Newton laws worksheet 16

Static and kinetic friction

So far we've only used the general term friction. But in reality there are 2 types of friction. Friction when you are standing still (called static friction) and friction when you are moving (called kinetic friction)

You calculate them as follows:

$$f_s = \mu_s . F_N$$

$$f_k = \mu_k . F_N$$

f_s- static friction

μ_s – coefficient of static friction (this is basically a measure of how 'rough' the surface is). **It has no unit.**

μ_k - coefficient of kinetic friction

*F_N (sometimes given as just- N on data sheets) – normal force on the object

**now it might also make sense, why we spent so long calculating normal force on the previous worksheet*

The coefficients (μ) are usually given to you and they differ for different surfaces

Material	**coefficient of static friction**	**coefficient of kinetic friction**
copper	1,05	0,29
aluminium	0,61	0,47
cast iron	1,1	0,15

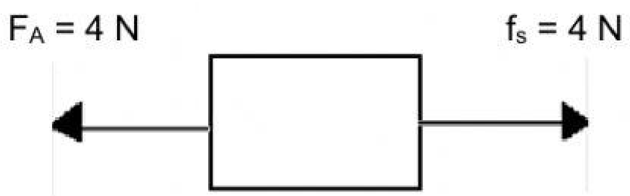
Notice how the coefficient of static friction (and thus the static friction itself) is always higher than the coefficient of kinetic friction (and thus kinetic friction). This is because it is always more difficult to start an object moving then it is to keep an object in motion, once it is moving.

Maximum static friction (f_s^{max})

The maximum static friction is the maximum friction a surface can provide, before an object will actually start moving.

Let's look at an example where the max static friction the surface can provide is 8N. Thus f_s^{max} = 8N for this specific surface.

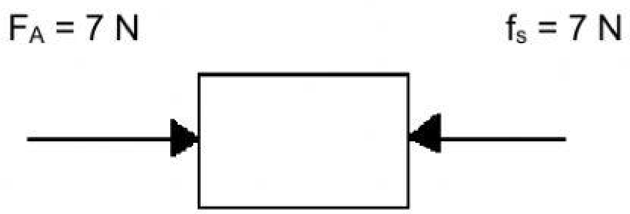
Situation 1:



If the f_s^{max} in the above example is 8 N then any applied force below 8 N will not cause the object to move. And the static friction that the surface will provide will be just 4 N. {since it cannot be 8N, as this will mean that the object will start moving backwards.}

Situation 2:

A force of 7N is applied to an object

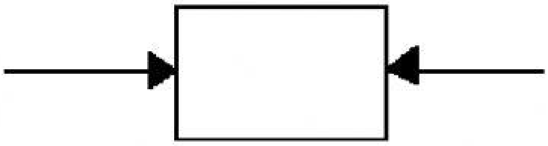


When the applied force is increased the f_s also increase, (thus fs for the above example can vary between zero and 8 N) but the object still doesn't move.

Situation 3:

A force of 8N is applied to the object

F_A = 8N f_s^{max} = 8N



The object still does not move

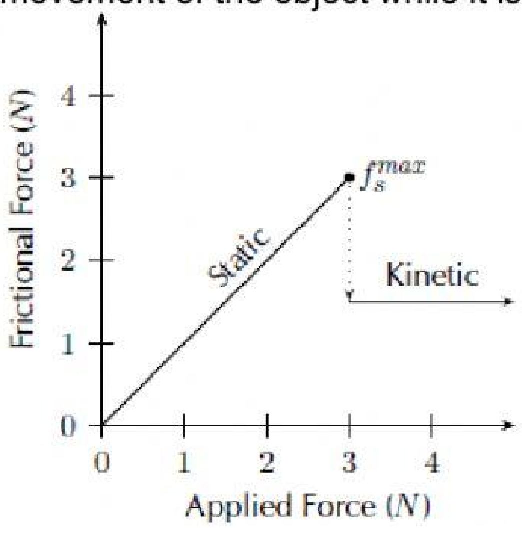
Situation 4:

F_A = 8,01 N f_s^{max} = 8N

If the applied force **exceeds** the f_s^{max} then the object will start to accelerate.

However the surface cannot provide a frictional force greater than 8N.

Once the object is moving we start to look at the kinetic friction (f_k). This value stays constant (unlike fs, which can increase up to f_s^{max}). Once the object is in motion there is a frictional force acting on it called kinetic friction. This is the frictional force which opposes the movement of the object while it is in motion.



The max coefficient of static friction (μ_s) is always larger than the coefficient of kinetic friction (μ_k), since it takes a greater force to initially set the object in motion than to keep it moving once it is in motion.

If μ is a small value the resistance of the surface is low.

How do we actually calculate the frictional force that a surface can provide?

$f_s = \mu_k . F_N$

We learnt in the previous worksheet how to calculate the normal force of a surface, for this exact reason.

The coefficients are usually given to us in the question. (unless they want us to calculate them).

Here are a few examples below of certain substances' coefficients of frictions. Again notice how the coefficient of kinetic friction is always lower than the coefficient of static friction of any surface.

Examples:

1. A box of mass 5 kg is resting on a table. The coefficient of static friction is 0,34.

Calculate

1.1 The maximum static frictional force.
1.2 Calculate the kinetic friction on the box, if the coefficient of kinetic friction is 0,2.
1.3 The acceleration of the box, if a 40N force is applied to it.

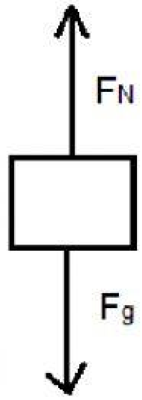
Answers:

1.1 $f_s^{max} = \mu_s.F_N$

$= 0,34(5 \times 9,8)$

$= 16,66N$

Remember that when a box is resting on a table $F_g = F_N$



{the direction doesn't need to be given – since the object isn't moving – thus we can't say in what direction the static friction is acting.}

1.2

$f_k = \mu_k.F_N$

$= 0,2\ (5 \times 9,8)$

$f_k = 9,8$ N in opposite direction as applied force

Notice the coefficient of kinetic friction, and therefore the kinetic friction on the same surface is always less than the static friction

1.3

***Firstly, check if it is not a trick question – is the Fa greater than the f_s^{max}?**

Since $F_A > f_s$, the object would actually move, thus it is not a trick question

Fnet = m.a

$F_A - f_k = m.a$

$40 - 9,8 = 5.a$

$a = 6,04\ m.s^{-2}$ in the direction of the applied force

2. A box of mass 10 kg is resting on a surface. The coefficient of static friction is 0,4. The coefficient of kinetic friction is 0,25 and a force of 30 N is applied to the object to the right.

Calculate

2.1 the maximum static friction

2.2 the kinetic friction on the box

2.3 the acceleration of the object if

2.1 $f_s^{max} = \mu_s.F_N$

$f_s^{max} = 0,4\ (10x9,8)$

f_s^{max} = ____ N

2.2 $f_k = \mu_k.F_N$

= 0,25 (10 x 9,8)

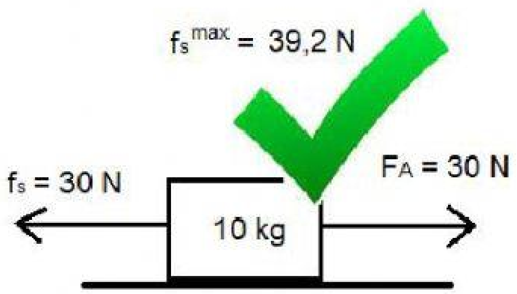
f_k = _______ is _______ {direction}

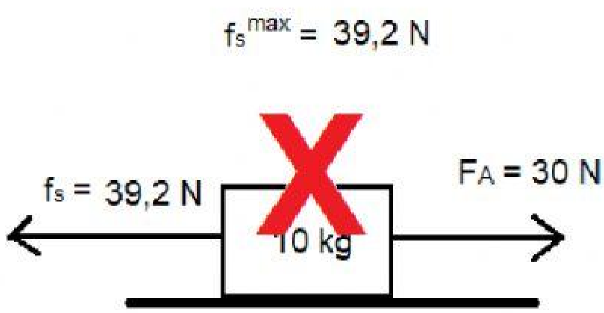
2.3 Fnet = m.a

However – notice the applied force is 30 N, but the f_s^{max} for the surface is 39,2 N.

Thus the object would not be able to move it you applied a force of just 30 N on it, as the $\mathbf{F_A < f_s^{max}}$

Thus the fs that is actually exerted on the object is 30N (and not the 39,2N, since the actual applied f_s can never exceed the applied force.)

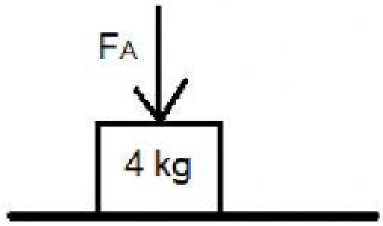




Thus a = $0 m.s^{-2}$ (in fact the velocity is $0 m.s^{-1}$)

3. An object with a mass of 4 kg is pushed down with a force of 10 N. The coefficient of static friction is 1,2 and the coefficient of kinetic friction is 0,9.

The object is pulled to the right with a force of 70 N.



Calculate:

3.1 The normal force on the object

3.2 The maximum static friction on the object

3.3 The kinetic friction on the object

3.4 The acceleration of the object

3.1 $F_N = F_A + Fg$

$F_N = 10 + m.g$

$F_N = 10 + 4(9{,}8)$

$F_N = 49{,}2$ N upwards

3.2 $f_s^{max} = \mu_s.F_N$

$= 1{,}2\ (49{,}2)$

$f_s^{max} = 59{,}04$ N

3.3 $f_k = \mu_k.F_N$

$= 0{,}9\ (59{,}04)$

$f_k = 48{,}64$ N ________ {direction}

3.4 check first if the applied force is greater than f_s^{max}

$F_A > f_s^{max}$

Great, now you can continue

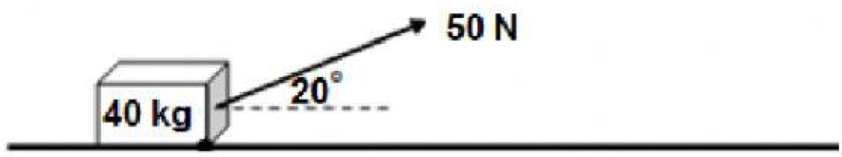
Fnet = m.a

$F_A - f_k = m.a$

70 – 48,64 = 4.a

a = 5,34 m.s^{-2} right

4. The coefficient of kinetic friction on the box is 0,1



Calculate

4.1 the normal force on the box

4.2 the kinetic friction on the box

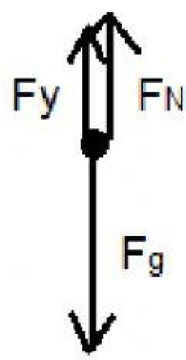
4.3 the acceleration of the box if you apply a

4.1 Thus Fy + F_N = Fg

F._____Θ + F_N = m.g

50._____ 20 + F_N = 40(9,8)

F_N = 374,90N



4.2 fk = $\mu.F_N$

fk = 0,1 (374,9)

fk = 37,49 N ____________{direction}

Remember not to subtract f_k from F_A – as they are not in a straight line. You need to calculate F_x first.

4.3 $F_{net} = m.a$

$F_x - f_k = m.a$

F.____ θ - f_k = m.a

50.______20 – 37,49 = 40.a

a = ________ $m.s^{-2}$ __________{direction}