# PHYS1001 – PL3. Queensland Police Forensics Lab: Measuring coefficients of friction

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| **Student Number:** | **4803050** | **Date:** | **10/4/24** |
| **Other Group Members: Emily Cooke** | | | |

**Your worksheet will be given a Satisfactory/Unsatisfactory mark. To hand in your work, upload your worksheet at the Blackboard link under Learning Resources** *>* **Laboratory /**

**Practicals.**

1. **If you are finished in class, first show your worksheet to your tutor for on-the-spot marking, then upload your worksheet (we need this for record-keeping).**
2. **If you are not finished by the end of class, you must show your work to your tutor and ask for permission to upload your worksheet after class for marking and record-keeping. If you are granted permission you have 24 hours after the end of your class to do so.**

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| **Today’s aim:** | Devise a method for testing a hypothesis |
| **Overall mark:** | **Satisfactory (1)** □ **/ Unsatisfactory (0)** □ |

A satisfactory submission will generally exhibit the following criteria - if unsatisfactory, tutors will indicate which are missing:

* Communication & Presentation
  + Neat presentation and intelligible writing
  + Clear calculations
  + Clear writing, logical flow of ideas, and good grammar.
  + Coherent data presentation in tables and graphs with suitable labelling. **–** Completeness
* Scientific Method
  + Quality of data and record keeping indicates appropriate care in experimental process
  + Methods used are appropriate for the experiment
* Uncertainty
  + Uncertainties in raw data estimated and **justified**.
  + Correct use of significant figures and units.
  + Propagation of uncertainties.
* Analyse & Assess
  + Analyse the data and come to correct scientific conclusions
  + Critical evaluation of results
* Actively contributed to group (noting that participation looks different for everyone)
* Presented original work

If you receive a mark of Unsatisfactory, please email us to book a time for another attempt!

# A Practical Lab 2 – Queensland Police Forensics Lab

In this practical lab, you will combine several physics concepts and experimental measurements to produce a single estimate of the coefficient of kinetic friction and its associated uncertainty.

## Background

The Forensics Lab of the Queensland Police is interested in relating the length of skid marks to the speed of a vehicle before it started skidding. Your lab group is asked to devise a procedure to determine the coefficient of friction between the tyre rubber and the asphalt using a collision process. They have also asked you to record your experiment with sufficient details so that they can replicate it.

You come up with the following prototype of the experiment with cheap materials: A pendulum bob swings down from a horizontal starting position and hits a box. The box slides across the table and eventually stops. This process resembles a car collision, and the distance that the box slides on the table is similar to the skidding of a car after a collision. You decide to make measurements concerning the above process and use your physics knowledge to determine the coefficient of kinetic friction between the box and the table surface.

*Available equipment:* Plastic storage box, pendulum with bob, wooden rails for the box, dressmaker’s tape, spring balance, meter rule, and scales.

## A.1 Learning Objectives for this Practical Lab

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| Physics concepts you will use:   * Conservation of energy * Conservation of momentum * Friction | Lab skills you will practice:   * Apparatus design * Breaking an experiment into parts * Uncertainty estimation |

• Multi-step uncertainty propagation

## A.2 THEORY

This experiment will require you to combine a few different physics concepts. Start by making a rough plan for how you will solve the problem. In particular, divide the big problem into two or more smaller problems that each involve one basic physics concept.

You must devise your own mathematical procedure to move from the physics of a pendulum to the calculation of the coefficient of kinetic friction *µk*. Recall that the force due to kinetic friction, *Fk*, is determined by

*Fk* = *µkN,*

where *N* is the net normal force. You will be prompted to identify the necessary equations and draw the system with any important variables labelled.

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| Material | Coefficient of Kinetic | Material | Coefficient of Kinetic |
|  | Friction, *µk* |  | Friction, *µk* |
| Rubber on dry concrete | 0.80 | Steel on dry steel | 0.60 |
| Rubber on wet concrete | 0.25 | Wood on wood | 0.20 |

Table 1: Coefficients of Friction (*Physics for Scientists and Engineers* (4th Ed), R. Knight).

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| **Box 1: Diagrams** Draw FOUR diagrams, labelling the important physical quantities such as lengths, masses and velocities. Hint: use subscripts for variables to indicate which object they belong to.   1. At the start of the experiment 2. Just BEFORE the collision 3. Just AFTER the collision   At a convenient time after the box has stopped moving (remember that the pendulum will probably still be swinging!) |
| **Box 2: Conservation Laws** For the diagrams you drew above, what conservation laws are applicable for each of the transitions between diagrams: (a) 1 to 2, (b) 2 to 3, and (c) 3 to 4? Make sure you include any assumptions you need to make in order to use these laws. |

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| **Box 3: Mathematics** Explain your mathematical procedure to move from the physics of a pendulum to the calculation of the coefficient of kinetic friction, *µ*k. Be concise, using short sentences or dot points, and include equations. Refer to your diagrams (or draw any additional ones) as necessary.  **Warning: Avoid using angles in your equations. If you cannot think of how to do this, ask your tutor for advice.** |

**CHECKPOINT: Stop here and describe your conservation laws and mathematical procedure to a tutor before proceeding.**

## A.3 METHOD – Devising a procedure

Now that you’ve broken down the problem into components, you must devise a procedure for taking the measurements you need at each step, and identify how you will minimise the uncertainties.

Before taking any measurements, play around with the apparatus and think about where uncertainties will arise.

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| **Box 4: Assumptions:** What assumptions are you going to make about the experiment? What quantities are you going to need to determine/measure experimentally? |

Have a think about the following points (keep your own rough notes in preparation for the method and analysis you will be writing up).

* How long would you have make the pendulum? Why?
* What initial amplitude would you choose? Why?
* Will you need repeated experimental measurements? How many times?
* How are you going to estimate the uncertainties in the quantities you are going to measure?

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| **Box 5: Method** Now that you have made decisions about the ideal procedure, write up the actual method you will use. You may write in paragraphs or dot points, but you must use full sentences. Remember a method is not only a description of the steps you take, but also a justification of those steps. It is more than just a set of instructions. (It may be helpful to structure your method around your mathematical procedure.)  The experimental method consisted of the setup shown in figure 1. A wire of length 30cm was tied to a mass of 0.27kg and on the other end a retort stand. The retort stand claw was positioned at a height such that the mass hung to the midpoint of a tissue box placed on the floor. Two supporting lengths of wood were placed to ensuring that the tissue boxes motion was as straight as possible, minimising loss of energy to an unwanted direction of motion. A meter long ruler was used to measure both the horizontal displacement of the tissue box, in addition to the height at which the pendulum mass was dropped.  The experiment was conducted by pulling the pendulum up to a starting 90 degrees, such that its drop height was approximately 0.38m. The rope was intentionally pulled with tension to ensure no non-uniform ‘drop’ took place. This pendulum then swung and hit the tissue box, forcing it down the wooden tracks. The displacement of the tissue box was then recorded. 5 trials of this experiment were conducted in order to minimise random error in the results.  The values for the initial height, the mass of the pendulum and tissue box, and the displacements of the tissue box were then used to calculate an experimental value of kinetic friction, according to the formula: |

**CHECKPOINT: Stop here and describe your method to a tutor before proceeding.**

## A.4 RESULTS – Recording measurements and propagating uncertainties

Begin your experiment. Remember to use significant figures when recording your measurements.

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| **Box 6: Results** - Record all your measured controlled variables and their uncertainties, then create a table to record the rest of your data. Make sure to justify all uncertainties stated.    The raw data was recorded as previewed in table 1.   |  |  | | --- | --- | | Trial | X (m) | | 1 | 40 x 10^(-2) | | 2 | 32 x 10^(-2) | | 3 | 32 x 10^(-2) | | 4 | 45 x 10^(-2) | | 5 | 34 x 10^(-2) |   Although half the smallest increment of the meter ruler was 0.0005m, this uncertainty was unjustified as we had to ‘eyeball’ from the ruler to the boxes back position. We therefore set a more reasonable uncertainty of 0.01m for the x value. |

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| **Box 7: Analysis** - Using your data, perform all necessary calculations to obtain *µ*k. Remember to propagate your uncertainties as you go, and to explain what you are doing in words. Mathematical working alone is not acceptable! You can assume *g* = 9*.*8 m.s−2 is a constant with no uncertainty.  The results from the table of raw data were then used to calculate an experimental result for kinetic friction and its corresponding uncertainty. A sample of the calculations is given below.  Image preview |

## A.5 RESULTS – Discussion

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| **Box 8: Discussion**  Restate your final result for *µk*. Make sure you use significant figures, uncertainties and units. It is essential that you assess your result, to make sure it seems reasonable. This will save you from major errors. Is your result for *µk* reasonable? How do you know?  The experiment concluded that the kinetic friction (µk) table and the tissue box was 1.0±0.6. This is easily assessable. Reasonable values for kinetic friction usually sit between 0-1, therefore, it is plausible that our value of 1 is fairly reasonable. Although mildly reasonable the experimental value of kinetic friction was extremely susceptible to error. This was evident in the large range of values for the displacement of the tissue box, likely due to not all the energy of the pendulum being transferred into the moving component of the tissue box. |

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| **Box 9: Consequence Question** Now that you have completed your investigation, it is time to answer the Queensland Police Service’s question: ‘How do you relate the length of a skid mark to the speed of the vehicle before it began to skid?’ and explore the consequences of the uncertainty in our measurements. The coefficient of kinetic friction, *µ*k = 0*.*8±0*.*1, and the car left skid marks 42*.*0±0*.*5 m long. What was the initial speed of the car and what is your uncertainty on that value?  If the speed limit was 80 km/h, and the tolerance*a* for speeding is 2 km/h, can you say with any certainty that the driver was speeding?  *a*This is not the true value used by the Queensland Police. Don’t speed, and don’t drink and derive. |

# END OF PRACTICAL LAB 3