IB Physics Investigations

Volume 1 (Standard Level)

COPY MASTERS

HIRING

ith the IB Diploma programme) (Fourth edition)

Author: Gregg Kerr Series editor: David Greig

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

AIM

Name

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.

Class

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.

 $F_f \alpha F_N \text{ or } F_f \alpha R$

 $F_f = \mu_s R$

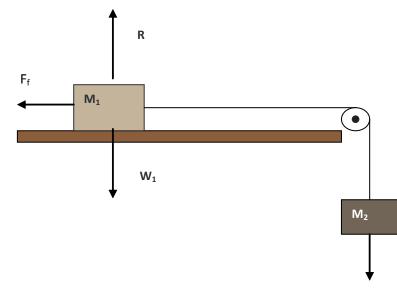
where μ_s is called the coefficient of static friction.

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:

 $F_t = \mu_k R$ 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.



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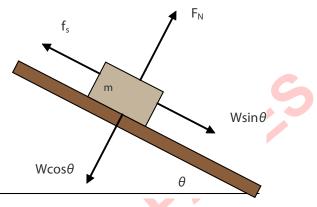
The wooden box (M_1) is placed on a laboratory bench and is connected by a string to a mass (M_2) , which is hung vertically by means of a pulley. To find the magnitude of kinetic friction, we hang just enough mass on the string so that if the block is set in motion and it slides at constant speed.

$F_f = W_2$ 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

 $F_f = Wsin\theta$ and $R = Wcos\theta$

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.

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DATA COLLECTION

Mass of wooden box (g): _____

Kinetic Friction – Flat Face

Trial	Mass in box	Normal Force (R)		Friction Force (F _f)	μ
1					
2					
3					
4				G	
5					
6			6		

Er

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: _____



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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.	1
			3.	1
			4.	1

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.

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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

Syllabus Correlation Table

Practical	umber
Practice	Title

	10	pic Sub ^{topic} Syllabus reference		ctical Number Title
0	e.	Syllabus reference	b ₁₃	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 	2A	Falling objects using stroboscopic photo
		• Analysing projectile motion, including the resolution of vertical and horizontal components of acceleration, velocity and displacement	2B 2C	Motion of a falling body. Terminal velocity in a
		And the relevant Aim 6 Statement as found in the IBO Physics Guide.	2D	fluid The range of a
	2.2	Using Newton's second law quantitatively and qualitatively	2E	projectile Newton's second Law
		 Describing solid friction (static and dynamic) by coefficients of friction And the relevant Aim 6 Statement as found in the IBO Physics Guide. 	2F	Static and kinetic friction
			2G	Static equilibrium
	2.3	Discussing the conservation of total energy within energy transformations	2H	Propulsion using elast potential energy
		Quantitatively describing efficiency in energy transfers And the relevant Aim 6 Statement as found in the IBO Physics Guide.		
	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 	21 2J	Energy and impulse Investigation circus
		 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. 		
3	3.1	 Describing temperature change in terms of internal energy Applying the calorimetric techniques of specific heat capacity or specific 	3A	Conservation of thermal energy
		 Describing phase change in terms of molecular behaviour 	3B	Specific heat capacity of a metal
		 Sketching and interpreting phase change graphs Calculating energy changes involving specific heat capacity and specific latent heat of fusion and vaporization 	3C	Latent heat of fusion of ice
		And the relevant Aim 6 Statement as found in the IBO Physics Guide.		
	3.2	 Solving problems using the equation of state for an ideal gas and gas laws 	3D	Universal Gas Law determination
		 Sketching and interpreting changes of state of an ideal gas on pressure– volume, pressure–temperature and volume–temperature diagrams 	3E	Boyle's Law determination (data-
		 Investigating at least one gas law experimentally And the relevant Aim 6 Statement as found in the IBO Physics Guide. 	3F	based) Charles' Law and Pressure Law determination (data-
			3G	based) Zartmann Investigation

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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 14B 14C	Moment of inertia Translational equilibrium Biomechanics
С	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 Sketching and interpreting HR diagrams	15B 16A	The refracting telescope Hertzsprung-Russell
D	D.2	•	Identifying the main regions of the HR diagram and describing the main properties of stars in these regions	5	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
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Biology Investigations

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Investigation 2F STATIC AND KINETIC FRICTION

Syllabus relevance: 2.2 Skills and Alm 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.

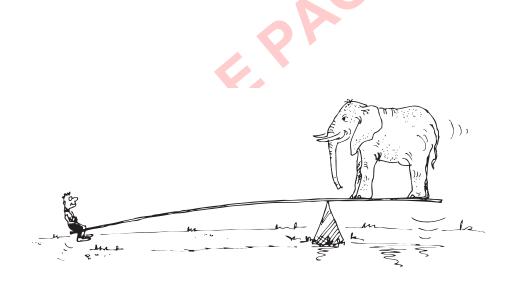
Investigation 2G STATIC EQUILIBRIUM

Syllabus relevance: 2.2 Skills and Alm 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.



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