IB Physics Investigations

Volume 1 (Standard Level)

COPY MASTERS

(For use with the IB Diploma programme)

(Fourth edition)

Author: Gregg Kerr

Series editor: David Greig

Table of Contents

Name ______________________ **Date** ________ **Class** ______________________ **Time: 90 mins**

In this investigation you may be assessed using school-based criteria.

AIM

To determine the coefficients of kinetic and static friction for a wooden box on a laboratory surface and to determine that the force of friction does not depend on the amount of surface area in contact with the laboratory surface.

BACKGROUND

Whenever two surfaces touch, they exert forces on each other. The ultimate source of these surface forces is the electromagnetic attraction or repulsion between the charged particles – electrons and protons – of which all matter is made. The vector sum of all the microscopic forces between the particles in the surfaces is a macroscopic force that we can measure in the laboratory.

Suppose you attached a newton balance to a block of wood in contact with a surface such as the bench top in a laboratory. You then pull on the newton balance but the object does not move because the component of the applied force parallel to the surface balances the static frictional force. As you continue to pull on the newton balance, there will be a certain applied force registered when the block just begins to move. At this point the applied force is slightly greater than the maximum static frictional force.

Experimental evidence shows that the frictional force is independent of the actual area of the two surfaces in contact, provided the surfaces in contact with each other are hard. The evidence suggests that the magnitude of the frictional force is directly proportional to the magnitude of the normal reaction force.

$F_f \propto F_N$ or $F_f \propto R$

$F_f = \mu_s R$

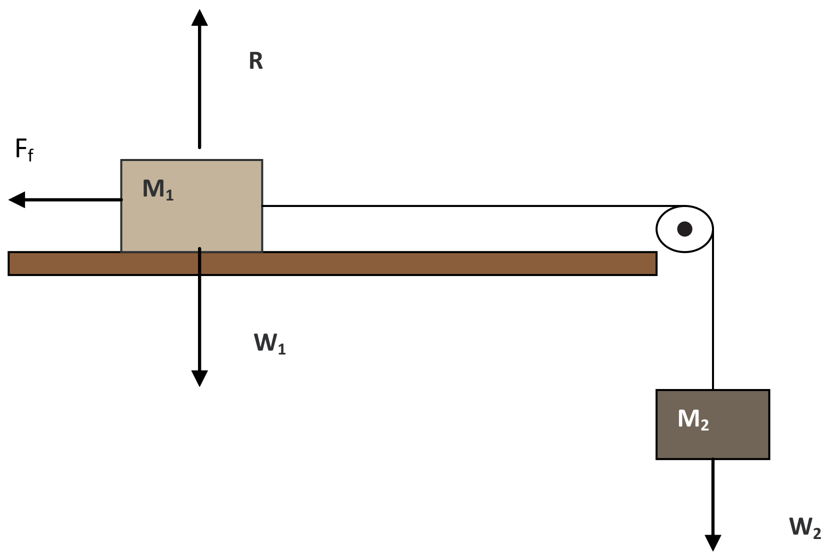
where μ_s is called the coefficient of static friction.

When a force is then applied that causes the block of wood to slide along the surface, the magnitude of the force registered on the newton balance rapidly decreases and then becomes a steady value provided the block is moved with a uniform speed. The frictional force is then given by:

$F_f = \mu_k R$ where μ_k is called the coefficient of kinetic friction.

The coefficient of static friction will always be a larger value. As an approximate guide, the coefficient of static friction between a polished wood block and polished wood surface is around 0.4 and the coefficient of kinetic friction for the same materials is 0.2. Both coefficients are dimensionless.

In this investigation, we will first determine the coefficients of static and kinetic friction between two surfaces (a wooden box and a laboratory bench), as shown in the diagram.



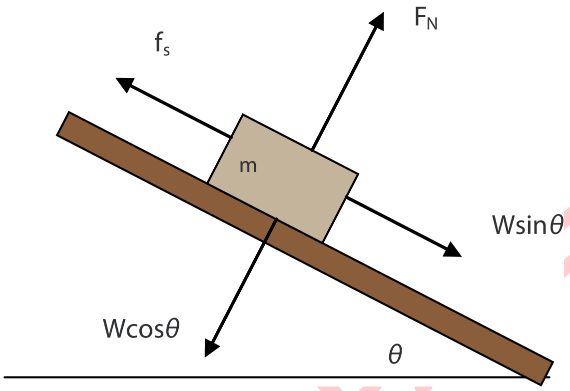
The wooden box (M_1) is placed on a laboratory bench and is connected by a string to a mass (M_2), which is hung vertically by means of a pulley. To find the magnitude of kinetic friction, we hang just enough mass on the string so that if the block is set in motion and it slides at constant speed.

$F_f = W_2$ and $R = W_1$

We can determine the coefficient of kinetic friction by running several trials and calculating the ratio of the masses for each trial.

The coefficient of static friction can be determined in much the same way. In this case we leave the block at rest and look for that hanging mass which just starts the block sliding.

There is a second way of determining the coefficient of static friction. Refer to the diagram below. You can put the wooden box on a plank and raise one end of the plank so that it makes an angle θ with the horizontal. When the angle is large enough, the block will slide down the incline.



At an angle just before the block begins to slide, the forces are still balanced and we have

$F_f = W\sin\theta$ and $R = W\cos\theta$

PROCEDURE

1. Set up the apparatus as shown in the first diagram.
2. Record the mass of a wooden box.
3. Wipe clean the surfaces of the wooden box and the laboratory bench.
4. Determine the mass that needs to be added so that the system moves at constant speed.
5. Give the block a slight push to start it moving. If the block accelerates (speeds up), take a little mass off and try again. If the block decelerates (slows down), add a little more mass and try again.
6. Record the total hanging mass and its weight.
7. Repeat the above process, adding 100 grams to the wooden box for each new trial, for a total of six trials.
8. To test the hypothesis that the force of friction is independent of the surface area in contact, repeat the above using the narrow face of the wooden box.
9. Use the same set-up as in the kinetic friction experiments, with the wide face of the wooden box down. This time, however, determine what hanging mass is necessary to just start the block moving without a push.
10. Design an investigation to find the coefficient of static friction using the wooden box on an incline plane.

DATA COLLECTION

Mass of wooden box (g): ____________________

Kinetic Friction – Flat Face

Trial	Mass in box	Total Mass (m_1)	Normal Force (R)	Hanging mass (m_2)	Friction Force (F_f)	μ_k
1						
2						
3						
4						
5						
6						

Average μ_k: ________

Uncertainty: ________

Kinetic Friction – Narrow Face

Trial	Mass in box	Total Mass (m_1)	Normal Force (R)	Hanging mass (m_2)	Friction Force (F_f)	μ_k
1						
2						
3						
4						
5						
6						

Average μ_k: ________

Uncertainty: ________

Static friction table

Mass of block (g): ____________________

Mass in box	Total Mass (m_1)	Normal Force (R)	Hanging mass (m_2)	Average hanging mass
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4	
			1.	
			2.	
			3.	
			4	
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4.	

DATA PRESENTATION AND ANALYSIS

Plot a relevant graph to determine the coefficient of static friction.

CONCLUSION AND EVALUATION

Comment on the graph obtained and justify your conclusion. Discuss the difference between the coefficients of static and kinetic friction. Discuss the surface area and its effect on the coefficients of static and kinetic friction.

IB Physics Investigations

Volume 1 (Standard Level)

TEACHING NOTES

(For use with the IB Diploma programme)

(Fourth edition)

Author: Gregg Kerr

Series editor: David Greig

SL

Syllabus Correlation Table

TN2

Core Topic	Sub topic	Syllabus reference	Practical Number	Title
1	1.2	• Explaining how random and systematic errors can be identified and reduced	1A	Errors in measurement
2	2.1	• Determining the acceleration of free-fall experimentally • Qualitatively describing the effect of fluid resistance on falling objects or projectiles, including reaching terminal speed • Analysing projectile motion, including the resolution of vertical and horizontal components of acceleration, velocity and displacement And the relevant Aim 6 Statement as found in the IBO Physics Guide.	2A 2B 2C 2D	Falling objects using stroboscopic photo Motion of a falling body. Terminal velocity in a fluid The range of a projectile
	2.2	• Using Newton's second law quantitatively and qualitatively • Describing solid friction (static and dynamic) by coefficients of friction And the relevant Aim 6 Statement as found in the IBO Physics Guide.	2E 2F 2G	Newton's second Law Static and kinetic friction Static equilibrium
	2.3	• Discussing the conservation of total energy within energy transformations • Quantitatively describing efficiency in energy transfers And the relevant Aim 6 Statement as found in the IBO Physics Guide.	2H	Propulsion using elastic potential energy
	2.4	• Determining impulse in various contexts including (but not limited to) car safety and sports • Applying conservation of momentum in simple isolated systems including (but not limited to) collisions, explosions, or water jets • Qualitatively and quantitatively comparing situations involving elastic collisions, inelastic collisions and explosions And the relevant Aim 6 Statement as found in the IBO Physics Guide.	2I 2J	Energy and impulse Investigation circus
3	3.1	• Describing temperature change in terms of internal energy • Applying the calorimetric techniques of specific heat capacity or specific latent heat experimentally • Describing phase change in terms of molecular behaviour • Sketching and interpreting phase change graphs • Calculating energy changes involving specific heat capacity and specific latent heat of fusion and vaporization And the relevant Aim 6 Statement as found in the IBO Physics Guide.	3A 3B 3C	Conservation of thermal energy Specific heat capacity of a metal Latent heat of fusion of ice
	3.2	• Solving problems using the equation of state for an ideal gas and gas laws • Sketching and interpreting changes of state of an ideal gas on pressure–volume, pressure–temperature and volume–temperature diagrams • Investigating at least one gas law experimentally And the relevant Aim 6 Statement as found in the IBO Physics Guide.	3D 3E 3F 3G	Universal Gas Law determination Boyle's Law determination (data-based) Charles' Law and Pressure Law determination (data-based) Zartmann Investigation

4	4.1	• Qualitatively describing the energy changes taking place during one cycle of an oscillation • Sketching and interpreting graphs of simple harmonic motion examples And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4A	Period of an oscillating spring
	4.2	• Explaining the motion of particles of a medium when a wave passes through it for both transverse and longitudinal cases • Sketching and interpreting displacement–distance graphs and displacement– time graphs for transverse and longitudinal waves • Investigating the speed of sound experimentally And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4B 4C	Waves in springs Speed of sound using resonance
	4.3	• Sketching and interpreting diagrams involving wavefronts and rays • Sketching and interpreting the superposition of pulses and waves • Describing methods of polarization And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4D 4E	Surface water waves in a ripple tank The polarisation of light
	4.4	• Sketching and interpreting incident, reflected and transmitted waves at boundaries between media • Solving problems involving reflection at a plane interface • Solving problems involving Snell's law, critical angle and total internal reflection • Determining refractive index experimentally And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4F	Properties of refraction
	4.5	• Describing the nature and formation of standing waves in terms of superposition • Distinguishing between standing and travelling waves • Observing, sketching and interpreting standing wave patterns in strings and pipes And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4G	Standing waves in a string
	5.1	• Identifying two forms of charge and the direction of the forces between them And the relevant Aim 6 Statement as found in the IBO Physics Guide.	5A	Electric field patterns
	5.2	• Drawing and interpreting circuit diagrams • Investigating combinations of resistors in parallel and series circuits • Describing practical uses of potential divider circuits, including the advantages of a potential divider over a series resistor in controlling a simple circuit • Investigating one or more of the factors that affect resistance experimentally • Identifying ohmic and non-ohmic conductors through a consideration of the *V/I* characteristic graph And the relevant Aim 6 Statement as found in the IBO Physics Guide.	5B 5C 5D	Voltage divider circuits Factors affecting electrical resistance Ohm's Law
	5.3	• Investigating practical electric cells (both primary and secondary) • Identifying the direction of current flow required to recharge a cell • Determining internal resistance experimentally	5E	Internal resistance of a dry cell
	5.4	• Determining the direction of force on a charge moving in a magnetic field • Determining the direction of force on a current-carrying conductor in a magnetic field • Sketching and interpreting magnetic field patterns • Determining the direction of the magnetic field based on current direction	5F	Force on a current carrying conductor
6	6.1	• Identifying the forces providing the centripetal forces such as tension, friction, gravitational, electrical, or magnetic • Qualitatively and quantitatively describing examples of circular motion including cases of vertical and horizontal circular motion And the relevant Aim 6 Statement as found in the IBO Physics Guide	6A	Uniform circular motion
7	7.1	• Determining the half-life of a nuclide from a decay curve • Investigating half-life experimentally (or by simulation)	7A	Half life of beer foam
	7.2	• These are suggestions only, obviously whether and how such excursions can be arranged will depend on local circumstances.	7B	A visit to a cyclotron
	7.3		7C	A Visit To An Atomic Energy Facility

Option Topic	Sub topic	Syllabus reference	Practical Number	Title
B	B.1	• Solving problems involving moment of inertia, torque and angular acceleration • Solving problems in which objects are in both rotational and translational equilibrium • Calculating torque for single forces and couples	14A	Moment of inertia
			14B	Translational equilibrium
			14C	Biomechanics
C	C.1	• Describing how a curved transparent interface modifies the shape of an incident wavefront • Identifying the principal axis, focal point and focal length of a simple converging or diverging lens on a scaled diagram • Explaining spherical and chromatic aberrations and describing ways to reduce their effects on images • And the relevant Aim 6 Statement as found in the IBO Physics Guide	15A	Focal length of a converging lens
	C.2	• Investigating the performance of a simple optical astronomical refracting telescope experimentally	15B	The refracting telescope
D	D.2	• Sketching and interpreting HR diagrams • Identifying the main regions of the HR diagram and describing the main properties of stars in these regions	16A	Hertzsprung-Russell diagram
		• Sketching and interpreting evolutionary paths of stars on an HR diagram • Describing the evolution of stars off the main sequence • Describing the role of mass in stellar evolution	16B	Stellar evolution

Investigation 2F STATIC AND KINETIC FRICTION

Syllabus relevance: 2.2 Skills and AIm 6

Describing solid friction (static and dynamic) by coefficients of friction

There are many possibilities as to how to carry out this investigation. Different surfaces can be used. Rather than using masses on the end of the pully, you could use a vessel containing water. Water can be added drop by drop at the critical point.

A graph of the frictional force, as a function of the normal force, will yield a straight line that will not pass through the origin because the wooden box has mass.

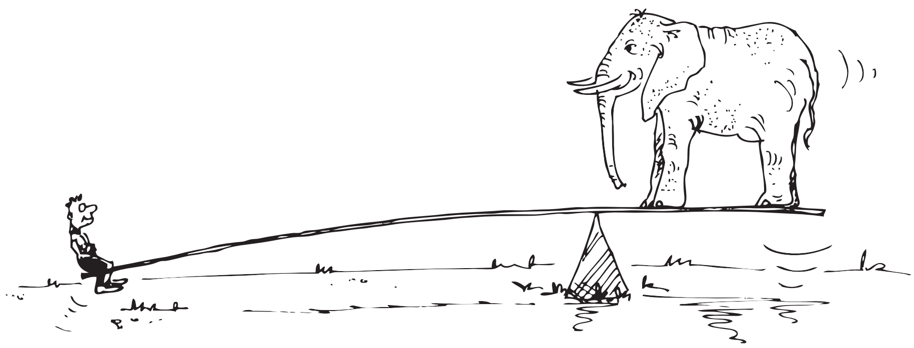
Investigation 2G STATIC EQUILIBRIUM

Syllabus relevance: 2.2 Skills and AIm 6

Solving problems involving forces and determining resultant force

Investigation 14B extends this for those undertaking the engineering physics Option B.

It is a very standard practical that can be carried out with basic equipment. Some schools have circular force boards made of Masonite with a series of holes in which to put the spring balances. These boards are good to buy.



These are **Sample Pages** only from the fourth edition of one of the IBID Science Volumes. This Volume is part of a series of full-colour **Copy Masters** as follows:

SUBJECT	VOLUME
BIOLOGY	Standard Level Investigations with Teaching Notes
	Higher Level Investigations with Teaching Notes
	Internal Assessment Handbook
CHEMISTRY	Standard Level Investigations with Teaching Notes
	Higher Level Investigations with Teaching Notes
	Internal Assessment Handbook
PHYSICS	Standard Level Investigations with Teaching Notes
	Higher Level Investigations with Teaching Notes
	Internal Assessment Handbook

These Volumes have been prepared and published specifically to support the teaching of the **IB Diploma Sciences**. They are for sale as either as paper copies or secure pdf files and may only be used by the purchasing school under the conditions of sale.

More information may be obtained from our website <*www.ibid.com.au*>