GIVE FEEDBACK

CONTINUE >

This section introduces some fundamental principles for the operation of machines.

Mechanical advantage, velocity ratio, effiency, load and effort are covered prior to considering the law of a machine.

An understanding of these concepts is a necessary foundation for investigations in the mechanics of machines.

Examples of machines range from the simple lever through to complicated devices with many interconnected components.

What are machines?

A **machine** can be defined as a mechanical device consisting of one or more rigid components, designed and used for transmitting force and motion, and for doing work.

GIVE FEEDBACK

OK

Type your answer in the box.

A [ ] can be defined as a mechanical device consisting of one or more rigid components, designed and used for transmitting force and motion, and for doing work.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the best description of a machine?

Click the correct answer.

A mechanical device consisting of one or more rigid components, designed and used for transmitting force and motion, and for doing work

A mechanical device consisting of one or more rigid components

A device consisting of one or more rigid components, designed and used for transmitting work

A set of rigid components designed and used for transmitting work and motion

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The purpose of machines

The general purpose of machines is to augment or replace human effort for the accomplishment of physical tasks.

In particular, the fundamental feature of most machines is that a large load is moved, or a large resistance is overcome, by means of a relatively small effort.

GIVE FEEDBACK

OK

Which of the following correctly describe the purpose of machines?

Check all that apply.

- [ ] To augment or replace human effort for the accomplishment of physical tasks
- [ ] To move a large load, or overcome a large resistance, by means of a relatively small effort
- [ ] To increase complexity in the performance of tasks
- [ ] To remove physical application of mechanical advantage
- [ ] To apply load to a given effort force

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Effort of a machine

All machines have an input side and an output side.

The force exerted on the machine on the input side is known as the **effort**, F_E.

GIVE FEEDBACK

OK

The force exerted on a machine on the input side is known as _____.

Click the correct answer.

effort

load

efficiency

advantage

leverage

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

The force exerted on the machine on the input side is known as the _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Load of a machine

All machines have an input side and an output side.

The resistance to be overcome, or the force on the output side of the machine, is called the **load**, F_L.

GIVE FEEDBACK

OK

The resistance to be overcome, or the force on the output side of the machine, is known as the _____.

Click the correct answer.

load

effort

efficiency

advantage

leverage

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

The resistance to be overcome, or the force on the output side of the machine, is known as the _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Mechanical advantage of a machine

Machines are usually of such design that by application of a small effort, a large load can be moved.

The relationship between the load and the effort, which gives an indication of the advantage that can be obtained by using the machine, is called the **mechanical advantage** of the machine.

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

$$\text{MA} = \frac{F_L}{F_E}$$

Mechanical advantage is usually greater than one; it depends on the type of machine which is being used and it varies with the load.

GIVE FEEDBACK

OK

Which of the following are correct descriptions of mechanical advantage?

Check all that apply.

- [ ] $\text{MA} = \frac{F_L}{F_E}$
- [ ] $\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$
- [ ] $\text{MA} = F_L F_E$
- [ ] $\text{MA} = F_L + F_E$
- [ ] $\text{MA} = F_L - F_E$
- [ ] Mechanical advantage = load + effort
- [ ] Mechanical advantage = load − effort
- [ ] Mechanical advantage = load · effort

Do you know the answer?

Velocity ratio of a machine

In order to do work, both the load and the effort must move. In some machines the motion is linear, while in others it is rotational.

The ratio of the distance moved through by the effort on the input side (S_E) to the distance moved through by the load on the output side (S_L) is called the **velocity ratio** of the machine.

$$\text{Velocity ratio} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$

$$\text{VR} = \frac{S_E}{S_L}$$

Velocity ratio is usually greater than one and, unlike the mechanical advantage, is constant for a given machine, i.e. it depends only on the arrangement of moving parts and is independent of the load.

GIVE FEEDBACK

OK

Which of the following are correct descriptions of velocity ratio?

Check all that apply.

- [ ] $\text{VR} = \frac{S_E}{S_L}$
- [ ] $\text{Velocity ratio} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$
- [ ] $\text{VR} = S_E + S_L$
- [ ] $\text{VR} = S_E - S_L$
- [ ] $\text{VR} = S_E \cdot S_L$
- [ ] Velocity ratio = distance moved by effort + distance moved by load

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The mechanical advantage and velocity ratio of a real machine

Ideally, the mechanical advantage of any given machine should be equal to its velocity ratio.

However, for a real machine, the actual mechanical advantage is always less than the ideal due to the presence of friction between moving parts such as bearing or sliding surfaces.

GIVE FEEDBACK

OK

Type your answer in the box.

Ideally, the mechanical advantage of any given machine should be _____ to its velocity ratio.

However, for a real machine, the actual mechanical advantage is always _____ than ideal due to the presence of friction between moving parts such as bearing or sliding surfaces.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the mechanical advantage of a machine

A simple machine is represented diagrammatically in the following figure.

The load is 450 N and the effort is 50 N.

The distances moved by the load and effort are 100 mm and 1200 mm respectively.

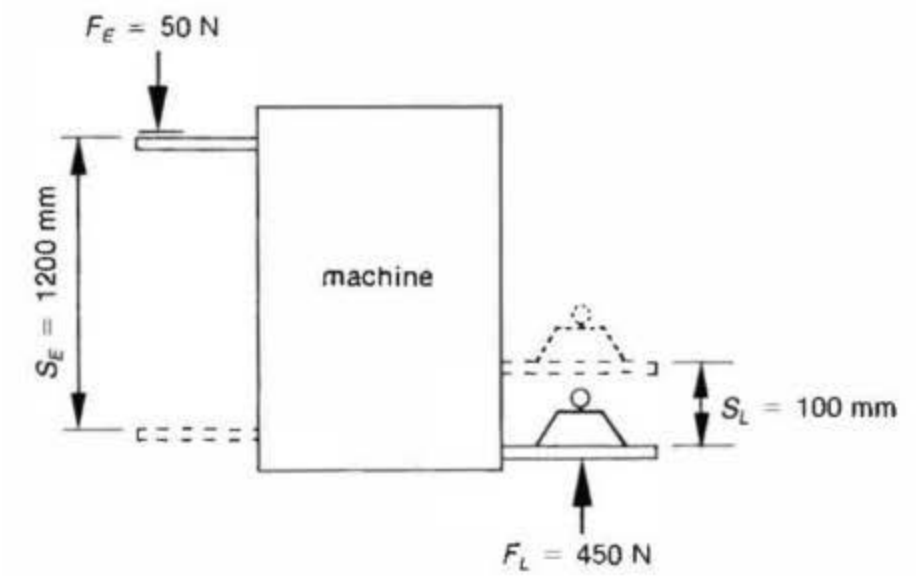
Calculate the mechanical advantage.

Example	Figure	Solution

GIVE FEEDBACK

OK

Calculate the mechanical advantage of a machine



Example | Figure | Solution

GIVE FEEDBACK

OK

Calculate the mechanical advantage of a machine

Mechanical advantage:

$$\begin{aligned} MA &= \frac{F_L}{F_E} \\ &= \frac{450\,N}{50\,N} \\ &= 9 \end{aligned}$$

The mechanical advantage of this machine is 9.

Note that mechanical advantage has no units.

Example	Figure	Solution

GIVE FEEDBACK

OK

A simple machine requires an effort of 75 N to produce a load force of 750 N.

Calculate the mechanical advantage in this case.

$+$ $-$ $\cdot$ $\div$ $\frac{\square}{\square}$ $1\frac{2}{3}$ $\square^2$ $\sqrt{\square}$ Clear

$(\square)$ ▼ $\leq$ ▼ π $\square_n$ $\overline{\square}$? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

A simple machine requires an effort of 240 N to produce a load force of 12,000 N.

Calculate the mechanical advantage in this case.

+ − · ÷ $\frac{\square}{\square}$ $1\frac{2}{3}$ $\square^2$ $\sqrt{\square}$ Clear

$(\square)$ ▼ ≤ ▼ π $\square_n$ $\overline{\square}$? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

A simple machine requires an effort of 40 N to produce a load force of 200 N.

Calculate the mechanical advantage in this case.

+ − · ÷ $\frac{\square}{\square}$ $1\frac{2}{3}$ $\square^2$ $\sqrt{\square}$ Clear

$(\square)$ ▼ ≤ ▼ π $\square_n$ $\overline{\square}$? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

Calculate the velocity ratio of a machine

A simple machine is represented diagrammatically in the following figure.

The load is 450 N and the effort is 50 N.

The distances moved by the load and by the effort are 100 mm and 1200 mm respectively.

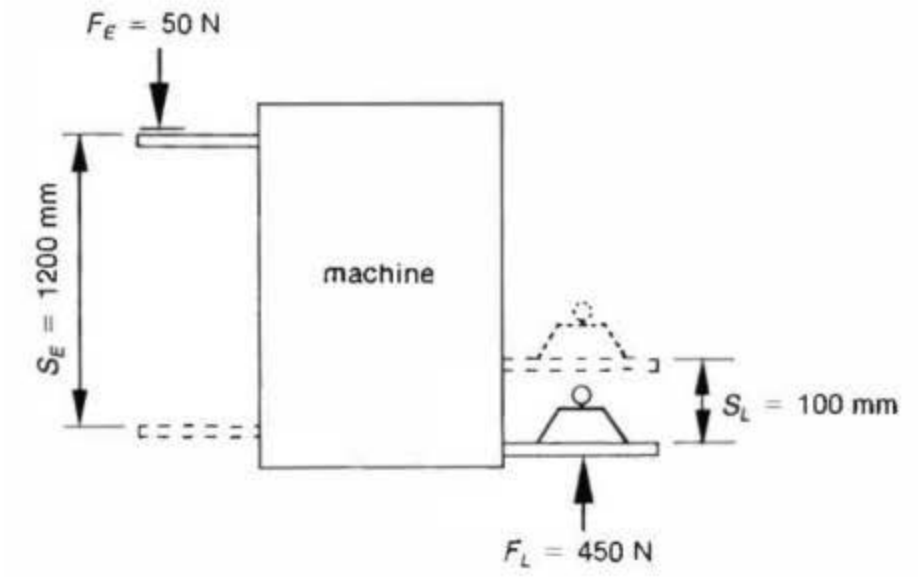
Calculate the velocity ratio.

Example	Figure	Solution

GIVE FEEDBACK

OK

Calculate the velocity ratio of a machine



Example | Figure | Solution

GIVE FEEDBACK

OK

Calculate the velocity ratio of a machine

Velocity ratio:

$$\begin{aligned} VR &= \frac{S_E}{S_L} \\ &= \frac{1{,}200 \text{ mm}}{100 \text{ mm}} \\ &= 12 \end{aligned}$$

The velocity ratio for this machine is 12.

Note that the velocity ratio has no units.

Example | Figure | Solution

A simple machine requires an effort distance of 1 m to produce a load distance of 200 mm.

Calculate the velocity ratio for this machine.

+ − · ÷ $\frac{\square}{\square}$ $\square^2$ $\sqrt{\square}$ Clear

$(\square)$ ▼ ≤ ▼ π $\square_n$ $\overline{\square}$? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

A simple machine requires an effort distance of 900 mm to produce a load distance of 20 mm.

Calculate the velocity ratio for this machine.

+ − · ÷ □/□ □² √□ Clear

(□) ▼ ≤ ▼ π □ₙ □̄ ? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

A simple machine requires an effort distance of 1.5 m to produce a load distance of 100 mm.

Calculate the velocity ratio for this machine.

+ − · ÷ □/□ □² √□ Clear

(□) ▼ ≤ ▼ π □ₙ □̄ ? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

Work done by effort

Whenever a force moves through a distance, the product of force and distance is the work done.

On the *input* side of a machine, the work done by the effort is equal to:

$$W_E = F_E \cdot S_E$$

where:

W_E is the work done by effort

F_E is the effort force

S_E is the effort distance

GIVE FEEDBACK

OK

Match each of the symbols from the equation $W_E = F_E \cdot S_E$ with the correct description.

Drag statements on the right to match the left.

W_E	Work done by the effort
F_E	Effort force
S_E	Effort distance

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct equation for the work done by effort on a machine?

Click the correct answer.

$W_E = F_E \cdot S_E$

$W_E = F_E + S_E$

$W_E = \frac{F_E}{S_E}$

$W_L = F_L \cdot S_L$

$W_L = F_L + S_L$

$W_L = \frac{F_L}{S_L}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Work done in moving a load

Whenever a force moves through a distance, the product of force and distance is the work done.

On the *output* side, the work done in moving the load is given by:

$$W_L = F_L \times S_L$$

where:

W_L is the work done moving the load

F_L is the load force

S_L is the load distance

GIVE FEEDBACK

OK

Match each of the symbols from the equation $W_L = F_L \cdot S_L$ with the correct description.

Drag statements on the right to match the left.

W_L	Work done in moving the load
F_L	Load force
S_L	Load distance

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct equation for the work done in moving a load?

Click the correct answer.

$W_L = F_L \cdot S_L$

$W_E = F_E + S_E$

$W_E = \frac{F_E}{S_E}$

$W_E = F_E \cdot S_E$

$W_L = F_L + S_L$

$W_L = \frac{F_L}{S_L}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

In simple terms, the efficiency is the output divided by the input.

Efficiency of a machine

The ratio of the useful work done by the machine in moving the load on the output side to the work put into the machine by the effort on the input side is called the **efficiency** of the machine.

$$\text{efficiency} = \frac{\text{work done in moving load}}{\text{work done by the effort}}$$

$$\eta = \frac{W_L}{W_E}$$

$$= \frac{F_L \times S_L}{F_E \times S_E}$$

GIVE FEEDBACK

OK

Match each of the symbols from the equation $\eta = \frac{W_L}{W_E}$ with the correct description.

Drag statements on the right to match the left.

η	Efficiency
W_L	Work done in moving the load
W_E	Work done by the effort

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct equation for the efficiency of a machine?

Click the correct answer.

$\eta = \frac{W_L}{W_E}$

$\eta = W_L + W_E$

$\eta = W_L - W_E$

$\eta = W_L \cdot W_E$

$\eta = \frac{W_L}{100}$

$\eta = \frac{W_E}{W_L}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculating the efficiency of a machine using mechanical advantage and velocity ratio

$$\eta = \frac{W_L}{W_E}$$
$$= \frac{F_L \times S_L}{F_E \times S_E}$$

Since MA = $\frac{F_L}{F_E}$ and VR = $\frac{S_E}{S_L}$, then:

$$\eta = \frac{\text{MA}}{\text{VR}}$$

where:

η is the efficiency

MA is the mechanical advantage

VR is the velocity ratio

Usually efficiency is expressed as a percentage and in the absence of friction it should ideally be equal to 100 per cent.

In actual machines efficiency is always less than 100 per cent.

GIVE FEEDBACK

OK

Match each of the symbols from the equation $\eta = \frac{MA}{VR}$ with the correct description.

Drag statements on the right to match the left.

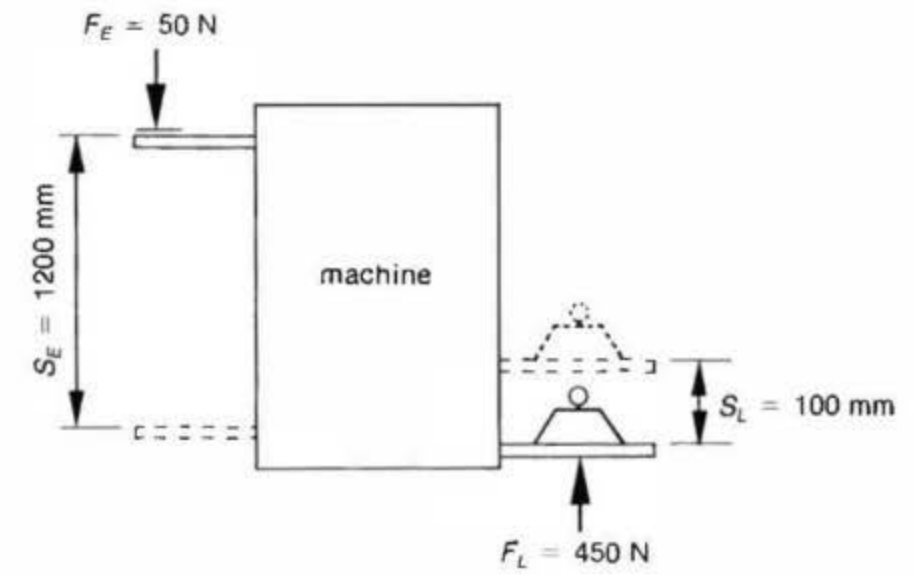
η	Efficiency
MA	Mechanical advantage
VR	Velocity ratio of the machine

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the input and output work

For the machine in the figure, calculate the input and output work.



Example	Input work	Output work

GIVE FEEDBACK

OK

Calculate the input and output work

Input work:

$$\begin{aligned} W_E &= F_E \times S_E \\ &= 50\ \text{N} \times 1.2\ \text{m} \\ &= 60\ \text{J} \end{aligned}$$

Calculate the input and output work

Output work:

$$\begin{aligned} W_L &= F_L \times S_L \\ &= 450\ \text{N} \times 0.1\ \text{m} \\ &= 45\ \text{J} \end{aligned}$$

GIVE FEEDBACK

OK

A simple machine requires an effort of 50 N moving through a distance of 1 m to produce a load force of 200 N that moves through 200 mm.

SMALL | MEDIUM | LARGE

Calculate the work done by the effort.

Clear

Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

A simple machine requires an effort of 50 N moving through a distance of 1 m to produce a load force of 200 N that moves through 200 mm.

SMALL | MEDIUM | LARGE

Calculate the work done in moving the load.

Clear

Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

A simple machine requires an effort of 75 N moving through a distance of 1.2 m to produce a load force of 750 N that moves through 100 mm.

SMALL | MEDIUM | LARGE

Calculate the work done by the effort.

Clear

Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

A simple machine requires an effort of 75 N moving through a distance of 1.2 m to produce a load force of 750 N that moves through 100 mm.

SMALL | MEDIUM | LARGE

Calculate the work done in moving the load.

Clear

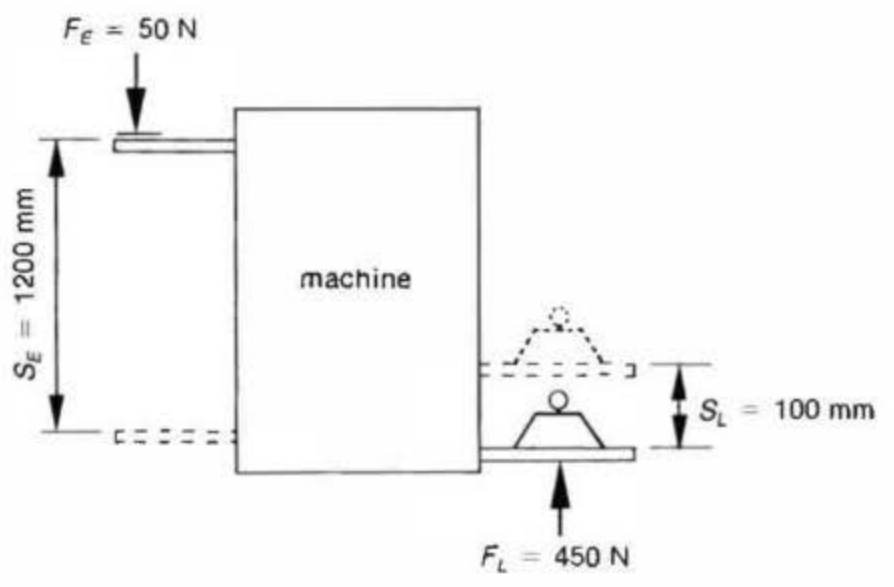
Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

Calculate the efficiency of a machine

For the machine in the figure, calculate the efficiency.



Example	Input work	Output work	Efficiency	Alternate solution

GIVE FEEDBACK

OK

Calculate the efficiency of a machine

Input work:

$$\begin{aligned} W_E &= F_E \times S_E \\ &= 50\ \text{N} \times 1.2\ \text{m} \\ &= 60\ \text{J} \end{aligned}$$

Calculate the efficiency of a machine

Output work:

$$\begin{aligned} W_L &= F_L \times S_L \\ &= 450\ \text{N} \times 0.1\ \text{m} \\ &= 45\ \text{J} \end{aligned}$$

GIVE FEEDBACK

OK

Calculate the efficiency of a machine

Efficiency:

$$\begin{aligned}\eta &= \frac{W_L}{W_E} \\ &= \frac{45}{60} \\ &= 0.75 \\ &= 75\%\end{aligned}$$

Example	Input work	Output work	Efficiency	Alternate solution

GIVE FEEDBACK

OK

Alternatively:

$$\eta = \frac{\text{MA}}{\text{VR}}$$
$$= \frac{9}{12}$$
$$= 0.75$$
$$= 75\%$$

A simple machine requires an effort of 50 N moving through a distance of 1 metre to produce a load force of 200 N that moves through 200 mm.

SMALL | MEDIUM | LARGE

Type your answer in the box.

The work done by the effort is _____ J.

The work done in moving the load is _____ J.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

A simple machine requires an effort of 50 N moving through a distance of 1 metre to produce a load force of 200 N that moves through 200 mm.

SMALL | MEDIUM | LARGE

Given that the work done by the effort is 50J and the work done by moving the load is 40J, calculate the efficiency η of the machine as a percentage.

Clear

Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

A simple machine requires an effort of 75 N moving through a distance of 1.2 m to produce a load force of 750 N that moves through 100 mm.

SMALL | MEDIUM | LARGE

Type your answer in the box.

The work done by the effort is _____ J.

The work done in moving the load is _____ J.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

A simple machine requires an effort of 75 N moving through a distance of 1.2 m to produce a load force of 750 N that moves through 100 mm.

SMALL | MEDIUM | LARGE

Given that the work done by the effort is 90 N and the work done in moving the load is 75 N, calculate the efficiency η of the machine as a percentage.

Clear

Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

The ideal machine

If a machine is perfect, no work would have to be done against friction and the efficiency would be 100 per cent.

This would mean that for a perfect machine:

$$\frac{\text{MA}}{\text{VR}} = 100\%$$

or that the ideal mechanical advantage is equal to the velocity ratio:

$$\text{MA} = \text{VR}$$

It also means that if there is no friction to be overcome, it would take a smaller effort to move the same load.

GIVE FEEDBACK

OK

Type your answer in the box.

If a machine is perfect, no work would have to be done against friction and the efficiency would be _____ %.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following equations is correct for an ideal machine?

Click the correct answer.

- MA = VR
- MA + VR = 1
- MA − VR = 1
- MA · VR = 1

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Theoretical effort

If there is no friction to be overcome by a machine, it takes a smaller effort to move the same load.

The effort required to move a given load F_L if the machine is 100 per cent efficient is called the **theoretical effort**, F_{Th}.

Substituting into $MA = VR$, we have:

$$\frac{F_L}{F_{Th}} = VR$$

or

$$F_{Th} = \frac{F_L}{VR}$$

GIVE FEEDBACK

OK

Match each of the symbols from the equation $F_{Th} = \frac{F_L}{VR}$ with the correct description.

Drag statements on the right to match the left.

F_{Th}	Theoretical effort
F_L	Load.
VR	Velocity ratio

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Actual effort

The actual effort (F_E) is the force exerted on the machine on the input side.

The relationship between effort (F_E) and load (F_L) is given by the law of a machine.

GIVE FEEDBACK

OK

Type your answer in the box.

The [ ] effort (F_E) is the force exerted on the machine on the input side.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Frictional effort

The difference between the actual effort (F_E) and the theoretical effort (F_{Th}) is the effort wasted in overcoming friction, known as the **frictional effort** (F_F).

Friction results in heat which is a loss to the machine, i.e. increased friction causes reduced efficiency.

GIVE FEEDBACK

OK

Type your answer in the box.

The difference between the actual effort (F_E) and the theoretical effort (F_{Th}) is the effort wasted in overcoming friction, known as the _____ effort (F_F).

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The difference between theoretical, actual and frictional effort

The effort required to move a given load if the machine is 100 per cent efficient is called the **theoretical effort** (F_{Th}).

The **actual effort** (F_E) is the force exerted on the machine on the input side.

The effort wasted in overcoming friction is known as the **frictional effort** (F_F).

GIVE FEEDBACK

OK

Match the following to give correct descriptions of actual, theoretical and frictional effort.

Drag statements on the right to match the left.

The **actual effort** (F_E)	⇔	is the force exerted on the machine on the input side.
The **frictional effort** (F_F)	⇔	is the effort wasted in overcoming friction.
The **theoretical effort** (F_{Th})	⇔	is the effort required to move a given load if the machine is 100 per cent efficient.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The relation between theoretical, actual and frictional effort

The difference between the actual effort (F_E) and the theoretical effort (F_{Th}) is the effort wasted in overcoming friction, known as the **frictional effort** (F_F).

This relationship can be expressed as:

$$F_F = F_E - F_{Th}$$

GIVE FEEDBACK

OK

Which of the following represents the correct relationship between actual, theoretical and frictional effort?

Click the correct answer.

$F_F = F_E - F_{Th}$

$F_F = F_E + F_{Th}$

$F_F = \frac{F_E}{F_{Th}}$

$F_F = F_E \cdot F_{Th}$

$F_F^2 = F_E^2 + F_{Th}^2$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the efforts of a machine

A simple machine is represented diagrammatically in the following figure.

The load is 450 N and the effort is 50 N.

The distances moved by the load and effort are 100 mm and 1200 mm respectively.

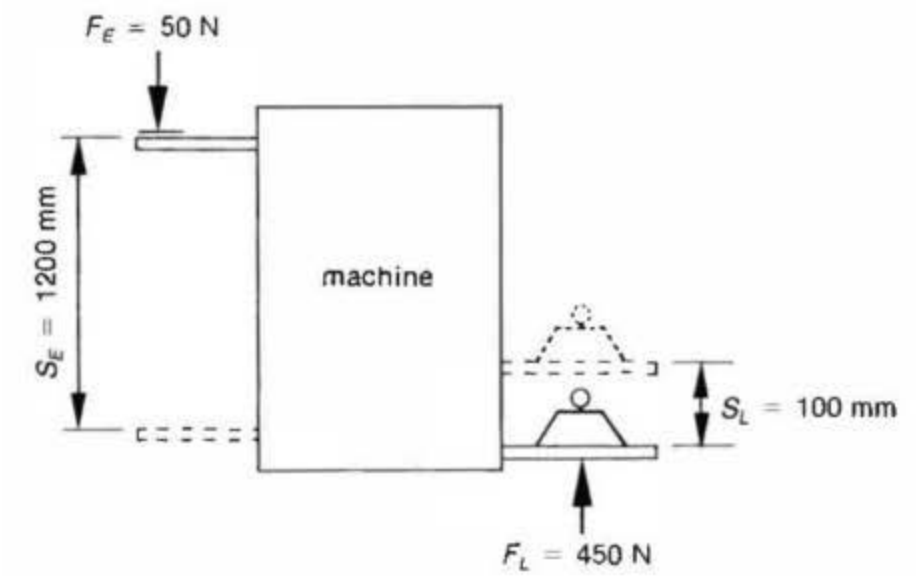
Calculate the theoretical and frictional efforts.

Example	Figure	Velocity ratio	Theoretical effort	Frictional effort

GIVE FEEDBACK

OK

Calculate the efforts of a machine



Example	Figure	Velocity ratio	Theoretical effort	Frictional effort

GIVE FEEDBACK

OK

Calculate the efforts of a machine

Velocity ratio:

$$VR = \frac{S_E}{S_L}$$
$$= \frac{1{,}200 \text{ mm}}{100 \text{ mm}}$$
$$= 12$$

Example	Figure	Velocity ratio	Theoretical effort	Frictional effort

GIVE FEEDBACK

OK

Calculate the efforts of a machine

Theoretical effort:

$$\begin{aligned} F_{Th} &= \frac{F_L}{\text{VR}} \\ &= \frac{450\ \text{N}}{12} \\ &= 37.5\ \text{N} \end{aligned}$$

Calculate the efforts of a machine

Frictional effort:

$$\begin{aligned} F_F &= F_E - F_{Tk} \\ &= 50\ \text{N} - 37.5\ \text{N} \\ &= 12.5\ \text{N} \end{aligned}$$

Example	Figure	Velocity ratio	Theoretical effort	Frictional effort

GIVE FEEDBACK

OK

Given that the velocity ratio is 12, calculate the theoretical effort.

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 simple machine requires an effort of 40 N moving through a distance of 900 mm to produce a load force of 200 N that moves through 150 mm.

SMALL | MEDIUM | LARGE

Type your answer in the box.

The velocity ratio for this machine is _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

A simple machine requires an effort of 40 N moving through a distance of 900 mm to produce a load force of 200 N that moves through 150 mm.

SMALL MEDIUM LARGE

A simple machine requires an effort of 40 N moving through a distance of 900 mm to produce a load force of 200 N that moves through 150 mm.

SMALL | MEDIUM | LARGE

Given that the theoretical effort is 33.33 N, calculate the frictional effort. (Answer correct to two decimal places.)

Clear | ? | Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

Given that the velocity ratio is 6, calculate the theoretical effort. (Answer correct to two decimal places.)

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 simple machine requires an effort of 75 N moving through a distance of 1.2 m to produce a load force of 750 N that moves through 100 mm.

SMALL | MEDIUM | LARGE

Type your answer in the box.

The velocity ratio for this machine is [ ].

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

A simple machine requires an effort of 75 N moving through a distance of 1.2 m to produce a load force of 750 N that moves through 100 mm.

SMALL MEDIUM LARGE

A simple machine requires an effort of 75 N moving through a distance of 1.2 m to produce a load force of 750 N that moves through 100 mm.

SMALL | MEDIUM | LARGE

Given that the theoretical effort is 62.5 N, calculate the frictional effort.

Clear | Undo | ?

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

The meaning of the law of a machine

The **law of a machine** is an equation which expresses the relationship between load (F_L) and effort (F_E).

The law applied to a particular machine can be used to predict the effort required to move any load by the machine.

GIVE FEEDBACK

OK

Type your answer in the box.

The **law of a machine** is an equation which expresses the relationship between _____ (F_L) and _____ (F_E).

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The equation of the law of a machine

In many cases the law of a machine, when plotted as a graph of effort against load (with effort as the vertical axis and load as the horizontal axis), is a straight line.

Therefore its mathematical equation is linear in form.

$$F_E = a F_L + b$$

where:

F_E is the effort

F_L is the load

a is the slope of the graph

b is the value of F_E where the graph cuts the F_E axis

After the constants have been determined for a particular machine, the law of the machine can be used to predict the effort required to move any load by the machine.

GIVE FEEDBACK

OK

Match each of the symbols from the equation $F_E = a\,F_L + b$ with the correct description.

Drag statements on the right to match the left.

F_E	Effort
a	Slope of the graph
F_L	Load
b	The value where the graph cuts the F_E axis

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

A machine was tested under different loads and the following efforts were recorded for each of the loading conditions:

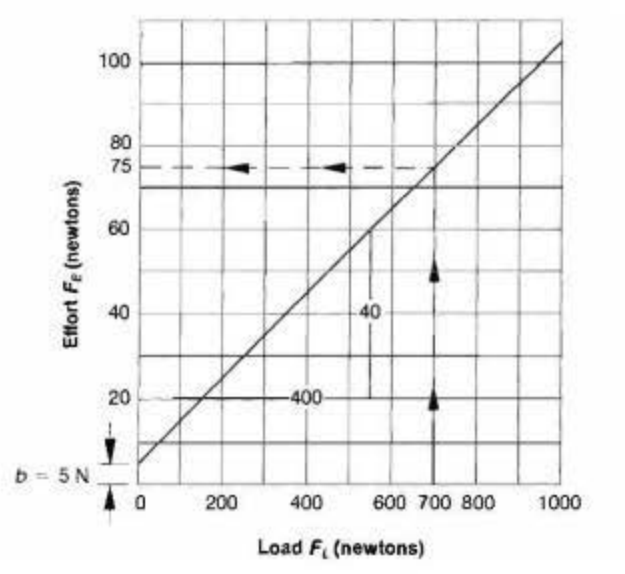
Load F_L (N)	0	200	400	600	800	1000
Effort F_E (N)	5	25	45	65	85	105

Plot the load–effort graph and determine the law of the machine.

GIVE FEEDBACK

CONTINUE >

Solution


100
80
75
60
40
20
b = 5 N
Effort F_E (newtons)
40
400
0
200
400
600
700
800
1000
Load F_L (newtons)

In the above load–effort graph, the line cuts the effort axis at $F_E = 5$. This is the value of b.

The slope is: $a = \dfrac{\Delta F_E}{\Delta F_L}$

Choosing appropriate values gives: $a = \dfrac{\Delta F_E}{\Delta F_L} = \dfrac{40}{400} = 0.1$

Therefore the law of the machine is:

$$F_E = 0.1\,F_L + 5$$

Type your answer in the box.

A machine was tested under different loads and the following efforts were recorded for each of the loading conditions:

Load F_L (N)	0	100	200	300	400	500
Effort F_E (N)	12	47	82	117	152	187

From the graph of these values, the law of this machine is F_E = _____ F_L + _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

A machine was tested under different loads and the following efforts were recorded for each of the loading conditions:

Load F_L (N)	0	20	40	60	80	100
Effort F_E (N)	3	7	11	15	19	23

From the graph of these values, the law of this machine is F_E = _____ F_L + _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Predict the effort required to move a load by a machine—Example

Example

A machine was tested under different loads and the law of the machine was found to be $F_E = 0.1\,F_L + 5$.

Use the law of this machine to estimate the effort required to move a load of 700 N.

GIVE FEEDBACK

CONTINUE >

Example

A machine was tested under different loads and the law of the machine was found to be $F_E = 0.1\,F_L + 5$.

Use the law of this machine to estimate the effort required to move a load of 700 N.

Solution

For a load of 700 N the effort required is:

$$\begin{aligned} F_E &= 0.1 \times F_L + 5 \\ &= 0.1 \times 700 + 5 \\ &= 75\ \text{N} \end{aligned}$$

The law of a given machine is shown below.

Determine the effort required to deliver a load force of 120 N.

$$F_E = 0.2 \cdot 120\ \text{N} + 3\ \text{N}$$

Clear

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

The law of a given machine is shown below.

Determine the effort required to deliver a load force of 280 N.

$$F_E = 0.35 \cdot 280\ \text{N} + 12\ \text{N}$$

Clear

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

The limiting efficiency of a machine

If we calculate and plot machine efficiency for experimental results under different load conditions, we find that the efficiency increases with the load.

However, the increase is not proportional to the load.

There is a limiting value to the efficiency of a particular machine, which is always less than 100 per cent.

This value is known as the **limiting efficiency**.

Type your answer in the box.

The efficiency of a particular machine is always less than _____ %.

The efficiency of the machine tends towards a value that is known as the _____ efficiency.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The value of the limiting efficiency can be found by combining the law of a machine with the definition of efficiency, as follows:

$$\eta = \frac{\text{MA}}{\text{VR}} = \frac{F_L}{F_E \times \text{VR}}$$

Also:

$$F_E = a\,F_L + b$$

GIVE FEEDBACK

CONTINUE >

Substitute:

$$\eta = \frac{F_L}{(a F_L + b)\mathrm{VR}} = \frac{1}{\left(a + \frac{b}{F_L}\right)\mathrm{VR}} = \frac{1}{a\,\mathrm{VR} + \left(\frac{b\,\mathrm{VR}}{F_L}\right)}$$

As the load F_L increases, the term $\frac{b \, \mathrm{V} \, \mathrm{R}}{F_L}$ becomes smaller, tending towards zero at very large loads, when the limiting efficiency becomes:

$$\eta = \frac{1}{a \, \mathrm{VR}}$$

Which of the following is the correct equation for the limiting efficiency of a machine?

Click the correct answer.

$\eta = \frac{1}{a\ VR}$

$\eta = a\ VR$

$\eta = a + VR$

$\eta = a - VR$

$\eta = \frac{a}{VR}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match each of the symbols from the equation $\eta = \frac{1}{a\ VR}$ with the correct description.

Drag statements on the right to match the left.

η	Limiting efficiency
a	Slope of the law of the machine
VR	Velocity ratio

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the limiting efficiency of a machine

The test results for a machine with a velocity ratio of 12 are shown below.

For each of these values, calculate the efficiency and show that it tends towards a limiting value at large loads.

Load F_L (N)	0	200	400	600	800	1000
Effort F_E (N)	5	25	45	65	85	105

Calculate the limiting efficiency of a machine

$$\eta_1 = \frac{F_L}{F_E\,\text{VR}} = \frac{0}{(5)(12)} = 0\%$$

$$\eta_2 = \frac{200}{(25)(12)} = 66.7\%$$

$$\eta_3 = \frac{400}{(45)(12)} = 74.1\%$$

$$\eta_4 = \frac{600}{(65)(12)} = 76.9\%$$

$$\eta_5 = \frac{800}{(85)(12)} = 78.4\%$$

$$\eta_6 = \frac{1{,}000}{(105)(12)} = 79.4\%$$

Example	Efficiency calculations	Limiting efficiency	Efficiency graph

GIVE FEEDBACK

OK

Calculate the limiting efficiency of a machine

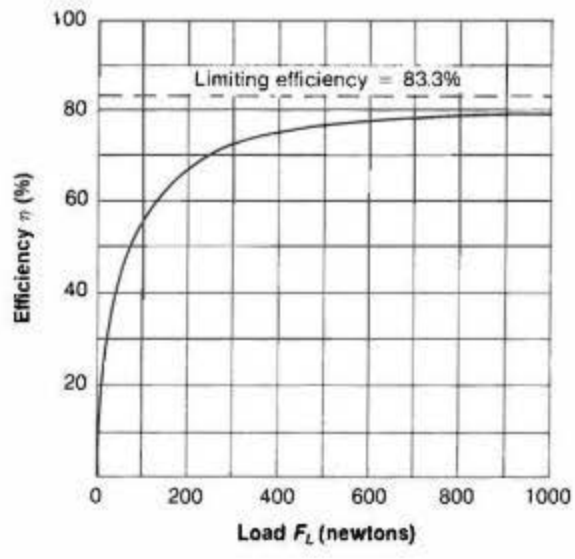
$$\eta = \frac{1}{a\,\mathrm{VR}}$$
$$= \frac{1}{(0.1)(12)}$$
$$= 83.3\%$$

GIVE FEEDBACK

OK

Calculate the limiting efficiency of a machine

This relationship is best illustrated by a graph as shown below.



Example	Efficiency calculations	Limiting efficiency	Efficiency graph

GIVE FEEDBACK

OK

Type your answer in the box.

The law of a given machine is $F_E = 0.35F_L + 12$ and its velocity ratio is 4.5.

The limiting efficiency of this machine is [ ] % (correct to one decimal place).

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

The law of a given machine is $F_E = 0.2\,F_L + 3$ and its velocity ratio is 7.

The limiting efficiency of this machine is [ ] % (correct to one decimal place).

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA