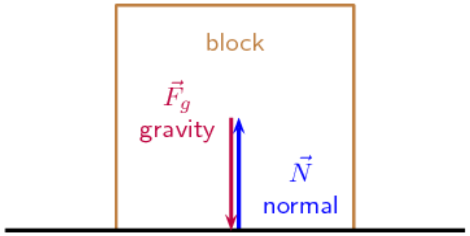
SUBJECT and GRADE	Physical Sciences; Grade 11
TERM 1	Week 4
TOPIC	Frictional forces and Newton's First law (an introduction)
AIM OF LESSON	**At the end of this lesson you should be able to:** • Define the static frictional force, f_s. • Solve problems using $f_s^{max} = \mu_s N$ • Define the kinetic frictional force, f_k. • Solve problems using $f_k = \mu_k N$ • Draw force diagrams. • Draw free-body diagrams. Resolve a two-dimensional force, e.g. the weight of an object on an inclined plane, into its parallel ($F_{//}$) and perpendicular ($F_{\perp}$) components. • Determine the resultant/net force of two or more forces. • State Newton's first law of motion. • Define inertia and state that the mass of an object is a quantitative measure of its inertia. • Discuss why it is important to wear seatbelts using Newton's first law of motion.
RESOURCES	**Paper-based / physical resources** • Prescribed CAPS Physical Sciences textbook, as well as Siyavula Grade 11 Physical Sciences resource (learner book, pg. 58 - 123); Physical Sciences CAPS document (pg. 62 - 64); and Grade 11 Physical Sciences Examination Guideline (pg. 7-8). *(Additional subject-related material, e.g. Mind the Gap, Science Clinic, Answer Series, etc.)*. • Scientific calculator, pen and pencil.

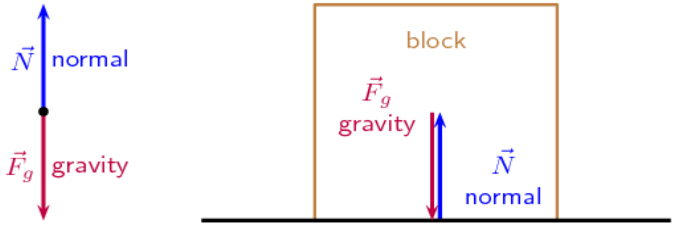
	Digital resources • Technological devices such as a cell phone, tablet, laptop, etc. and sufficient data would be very useful. • Website links to access recommended platforms: • Siyavula links (Forces): *https://intl.siyavula.com/read/science/grade-11/newtons-laws/02-newtons-laws-02* • Youtube videos: Free body diagrams https://youtu.be/3rZR7FSSidc https://youtu.be/4Bwwq1munB0 https://youtu.be/29YPIvj1zjc Static and Kinetic Friction https://youtu.be/3EbUa5ZDybg (Introduction) https://youtu.be/RSp_TY2IghY (with calculations) Newton's First Law https://youtu.be/5oi5j11FkQg https://youtu.be/LEHR8YQNm_Q Inertia https://youtu.be/adLj6kygwds • Mind the Gap: *https://www.education.gov.za/Curriculum/LearningandTeachingSupportMaterials(LTSM)/MindtheGapStudyGuides.aspx*
INTRODUCTION	1. Use the following link to enhance your background knowledge on the topic of forces using the accompanying video. These videos introduces you to the concept of "Force diagrams" and "Free body diagrams" and how to represent the. Free body diagrams https://youtu.be/3rZR7FSSidc https://youtu.be/4Bwwq1munB0 https://youtu.be/29YPIvj1zjc
CONCEPTS AND SKILLS	1. Force diagrams Force Diagrams are sketches of the physical situation you are dealing with. A block is drawn to represent the object and arrows for all the forces acting drawn from the object. For example, if a block rests on a surface then there is a force due to gravity pulling the block down is drawn from the "centre of mass" of the object and there is a normal force acting on the block drawn from the surface. In this situation, the

normal force and the force of gravity have the same magnitude. (This is not always the case. If you have an applied force acting on the object, at an angle, then the F_g and the F_N are not equal in magnitude. We will look at these cases in the next lesson plan.) The force diagram for this situation is:

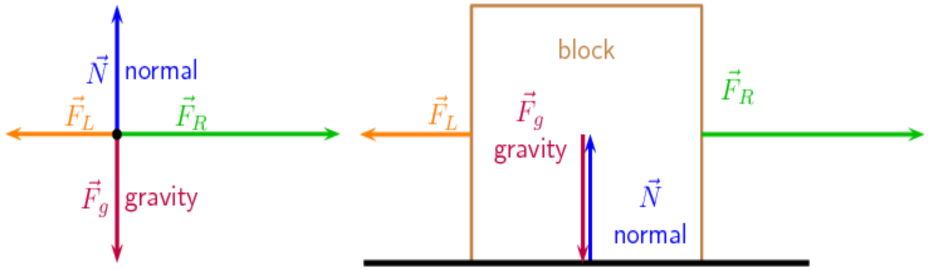


The arrows are the same length to indicate that the forces have the same magnitude. However, in tests and exams we are not too concerned about the length of the arrows.

2. Free-Body Diagrams
   In a free-body diagram, the object of interest is drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot. We can redraw the two force diagrams above as free body diagrams



3. Another example could be a the same block on a surface but with an applied force, F_L, to the left of 10 N and an applied force, F_R, to the right of 20 N. The weight and normal also have magnitudes of 10 N. The "Free-body diagram" below is on the left and the "Force-diagram" on the right.



4. Frictional Forces

Friction arises because the surfaces interact with each other. Think about sandpaper with lots of bumps on the surface. If you rub sandpaper the bumps will slot into any groove .

When the surface of one object slides over the surface of another, each body exerts a frictional force on the other. For example if a book slides across a table, the table exerts a frictional force onto the book and the book exerts a frictional force onto the table. Frictional forces act parallel to surfaces.

The magnitude of the frictional force depends on the surface and the magnitude of the normal force. Different surfaces will give rise to different frictional forces, even if the normal force is the same. Frictional forces are proportional to the magnitude of the normal force.

$F_{friction} \propto$ ormal force

For every surface we can determine a constant factor, called the coefficient of friction, that allows us to calculate what the frictional force would be if we know the magnitude of the normal force. We know that static friction and kinetic friction have different magnitudes so we have different coefficients for the two types of friction:

- μ_s is the coefficient of static friction
- μ_k is the coefficient of kinetic friction

Define the static frictional force, fs, as the force that opposes the tendency of motion of a stationary object relative to a surface. For static friction the force can vary up to some maximum value after which friction has been overcome and the object starts to move. So we define a maximum value for the static friction: $f_{s/max} = \mu_s N$.

When the applied force is greater than the maximum, static frictional force, the object moves but still experiences friction. This is called *kinetic friction*. **Define the kinetic frictional force, fk,** as the force that opposes the motion of a moving object relative to a surface. The kinetic frictional force on an object is constant for a given surface and

	equals $\mu_k N$. For kinetic friction the value remains the same regardless of the magnitude of the applied force. The magnitude of the kinetic friction is: $f_k = \mu_k N$. Now view the following Youtube videos: Static and Kinetic Friction https://youtu.be/3EbUa5ZDybg (Introduction) https://youtu.be/RSp_TY2IghY (with calculations) EXAMPLES 1. A box resting on a surface has a mass of 3 kg and the coefficient of static friction between the surface and the box, μ_s is 0,34. What is the maximum static frictional force? $f_s^{max} = \mu_s . N = \mu_s .(mg)$ …… NB: N = mg $=(0,34)(3)(9.8)$ $= 10$ N 2. The forwards of your school's rugby team are trying to push their scrum machine. The normal force exerted on the scrum machine is 10 000 N. The machine isn't moving at all. If the coefficient of static friction is 0,78. What is the minimum force they need to exert to get the scrum machine to start moving? $f_s^{max} = \mu_s . N = (0,78)(10\ 000) = 7\ 800$ N 3. A block of wood of mass 4 kg rests on a rough, horizontal surface. There is a rope tied to the block. The rope is pulled parallel to the surface and the tension (force) in the rope can be increased to 8 N before the block starts to slide. Determine the coefficient of static friction. $f_s^{max} = \mu_s . N = \mu_s .mg$ $8 = \mu_s(4)(9,8)$ $\mu_s = 0,204$ ……. NB: "μ" has no units.

NEWTON'S FIRST LAW OF MOTION

Newton's First Law is applied when the acceleration of an object is zero. When the acceleration is zero, the object is (a) either at rest or (b) moving at constant velocity in a straight line. Therefore Newton's first law is defined as "an object remains in a state of rest or travels at constant velocity unless acted on by an external unbalanced or resultant force".

Law of Inertia

Inertia is defined as the physical property or the ability of an object to resist any changes in its state of rest or constant velocity, unless acted on by an external unbalanced force. Have you ever experienced inertia (resisting changes in your state of motion) in a car while it is braking to a stop? The force of the road on the locked wheels provides the unbalanced force to change the car's state of motion, yet there is no unbalanced force to change your own state of motion. Thus, you continue in motion, sliding along the seat in forward motion. A person in motion stays in motion with the same speed and in the same direction ... unless acted upon by the unbalanced force of a seat belt. Yes! Seat belts are used to provide safety for passengers whose motion is governed by Newton's laws. The seat belt provides the unbalanced force that brings you from a state of motion to a state of rest. Perhaps you could speculate what would occur when no seat belt is used.

The law of inertia is most commonly experienced when riding in cars and trucks. In fact, the tendency of moving objects to continue in motion is a common cause of a variety of transportation injuries - of both small and large magnitudes. Consider for instance the unfortunate collision of a car with a wall. Upon contact with the wall, an unbalanced force acts upon the car to abruptly decelerate it to rest. Any passengers in the car will also be decelerated to rest if they are strapped to the car by seat belts. Being strapped tightly to the car, the passengers share the same state of motion as the car. As the car accelerates, the passengers accelerate with it; as the car decelerates, the passengers decelerate with it; and as the car maintains a constant speed, the passengers maintain a constant speed as well.

But what would happen if the passengers were not wearing the seat belt? What motion would the passengers undergo if they failed to use their seat belts and the car were brought to a sudden and abrupt halt by a collision with a wall? Were this scenario to occur, the passengers would no longer share the same state of motion as the

	car. The use of the seat belt assures that the forces necessary for accelerated and decelerated motion exist. Yet, if the seat belt is not used, the passengers are more likely to maintain its state of motion. Now view the following Youtube videos: Newton's First Law https://youtu.be/5oi5j11FkQg https://youtu.be/LEHR8YQNm_Q Inertia https://youtu.be/adLj6kygwds
CONSOLIDATION	1. A block rests on a horizontal surface. The normal force is 20 N. The coefficient of static friction between the block and the surface is 0,40 and the coefficient of dynamic friction is 0,15. a. What is the magnitude of the frictional force exerted on the block while the block is at rest? Answer: 8 N b. What is the minimum force required to start the block moving? Answer: 8 N c. What will the magnitude of the frictional force be if a horizontal force of magnitude 10 N is exerted on the block? Answer: 3 N d. What is the minimum force required to keep the block moving at constant velocity? Answer: 4 N 2. Attempt the questions 1 – 12, 22, 25, 26(a), 26(f), from Siyavula Grade 11: https://intl.siyavula.com/read/science/grade-11/newtons-laws/02-newtons-laws-06 3. Look through Mind The Gap Physical Sciences Part 1 Worked examples 4 (pg 9)
VALUES / APPLICATIONS IN PRACTICE	1. The application and understanding of Newton's first law and Inertia in everyday life in use of for example seat belts should make you aware to never travel without using seat belts. 2. Never travel at high speed on a wet slippery road.