



**DYNAMICS
FUNDAMENTALS
CP1505**

Inspiring The Next
Generation Of Engineers

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Contents

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WORKSHEETS

Worksheet 1 – The Flywheel

A flywheel is a heavy shaft-mounted disc which stores energy when it rotates.

For centuries, it has been used to store energy and to smooth rotation.

Today, flywheels, sealed in vacuum enclosures and rotating on magnetic bearings, are highly efficient at storing the output of intermittent energy sources, such as solar panels and wind turbines.



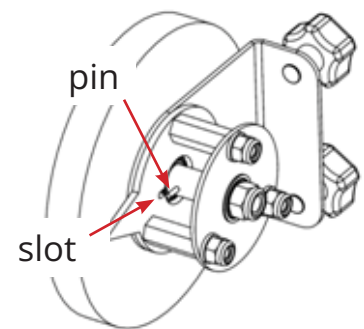
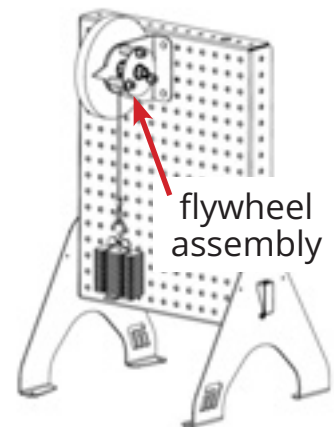
Over to you

Setting up the apparatus:

The diagram shows the arrangement for this investigation.

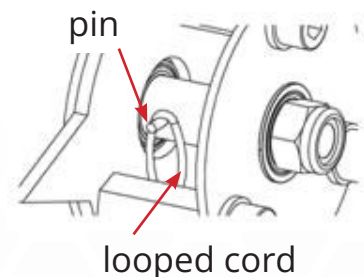
To construct the flywheel assembly:

- Slide the shaft through the holes in the main bracket.
- Rotate the shaft so that the pin can pass through the slot in the main bracket.
- Place the washer in position to hold the flywheel shaft.
- Tighten the nut on the shaft to keep the flywheel in place.



The flywheel assembly is then positioned at the top and in the middle of the work panel, to allow the maximum 'drop' for the weight.

- Place the empty mass hanger plus four slotted masses, a total mass of 100g (0.1kg), on the bench directly below the centre of the flywheel assembly.
- Make a cord 350mm long with loops on each end.
- Place one loop over the pin on the flywheel shaft.
- Connect the mass hanger to the lower loop.

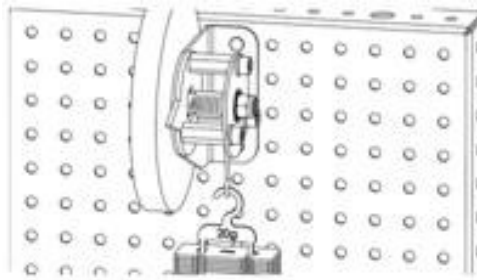


WORKSHEETS

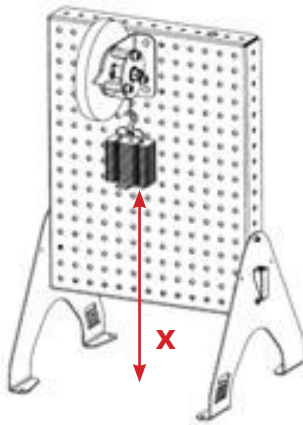
Worksheet 1 – The Flywheel

Over to you

- Turn the flywheel to coil the string around the shaft and raise the mass hanger to just below the flywheel assembly.



- Measure height, **x**, of the empty mass hanger above the bench top.



- Release the mass hanger and time how long it takes to reach the bench.
- Repeat this three times and calculate the average time.
- Record these measurements in the Student Handout.
- Increase the mass of the hanger to 200g (0.2kg).
- Repeat the process, timing three falls as before and working out the average.
- Record these measurements in the Student Handout.
- Increase the mass of the hanger in two further 100g steps to a maximum of 400g (0.4kg).
- Repeat the process described above and record the measurements in the Student Handout.

WORKSHEETS

Worksheet 1 – The Flywheel

So what

From equations of motion: $s = \frac{1}{2} a \times t^2$
 where: s = distance travelled,
 a = acceleration
 t = time of flight
 In this case: $s = x$
 t = *average* time of flight
 and so, the acceleration of mass hanger,
 $a = 2 \times x / t^2$

The force needed to produce this acceleration is given by:

$$F = m \times a \quad \text{where} \quad m = \text{mass of falling hanger.}$$

This force comes from the gravitational pull on the hanger, i.e. its weight W , where

$$W = m \times g \quad \text{where} \quad g = \text{acceleration due to gravity} = 9.8 \text{ m.s}^{-2}$$

The remainder of this weight generates a torque, τ , that increases the angular acceleration of the flywheel.

In other words, $\tau = [(m \times g) - (m \times a)] \times r$ where r = radius of the shaft = 8mm

The angular acceleration of the flywheel, α , is given by the equation:

$$\alpha = a / r$$

It is related to the torque by the equation:

$$\tau = I \times \alpha \quad \text{where} \quad I = \text{moment of inertia of the flywheel}$$

This equation predicts that a graph of torque, τ , vs angular acceleration, α , will produce a straight line with a gradient of I , the moment of inertia of the flywheel.

- In the Student Handout, use the grid provided to plot a graph of torque, τ , vs angular acceleration, α and use it to obtain a value for the moment of inertia of the flywheel.
- Then calculate the theoretical value of this moment of inertia and use that to calculate the final angular velocity of the flywheel in rad.s^{-1} and revs.s^{-1} .

In practice:

A flywheel's capacity to store energy depends on its mass and its rotational speed. Modern flywheels are made of lightweight, high strength materials because while doubling its mass doubles its kinetic energy, doubling its rotational speed quadruples it.

WORKSHEETS

Worksheet 2 – Controlling Friction

Friction - sometimes a blessing, sometimes a curse!
Without it:

- we couldn't walk or run;
- cars wouldn't move and if they did, wouldn't stop;
- trains would slip endlessly on railway lines;
- ladders would slide down walls.

However, because of it:

- vehicles use more fuel;
- the range of aircraft is reduced;
- bearings in machinery heat up and wear out.

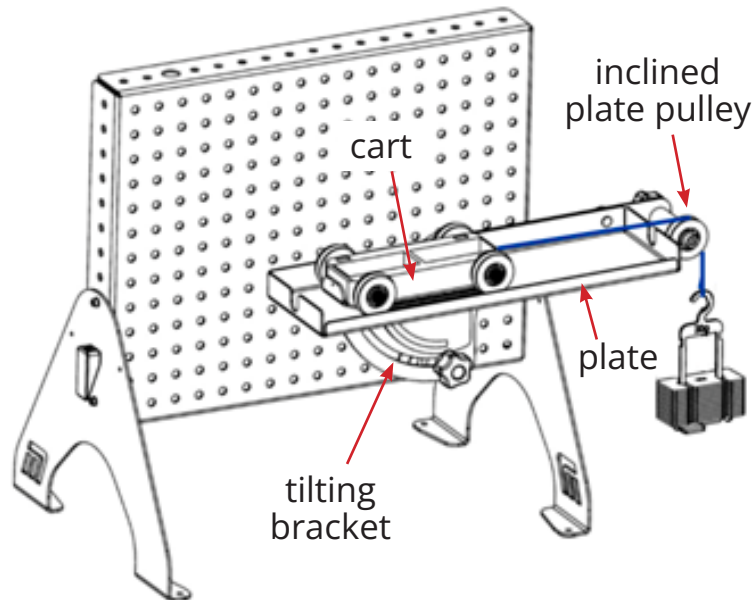


1. Types of Friction

Over to you

Setting up the apparatus:

The diagram shows the apparatus arrangement for this investigation.



To construct the inclined plane assembly:

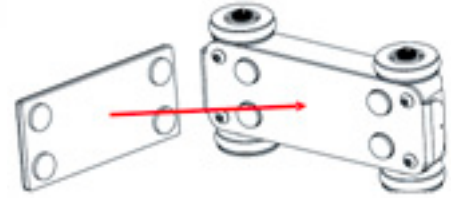
- fasten the plate to the tilting bracket with the two bolts;
- fasten the pulley to the end of the tilting bracket;
- connect the inclined plane assembly to the work panel in the position shown;
- adjust the cord attached to the cart by creating a loop just below the pulley.

WORKSHEETS

Worksheet 2 – Controlling Friction

Over to you

- Adjust the inclined plane until it is horizontal (i.e. the pointer indicates zero degrees) and clamp it in position.
- Attach the metal plate to the bottom of the cart using the Velcro tabs, as shown opposite.
- Place the cart on the empty plate with its wheels in contact with the plate.
- Add the empty mass hanger to the loop hanging over the pulley.
- Place slotted masses, one at a time, on the mass hanger until the cart starts to move.
(This requires a very steady hand! Tap the work panel gently to remove the effect of static friction!)
- In the Student Handout, record the weight needed to start the cart moving. This indicates the frictional force holding the cart stationary.
(If the cart moves when the mass hanger is empty, record this as " $<0.2\text{N}$.)
- Now repeat the process with the car turned upside down, i.e. metal plate in contact with metal plate, a metal / metal contact. Notice that the mass of the cart remains unchanged.



Challenge

Repeat the experiment using different materials attached to the cart and different materials inside the plate. Hence explore the frictional forces between the following combinations:

wood/wood wood/metal wood/rubber metal/metal metal/rubber rubber/rubber

So what

The results show some of the factors affecting frictional forces between surfaces in contact. Once the cart starts to move, it accelerates, since the frictional force it experiences while moving, called sliding friction, is smaller than the one it experienced when stationary, called static friction. This means that once an object is moving, it's much easier to keep it moving. The size of the frictional forces depends on the materials in contact.

Controlling friction is of huge importance in applications such as automotive engineering.



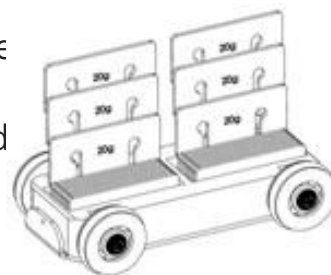
WORKSHEETS

Worksheet 2 – Controlling Friction

1. Static and Sliding Friction

Over to you

- The apparatus is set up as in the previous investigation, but this time, the materials remain the same, but the mass of the cart is changed to see what effect this has.
- Clamp the plate in a horizontal position and place the wooden floor in it.
- Attach the wooden plate to the bottom of the cart using the Velcro tabs.
- Weigh the cart on the force meter and record its weight in the Student Handout.
- Place the cart on the plate so that the wooden plate is in contact with the wooden floor. The floor provides an upward reaction force equal to the weight of the cart, acting normal to the surface - i.e. the *normal force* is the weight of the cart.
- Add the empty mass hanger to the loop hanging over the pulley.
- Place slotted masses on the mass hanger, one at a time, until the cart starts to move.
- At this point, the weight on the hanger equals the *frictional force* between cart and floor. (This time, do not tap the work panel. Take care not to disturb the bench in any way.)
- In the Student Handout, record the **weight** of the hanger needed to start the cart moving.
- Now increase the weight of the cart by 2N by placing ten slotted masses in it.
- Repeat the procedure and record the hanger weight needed to start the cart moving now.



So what

- Static friction, more commonly known as 'stiction', is caused by attractive forces between the molecules of the materials placed in close contact.
- Surface roughness increases this effect.
- The size of the frictional force depends on the coefficient of static friction, μ_s , between the materials. This is the ratio of the frictional force to the normal force.
- Use your results to calculate two estimates for μ_s between the wooden plates.

Challenge

- Repeat the experiment for different pairs of materials to determine the coefficient of static friction between them.
- Carry out a more extensive investigation into the coefficient of static friction between two materials by progressively adding more and more weight to the cart and measuring the static frictional force each time. A graph of the normal force (weight of the cart) against the static frictional force (hanger weight needed to start it moving) should produce a straight line graph whose gradient gives the coefficient of static friction between the two materials.

WORKSHEETS

Worksheet 2 – Controlling Friction

3. Angle of Friction

Over to you

- The apparatus is the same as in previous investigations.
- Adjust the plate until it is at an angle of 5° to the horizontal.
- Remove the wooden friction plate from the cart and replace it with the metal one.
- Place the cart at the top of the slope with the rope stored inside it. *There is no mass hanger attached this time.*
- Gently tap the work panel to remove the effect of static friction.
- Slowly and very carefully, increase the angle of the plate until the cart slides smoothly down it.
- In the Student Handout, record the angle, θ , at which this happens and hence calculate the coefficient of *sliding* friction, μ_k .

So what

The minimum angle at which the cart slides down the plate can be used to determine the coefficient of sliding friction, μ_k .

The diagrams show the forces acting on the cart:

- its weight, W ;
- the normal (i.e. perpendicular) reaction, R_N ;
- the parallel reaction, R_p due to friction.

The middle diagram shows the result of applying the triangle of forces rule. This creates the triangle shown at the bottom and trigonometry leads to the results:

$$R_N = W \cos \theta \text{ and } R_p = W \sin \theta$$

The coefficient of sliding friction, μ_k , is defined by:

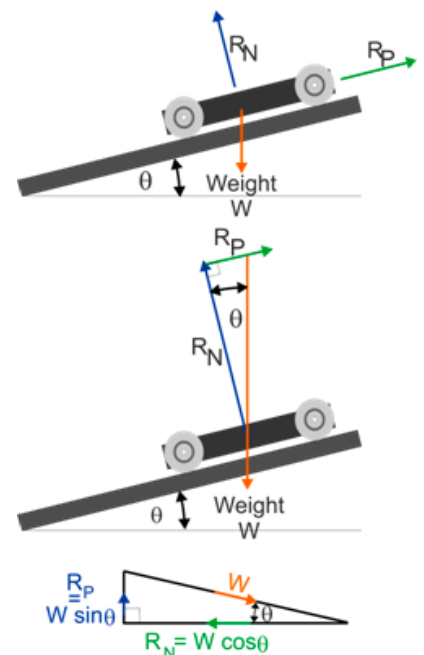
$$\mu_k = \frac{R_p}{R_N} = \frac{W \sin \theta}{W \cos \theta} = \frac{\sin \theta}{\cos \theta} = \tan \theta$$

Your results can be used to work out the coefficient of sliding friction between metal surfaces.

Notice that the weight of the cart does not affect the result in this test because it cancels out in the equation for the coefficient of friction.

Challenge

Repeat the experiment for different pairs of materials and hence determine the coefficient of sliding friction between them.



WORKSHEETS

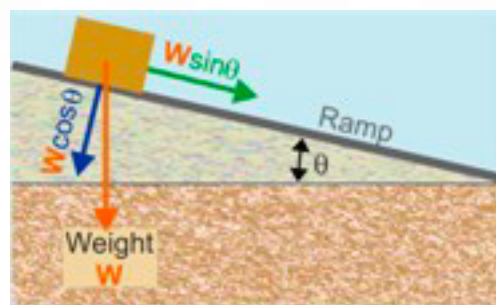
Worksheet 3 – Inclined Forces

When an object sits on a ramp, its weight is trying to do two things:

- press it into the ramp's surface;
- push it down the ramp.

The diagram shows that the forces involved depend on the angle, θ , of the ramp. The force pressing into the surface is $W \cos \theta$ and that trying to push it down the ramp is $W \sin \theta$, where W is the weight of the object.

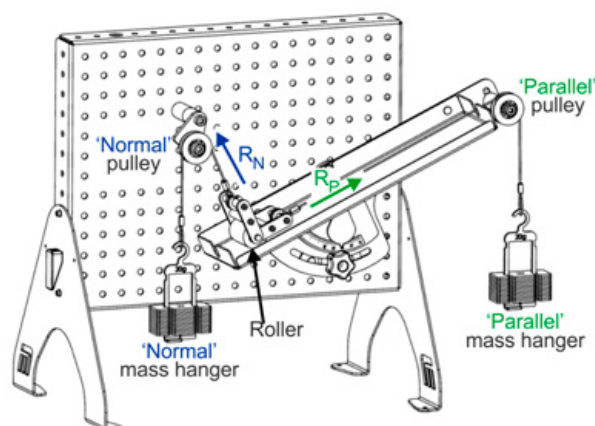
The aim of this investigation is to measure these two components of the object's weight.



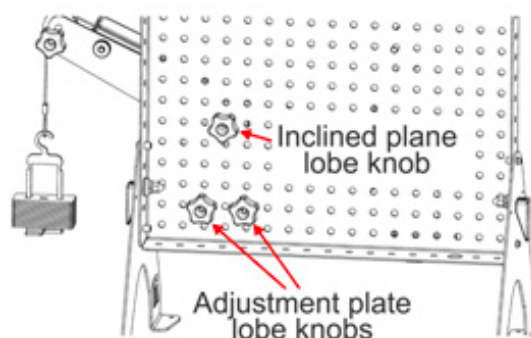
Over to you

Setting up the apparatus:

The diagram shows the setup for this investigation.



- Clamp the work panel in 'landscape' orientation.
- Fasten the centre of the plate four holes from the right hand edge of the work panel.
- With the plate horizontal, fix the adjustment plate assembly four holes lower, so that the two lobe knobs are separated by one column of holes.
- Attach the 'Normal' pulley in the position shown.
- Check that the 'Parallel' pulley is sitting at the bottom of the adjustment slot so that the string sits parallel to the surface of the plate.



WORKSHEETS

Worksheet 3 – Inclined Forces

Over to you

- Weigh the roller assembly on the force meter and record it in the Student Handout.
- Tilt the plate to an angle of 20° and tighten the lobe nuts to hold it there.
- Place the roller at the bottom of the slope and hang the two cords over the pulleys. The pulleys and cords should line up as in the diagram.
- Hang the 'Normal' mass hanger and the 'Parallel' mass hangers in place.
- Slowly add weights to each hanger until the roller just lifts off the plane and the two strings connected to the roller form a right angle.
- Use the smaller value weights to make fine adjustments.
At this point, the 'Normal' force, R_N , is equal to the weight of the 'Normal' mass hanger and the 'Parallel' force, R_p , is equal to the weight of the other hanger.
- Record both hanger weights in the Student Handout.
- Repeat this procedure for plate inclinations of 30° , 40° and 50° , recording all results in the Student Handout.
(As the inclination increases, the 'Normal' pulley may have to be moved to keep the mass hanger away from the plate and keep the looped string perpendicular to it.)



So what

- Calculate the theoretical values for the 'Normal' and 'Parallel' components and hence complete the table in the Student Handout. (The roller weighs 1.8N)
- Compare these values with those measured experimentally .
- Try to explain any discrepancies by considering possible sources of error, and record your ideas in the space provided in the Student Handout.

As the inclination of the plate increases, more of the weight of the object is transferred to the 'Parallel' force, trying to push the object down the slope, and less to the 'Normal' component, pushing it into the surface.

When the plate is vertical, the 'Normal' component is zero and the 'Parallel' component equals the full weight of the object.

When the plate is horizontal, the situation is reversed. There is no force trying to push the object along the plate.

Not a surprising result for pedestrians!

After all, the steeper the slope, the more likely you are to slide down it!

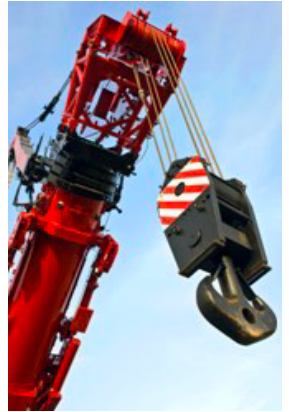
WORKSHEETS

Worksheet 4 – Pulley Systems

A pulley is a simple machine, designed to make a task easier. It can change the direction in which a force needs to act. It may make it easier to lift an object.

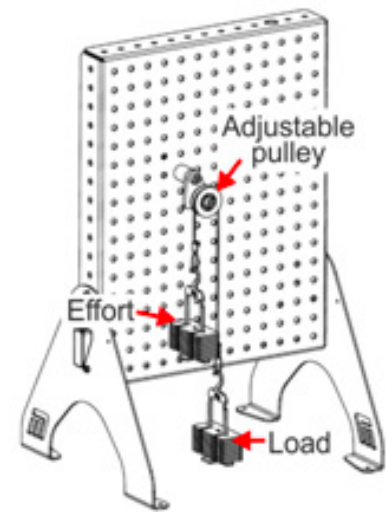
They have been used for centuries, to raise containers of water, hoist sails on sailing ships, perhaps even lift the stones that make up the great pyramids in Egypt.

However, a pulley cannot generate energy. In reality, it wastes it but in doing so make the task easier to perform. Apart from friction between moving parts, it usually involves lifting the pulley itself and the cables passing over it, all of which takes energy.



1. A change in direction:

The diagram shows the setup used in the next investigation:



Over to you

- Clamp the work panel in 'portrait' orientation.
- Fix the adjustable pulley as shown in the diagram.
- Arrange two empty mass hangers, connected by a cord passing over the pulley.
- Add four slotted weights to the right-hand hanger, giving the 'Load' a total mass of 100g (i.e. a weight of 1N).
- Slowly increase the weight of the 'Effort' mass hanger, from 0.2N (one slotted mass) to 1.2N (five slotted masses).
- In the Student Handout, describe what happens as you do so.
- Remove the 'Effort' mass hanger, while holding onto the cord. Notice how hard you need to pull to raise the load.

So what

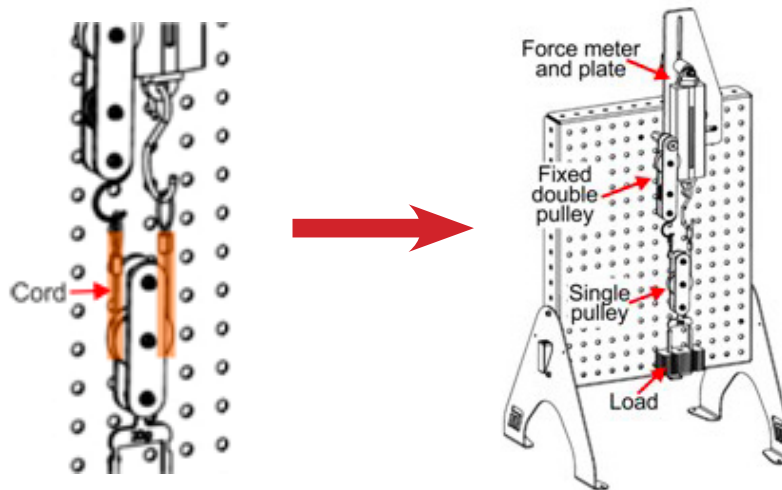
This arrangement creates no force multiplication (i.e. its mechanical advantage = 1), though, equally, the velocity ratio is 1 - both load and effort travel the same distance. There may be an advantage in using this approach where a worker is hoisting a load up a building. The worker's bodyweight can be used as part of the effort.

WORKSHEETS

Worksheet 4 – Pulley Systems

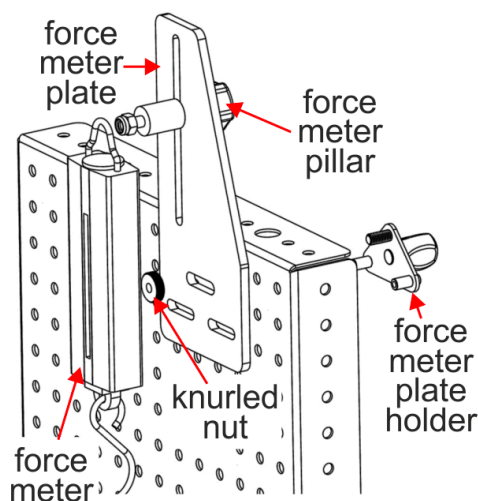
2. Force multiplication:

The setup is changed to the one shown below:



Building the force meter assembly:

The diagram below shows the force meter plate and fixtures:



- Secure the force meter plate holder to the work panel in the chosen position, with the threaded stud uppermost.
- Place the force meter plate over the plate holder and fix it in place using the knurled nut.
- Attach the force meter pillar as shown in the diagram.
- Hang the force meter on the rod protruding from the force meter pillar.

WORKSHEETS

Worksheet 4 – Pulley Systems

2. Force multiplication:

- Place the fixed double pulley assembly in the middle near the top of the work panel.
- Then position the force meter and plate just to the side of the pulleys.
- Attach an S-hook to the bottom of the double pulley, thread the cord through the single pulley and hang the loops over the hooks, as shown in the detail above.
- Hook an empty mass hanger onto the bottom of the single pulley.
- 'Zero' the force meter to eliminate the weights of the pulley and empty hanger.
- Add five slotted weights to the empty mass hanger to increase the load by 1N.
- Record the reading on the force meter, the effort in this case, in the Student Handout.
- Increase the load by adding two more slotted weights, 0.4N and record the new effort.
- Continue in this way until the load reaches 3N.
- Complete the table by calculating the mechanical advantage for each value of load.
- Unhook the force meter and instead pull up on the cord to see how hard you need to pull to raise the load.

So what

This arrangement shows that a pulley that can move, rather than be fixed, like the one in the previous experiment, can offer force multiplication - here only half the effort is needed to lift the same load. This equates to a mechanical advantage of 2. However, there can be no energy multiplication!

In other words:

work done by effort = work done by load in an ideal system,
i.e. effort x distance moved by effort = load x distance moved by load

In real systems, the work done by the effort is always larger than that done by the load,

and effort x effort distance = load x load distance + work done to overcome friction.

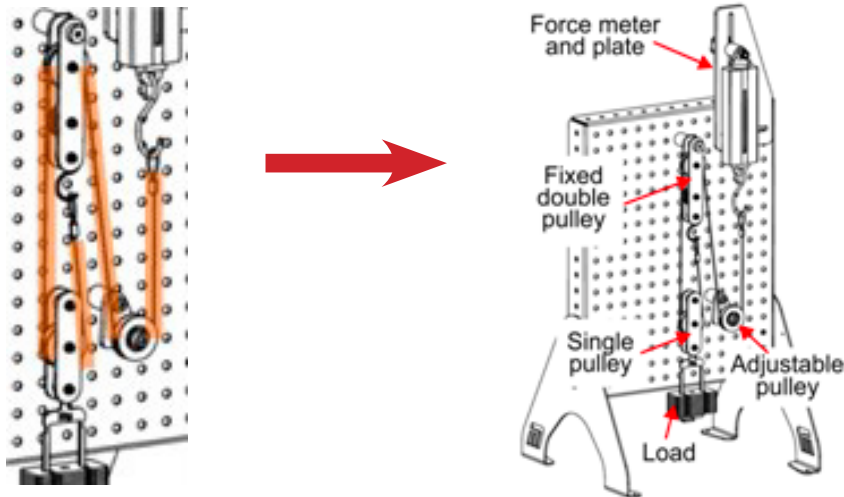
In other words, the energy efficiency is less than 100%

WORKSHEETS

Worksheet 4 – Pulley Systems

3. Force multiplication - the same but different:

- Now modify the setup slightly by moving the force meter and plate to the right to allow room for the adjustable pulley:



- Fix the adjustable pulley directly below the force-meter near the bottom of the work panel.
 - The procedure is exactly the same as in the previous experiment:
 - 'Zero' the force meter to eliminate the weights of the pulleys and empty hanger.
 - Add slotted weights to increase the load by 1N.
 - Record the effort reading on the force meter in the Student Handout.
 - Increase the load by 0.4N and record the new effort.
 - Continue in this way until the load reaches 3N.
 - Complete the table in the Student Handout by calculating the mechanical advantage for each value of load.
- Finally, unhook the force meter and instead pull up on the cord to see how hard you need to pull to raise the load.

So what

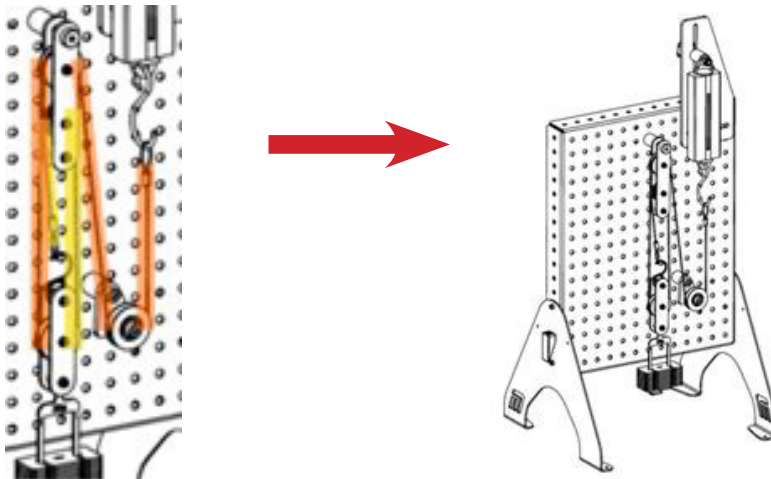
This setup looks more potent, but it still has a mechanical advantage of 2. The adjustable pulley means that the direction of the effort can be changed, often an advantage in that it allows the system designer more flexibility.

WORKSHEETS

Worksheet 4 – Pulley Systems

4. Force multiplication - even bigger:

- The hardware is set up as in the last experiment but the stringing is different. Notice that, this time, five strings pass between and around the pulleys. Last time, it was four.



- The extra string is the loop over the lower pulley on the fixed pulley assembly, connected to the top of the free single pulley, (highlighted in yellow).
- The procedure is exactly the same as before:
 - 'Zero' the force meter to eliminate the weights of the pulleys and empty hanger.
 - Add slotted weights to increase the load by 1N.
 - Record the effort reading on the force meter in the Student Handout.
 - Increase the load by 0.4N and record the new effort.
 - Continue in this way until the load reaches 3N.
 - Complete the table in the Student Handout by calculating the mechanical advantage for each value of load.
- Finally, unhook the force meter and instead pull up on the cord to see how hard you need to pull to raise the load.

So what

The mechanical advantage of this arrangement is bigger and so a heavier weight can be lifted with less effort.

The bigger number of loops causes more friction and so the efficiency of the system is lower.

WORKSHEETS

Worksheet 5 – The Toggle Mechanism

All mechanical systems have design limits beyond which they should not pass - just ask the athlete in the photograph.

This applies to dynamics as well. This investigation looks at the performance of a spring-loaded toggle mechanism. Some applications, such as toggle switches, are designed to operate at these limits.

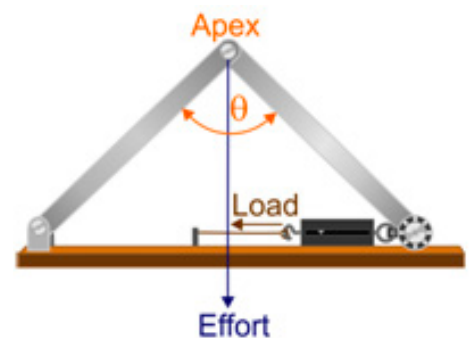


The idea:

The diagram illustrates the principle.

The force meter spring exerts a force that prevents the mechanism from collapsing. Should this force, known as the load in this case, increase, the apex of the toggle mechanism starts to drop and angle θ increases.

Increasing the effort counteracts this (i.e. reduces angle θ).

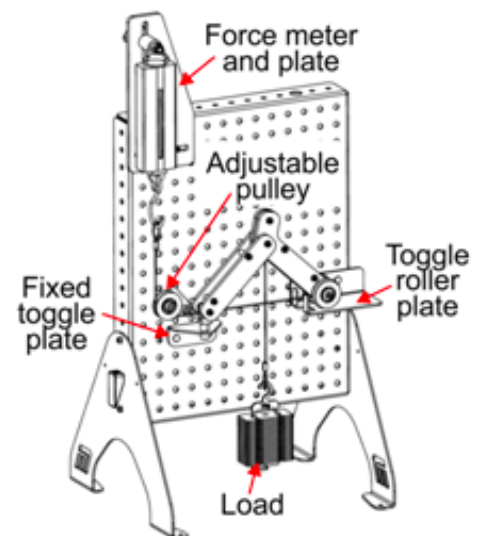


Over to you

Setting up the apparatus:

The diagram shows the setup for this investigation:

- Fasten the force meter and plate in the top left corner of the panel, with the screw placed four rows down from the top and one row in from the left-hand side.
- Position the adjustable pulley directly below the force meter with its screw in 'row 8', 'column 3', shown in the detail diagram. This needs to be fastened tightly.
- The fixed toggle plate is attached with screws in 'row 4', 'columns 3 and 5'.
- The toggle roller plate is placed with the screws in 'row 6' columns 11 and 13'.
- Loop the cord from the toggle roller onto the force meter hook, via the adjustable pulley.
- Allow the other cord to hang down from the centre of the toggle mechanism.
- Adjust the first cord so that the apex of the mechanism forms roughly a right-angle, when the toggle rollers are close to, but not touching, the end stops of the toggle roller plate.



WORKSHEETS

Worksheet 5 – The Toggle Mechanism

Over to you

- Place an empty mass hanger on the cord hanging down from the centre of the toggle mechanism.
- Press down gently on the apex of the toggle. The angle θ increases. As it approaches 180° , the mechanism 'snaps' downwards and locks - the toggle 'snap' action.
- 'Zero' the force meter.
- Gently, add two slotted masses (i.e. add 0.4N) to the mass hanger.
- Tap the work panel gently until the force meter gives a consistent reading.
- Record the force meter reading in the corresponding row of the 'load' column in the table in the Student Handout.
- Increase the weight on the hanger by 0.4N (another two slotted masses) and repeat the process.
- Continue in this way until the weight added to the hanger is 3.2N.
- Repeat the series of readings to improve overall accuracy.
- Use these results with the axes and grid provided in the Student Handout to plot a graph of load against effort. (Do not expect a linear result!)

Challenge

Investigate the effort needed to make the mechanism 'snap'.

So what

The distance that the apex of the mechanism falls vertically is larger than the distance the toggle rollers move horizontally. This behaviour implies that the system offers a mechanical advantage.

The output force increases as the effort force increases. This means that a small increase in the effort can produce a large change in the output force when the toggle mechanism is nearing the end of its possible movement.

The mechanism 'snaps' into a locked position when it goes over the 'top dead centre' (TDC) point. Thereafter, the toggle mechanism exerts a constant output force.

This mechanism has a range of useful applications, from toggle switches through car jacks and oil-well pumps, to rock-crushing equipment.





STUDENT HANDOUT



STUDENT HANDOUT

Worksheet 1 - The Flywheel

Distance **x** above bench top = mm = m

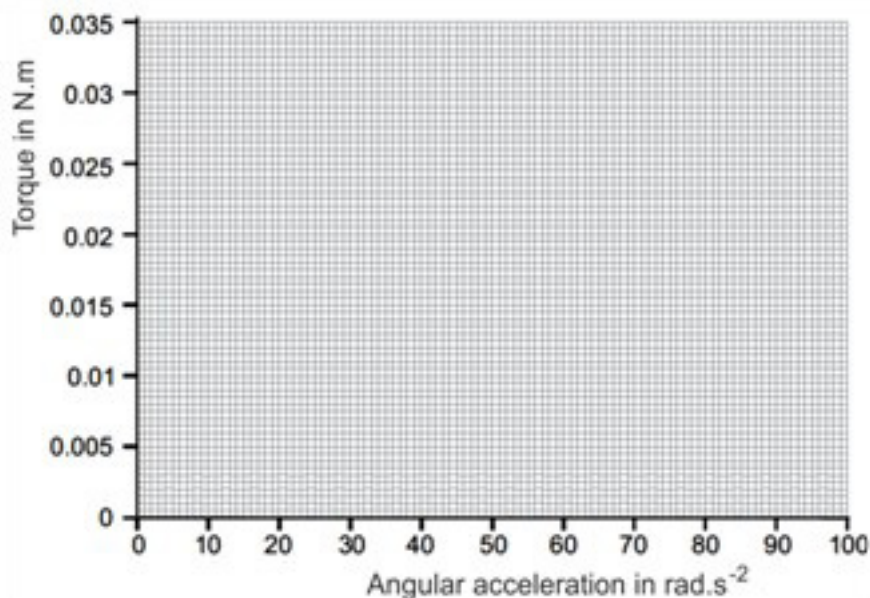
Falling mass in kg	Flight time			
	measurement 1 in s	measurement 2 in s	measurement 3 in s	average in s
0.1				
0.2				
0.3				
0.4				

Use your measurements to complete the following table:

Falling mass m in kg	Average flight time t in s	Linear acceleration a in m.s^{-2}	Angular acceleration in rad.s^{-2}	(m.g - m.a) in N	Torque in N.m
0.1					
0.2					
0.3					
0.4					

Graph of torque vs angular acceleration:

Show your measurements as small crosses. Use them as a guide to position a straight line passing through the origin.



Moment of inertia of flywheel = gradient of graph =

STUDENT HANDOUT

Worksheet 1 - The Flywheel

Calculate the theoretical moment of inertia for cylinder, like the flywheel using:

$$I = \frac{M \times R^2}{2} \quad \text{where} \quad \begin{array}{ll} M = \text{mass of flywheel} & = 1.45\text{kg} \\ R = \text{radius of flywheel} & = 65\text{mm} = 0.065\text{m} \end{array}$$

.....

Calculated value for the moment of inertia, **I**, is kg.m²

The gravitational potential energy lost by the falling mass hanger, **E_p** is given by:

$$E_p = m \times g \times x$$

Calculate the gravitational potential energy lost by the 400g mass hanger as it fell:

$$= \dots\dots\dots \text{J}$$

This is converted into kinetic energy of rotation, **E_k** of the flywheel.

Calculate the theoretical final angular velocity of the flywheel using the formula:

$$E_k = 1/2 I \omega^2$$

.....

Use the fact that there are **2π** radians in one revolution to convert this to show the rotational speed of the flywheel in revs / second.

.....

In practice, **E_k** will not be equal to **E_p**.

Explain why:

.....

STUDENT HANDOUT

Worksheet 2 - Controlling Friction

1. Types of friction

Test surfaces	Hanger weight in N	Horizontal force in N
wheels		
metal-metal		

(The blank rows are for the results of the Challenges)

2. Static and sliding friction

Weight of cart in N (i.e. normal force)	Hanger weight in N (i.e. frictional force)	Coefficient of static friction μ_s
(empty)		
(+2N)		

Wood / wood contact:

Weight of cart in N (i.e. normal force)	Hanger weight in N (i.e. frictional force)	Coefficient of static friction μ_s
(empty)		
(+2N)		

Challenge: contact:

Weight of cart in N (i.e. normal force)	Hanger weight in N (i.e. frictional force)

Comprehensive investigation: contact:

STUDENT HANDOUT

Worksheet 2 - Controlling Friction

3. Angle of friction

Test surfaces	Plate angle θ	$\mu_k = \tan \theta$
metal-metal		
metal-wood		
wood-wood		
rubber-wood		

Worksheet 3 - Inclined Forces

Measured values:

Weight of roller, **W** = **N**

Plate angle θ	'Normal' mass hanger load in g	Normal reaction force R_N in N	'Parallel' mass hanger load in g	Parallel reaction force R_p in N
20°				
30°				
40°				
50°				

Calculated values:

(using $R_N = W \cos \theta$ and $R_p = W \sin \theta$)

Plate angle θ	Normal reaction force R_N in N	Parallel reaction force R_p in N
20°		
30°		
40°		
50°		

Comparison of measured and calculated values:

.....

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.....

.....

.....

.....

.....

STUDENT HANDOUT

Worksheet 4 - Pulley Systems

1. A change in direction:

What happened as you increased the weight of the 'Effort' mass hanger?

.....

.....

.....

.....

.....

.....

2. Force multiplication:

Load in N	Effort in N	Mechanical advantage
1.0		
1.4		
1.8		
2.2		
2.6		
3.0		

3. Force multiplication:

Load in N	Effort in N	Mechanical advantage
1.0		
1.4		
1.8		
2.2		
2.6		
3.0		

4. Force multiplication - even bigger:

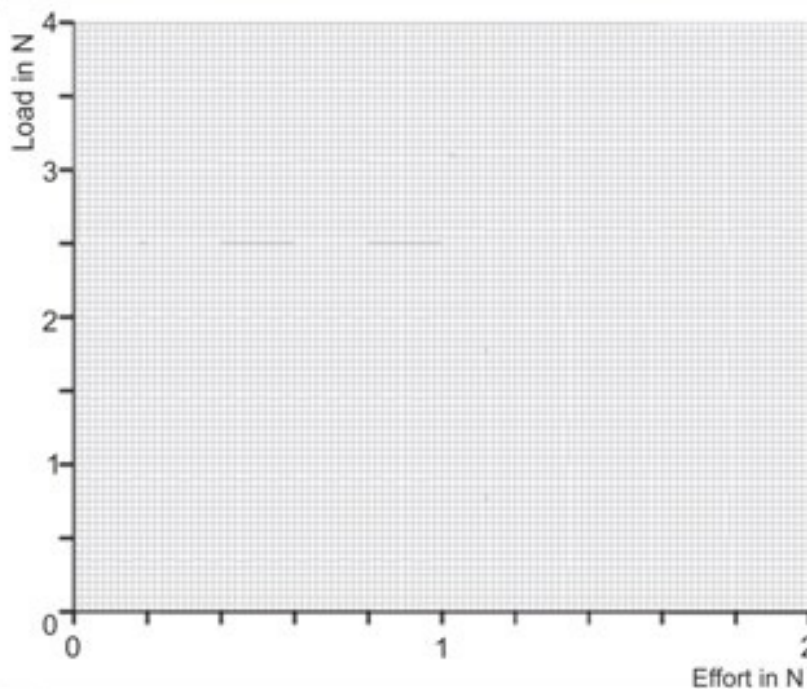
Load in N	Effort in N	Mechanical advantage
1.0		
1.4		
1.8		
2.2		
2.6		
3.0		

STUDENT HANDOUT

Worksheet 5 - The Toggle Mechanism

Effort in N	Load in N		
	1 st attempt	2 nd attempt	3 rd attempt
0.4			
0.8			
1.2			
1.6			
2.0			
2.4			
2.8			
3.2			

Relationship between forces in the toggle mechanism:



Challenge

What effort force causes the mechanism to 'snap'?

.....

[illegible]

[illegible]

DYNAMICS FUNDAMENTALS

CP1505

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