kN}$$

The total force to insert the wedge is 18.9 kN.



(a) *Free-body diagram* of the wedge

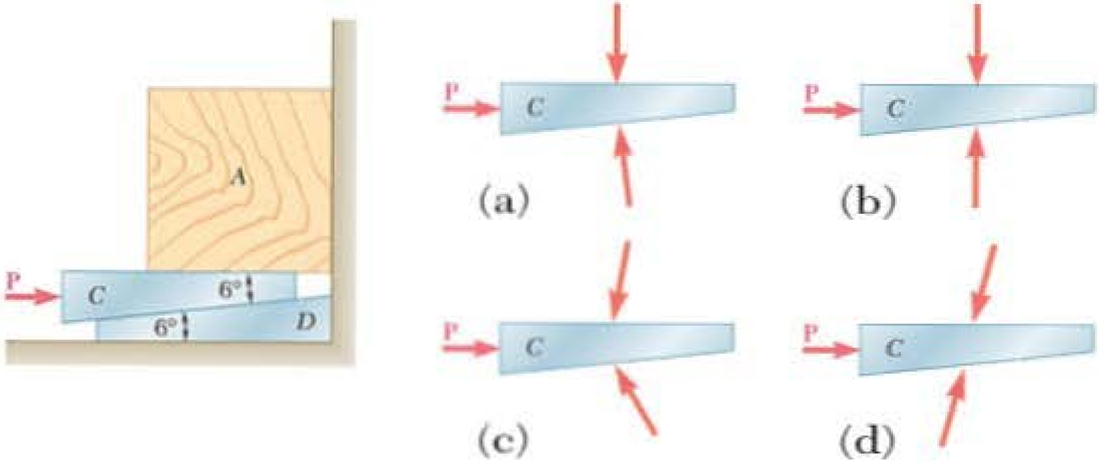


(b) *The triangle of forces*

Define the wedge problem	FBD of mass	Direction of friction reactions	Angles of forces in FBD	Solve force triangle	FBD of Wedge

GIVE FEEDBACK

OK



Which is the correct FBD for the 'C' wedge?

Assume applied force P = 0, and the wedge is self-locking.

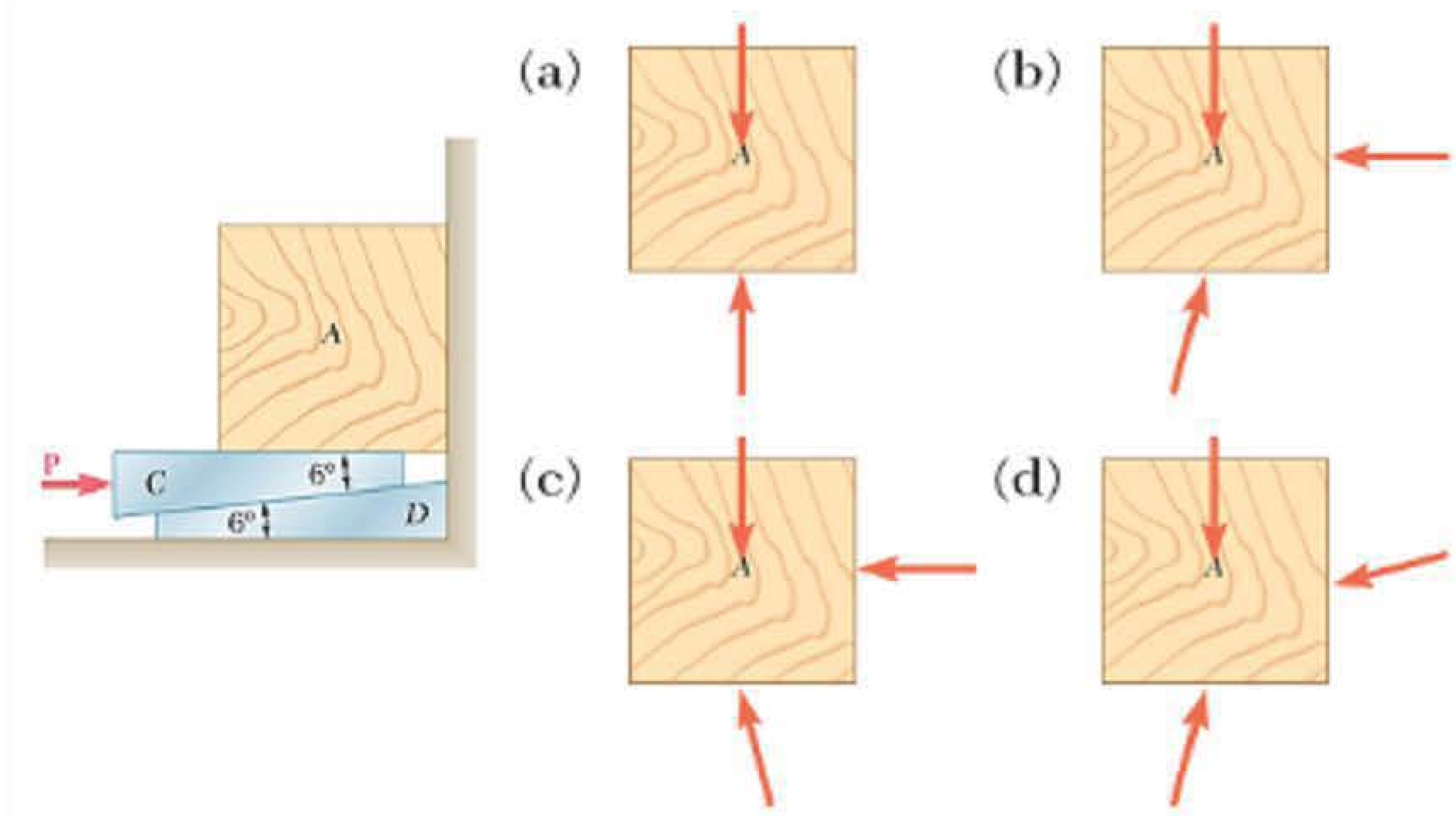
Click the correct answer.

Fig (a)

Fig (b)

Fig (c)

Fig (d)



Which is the correct FBD for the 'A' block?

Assume the angle of friction for all sliding surfaces is $\Phi = 15°$.

Assume applied force P is on the verge of moving the wedge.

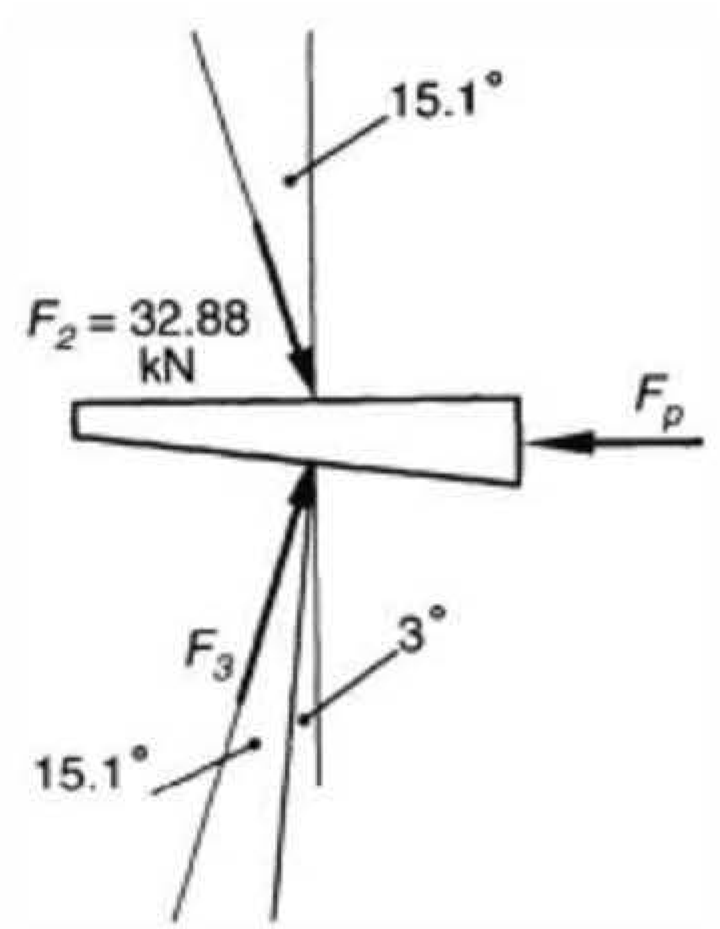
Click the correct answer.

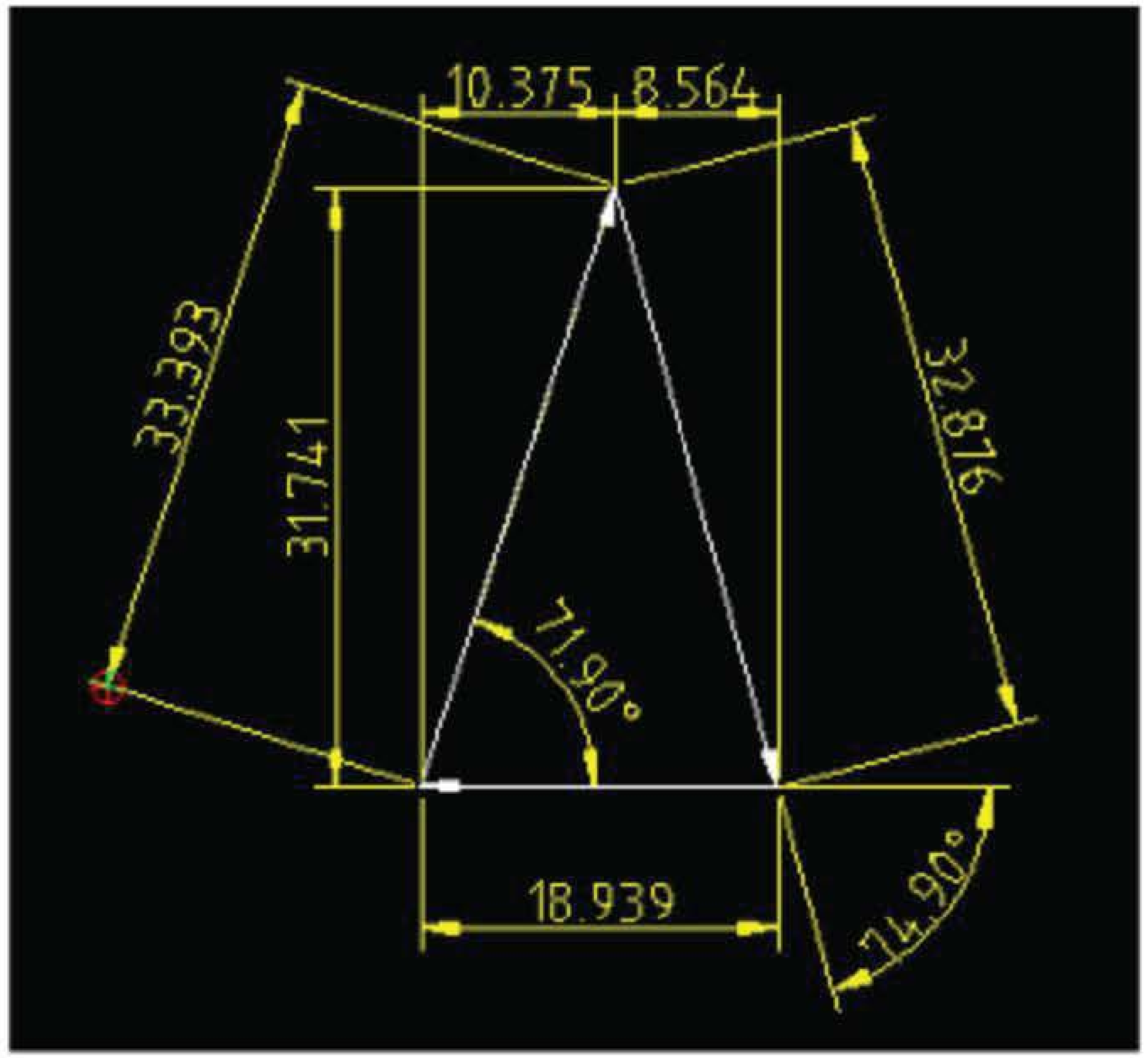
Fig (a)

Fig (c)

Fig (b)

Fig (d)

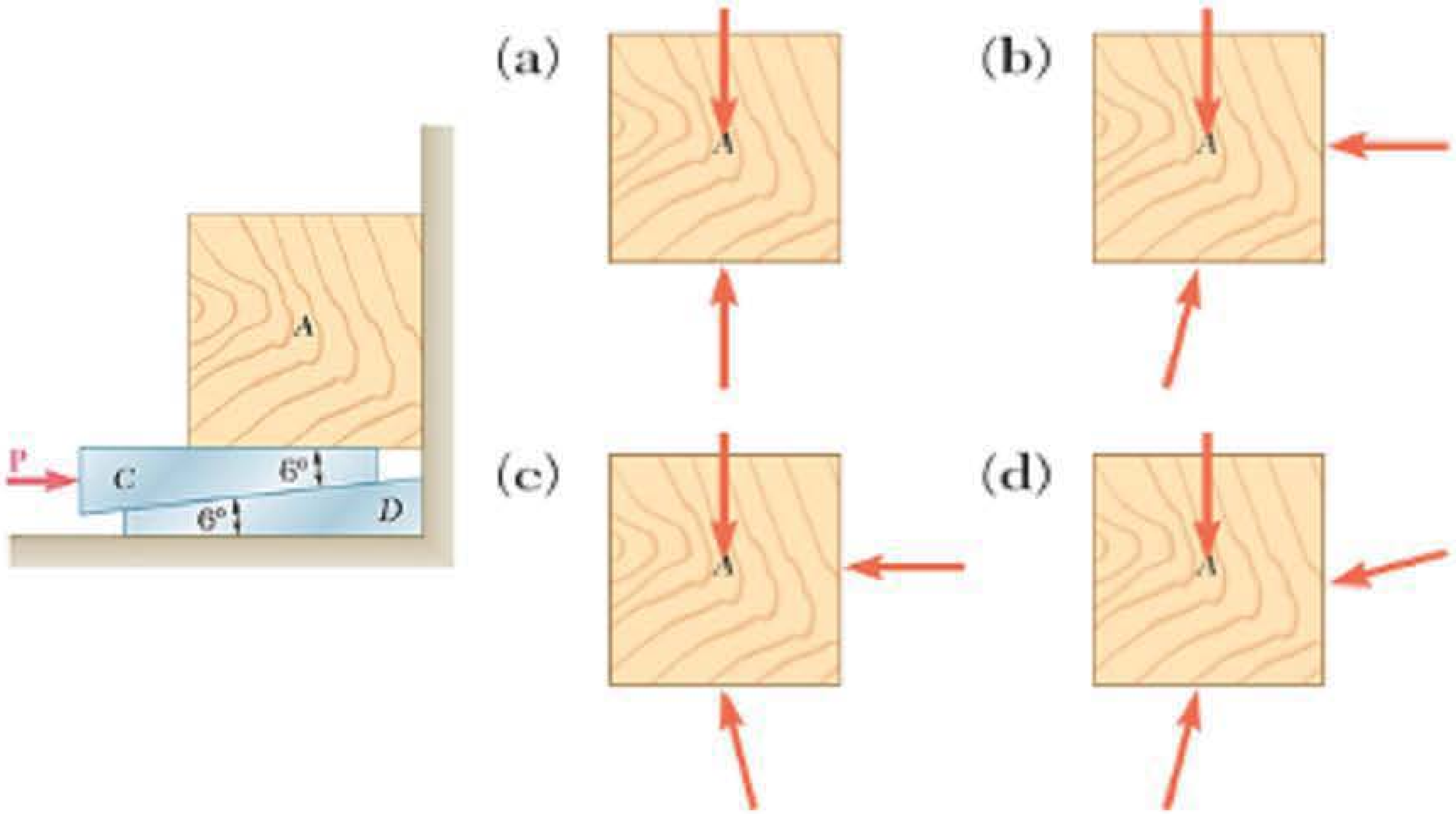




Match the following terms used in this FBD and force polygon.

Drag statements on the right to match the left.

F_2	18.939 kN
F_3	Not available on this force polygon
F_p	33.393 kN
Friction component of F_2	32.876 kN
Friction component of F_3	8.564 kN



Which is the correct FBD for the 'A' block?
Assume zero friction on the wall, with the wedge contact surface with an angle of friction of 15°.

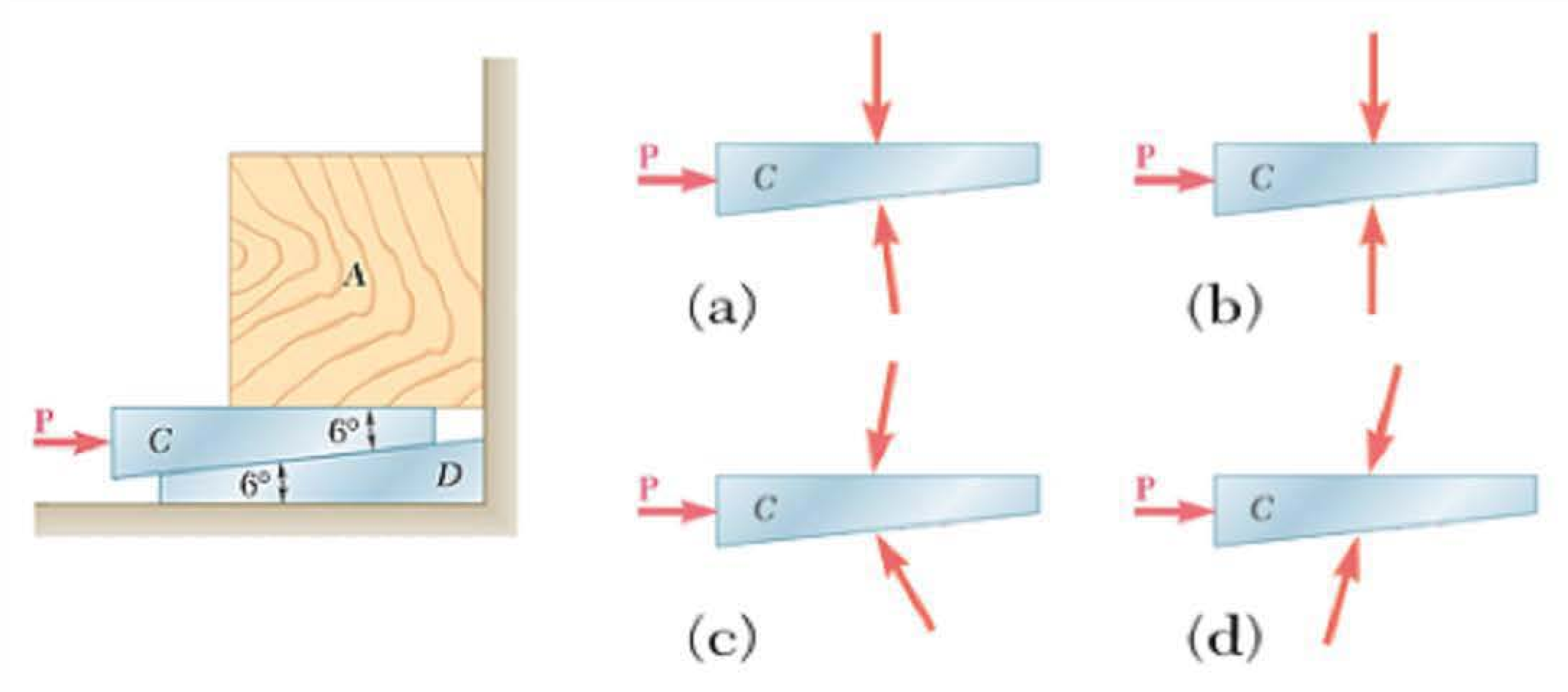
Click the correct answer.

Fig (d)

Fig (c)

Fig (a)

Fig (b)



Which is the correct FBD for the 'C' wedge?

Assume a coefficient of friction $\mu = 0.268$ (which is angle of friction $\Phi = 15°$)

Assume applied force is at the point of impending motion.

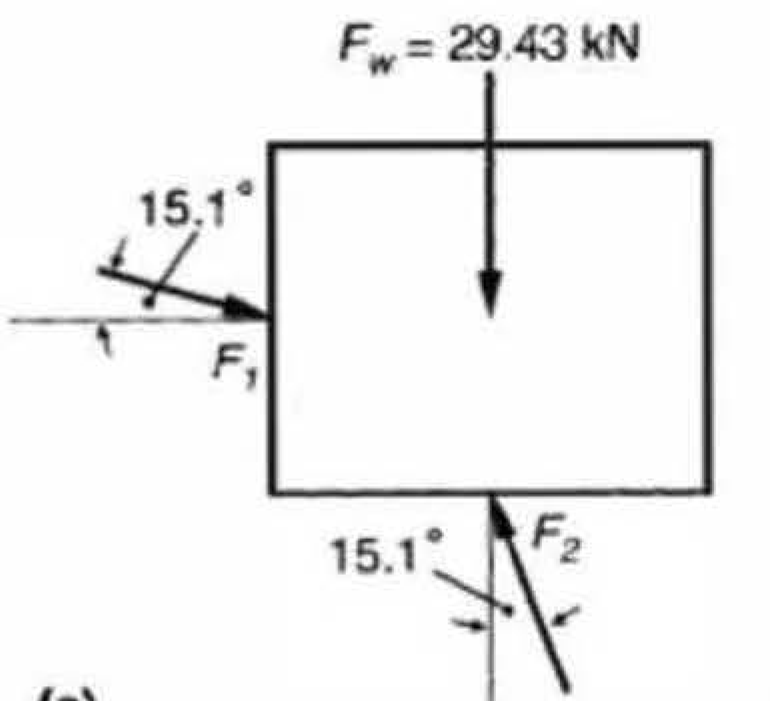
Click the correct answer.

Fig (a)

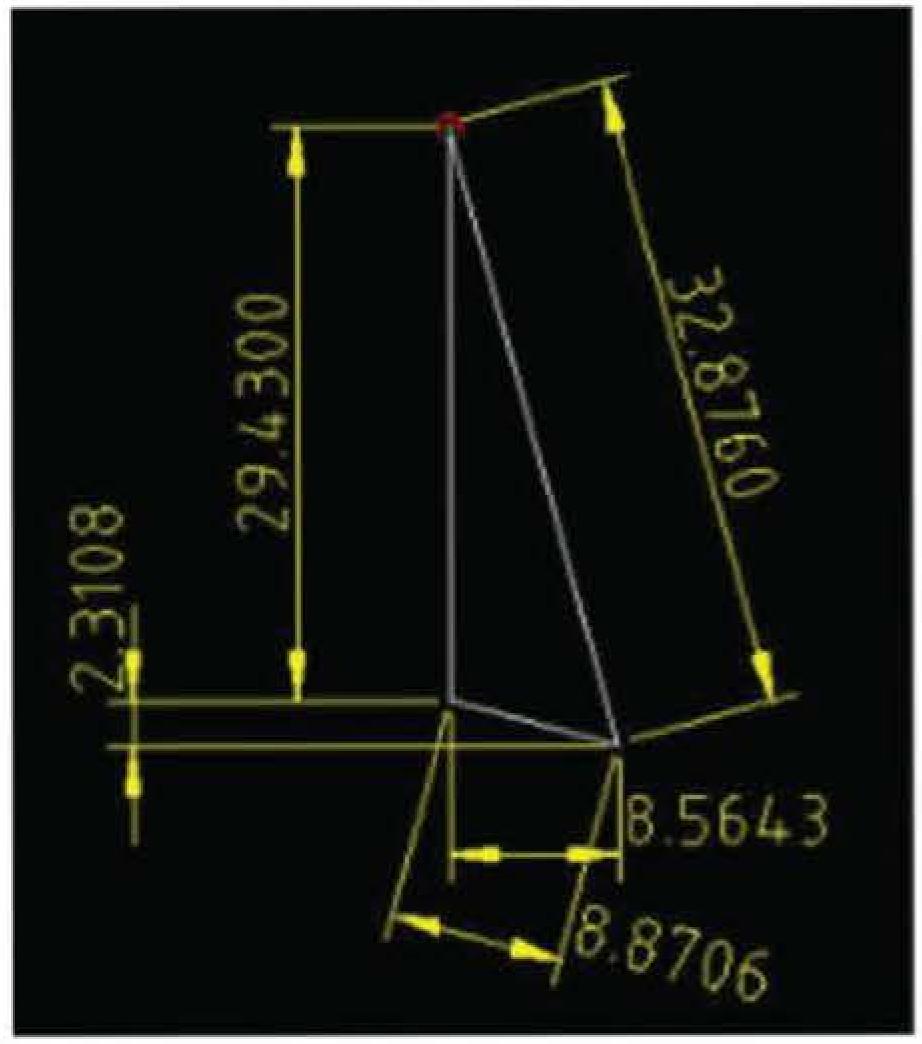
Fig (d)

Fig (c)

Fig (b)



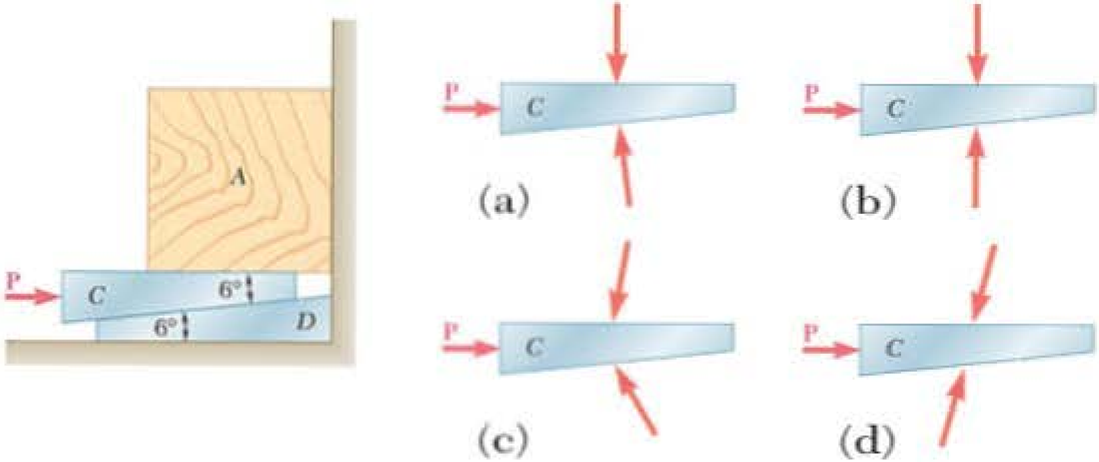
(a)



Match the following terms used in this FBD and force polygon.

Drag statements on the right to match the left.

F_w	32.88 kN
F_1	8.56 kN
F_2	2.31 kN
Friction component of F_2	8.87 kN
Friction component of F_1	29.43 kN



Which is the correct FBD for the 'C' wedge?
Assume zero friction on all sliding surfaces.

Click the correct answer.

- Fig (a)
- Fig (b)
- Fig (c)
- Fig (d)

The wedge (2) is mounted underneath the block (1). Identify the appropriate diagrams where FBD = Free Body Diagram and FP = Force Polygon.

FBD_1	FP_2	FBD_2	FP_1