

Lab 5: Circular Motion

LEARNING GOALS OF THIS LAB:

- 1) Use your knowledge of Newton's laws and circular motion to make a prediction about the outcome of an experiment.
- 2) Apply your knowledge of Newton's laws to solve a practical problem.
- 3) Use two independent methods to determine a quantity experimentally.
- 4) Evaluate simplifying assumptions that you use in your mathematical procedure.

I: Testing experiment: Circular motion, Pendulum

The goal of this experiment is to decide whether we can trust Newton's laws when an object is in circular motion.

Available equipment: a scale, a pendulum, a spring scale.

- a) Attach the pendulum bob to the spring scale. Let it hang freely and notice the reading of the spring scale. Explain the reading using a free body diagram for the bob. What force does the spring scale read? Explain.
- b) Now imagine that you pull the bob to the right and let it swing (do not perform the experiment yet). Use your knowledge of Newton's second law applied to circular motion to draw a velocity subtraction diagram and a free body diagram for the bob at the bottom of the swing. Make sure that the diagrams are consistent with each other.
- c) Now use the diagrams to predict whether the scale will read the same, more or less when the bob is at the bottom of the swing compared to when it is at rest. What are your assumptions?
- d) *Explain to Saalih why you need to make a prediction before performing the experiment.*
- e) Now perform the experiment and record the result. Did it match the prediction? If not, should you modify the idea under test or your application of this idea to this particular situation, or your assumptions?
- f) *Why was this experiment called a testing experiment? What physics idea were you testing?*
- g) *How are an explanation or an idea different from a prediction?*

II: Application experiments: Circular motion, Conical pendulum

Self-assessment

G1, G2, G3, G5, D5

Experiment

A conical pendulum is different from a regular pendulum that you used in experiment I. Instead of moving back and forth in a vertical plane, its bob moves in a horizontal plane following a circular path. The string follows a path of an inverted cone. Before you read on, set up a conical pendulum on your table and then call the instructor to check your set up.

Design two independent experiments to determine the magnitude of the net force exerted on a conical pendulum bob by other objects as the bob of the pendulum moves in a circular path.

Available equipment: A ring stand, a heavy bob at the end of a string, a meter stick, a spring scale, a stopwatch, a poster paper, a marker.

Include in your report for each experiment:

- a) Describe your experimental design. Include a labeled diagram.
- b) Devise a procedure that you will use to determine the net force.
- c) List the pieces of knowledge that you are going to apply to find the net force on the bob.
- d) List the physical quantities you will measure. Briefly (but specifically) describe how you will measure them. For example, if you are measuring the length of the pendulum string, mention which point on the bob you consider – the top of the bob, the center of the bob, or the bottom of the bob.
- e) List additional assumptions that you made. Explain how each assumption can affect the result.
- f) List sources of experimental uncertainty, and possible methods to minimize them. Evaluate how experimental uncertainties can affect the data.
- g) Perform each experiment and record the data. Make sure you take steps to minimize experimental uncertainties.
- h) Determine the net force based on your procedure and measurements. Use the weakest link rule to determine the uncertainty in the outcome.
- i) After you have performed both experiments, compare the two values you obtained. Decide if these values are different or not. If they are different, discuss possible reasons for the difference (think of the effects of your assumptions).
- j) *In one of the experiments you probably tried to get the bob to move in circle. However you noticed that the path that the ball followed was not an exact circle – it looked more like an ellipse. Compare the net force exerted on the bob at different points of the trajectory (try to make the comparison quantitative). Now think whether the assumption that the path is circular makes you overestimate or underestimate the average net force.*

III. Why did we do this lab?

- a) *Explain how your understanding of physics or scientific abilities is different now compared to before the lab.*
- b) *What would you improve in this lab?*

IV. Homework

This homework will help you to understand the different stages of the construction of scientific knowledge. Read the following passage focusing your attention on the scientific procedures and scientific abilities. Please complete before coming to lab 6.

Ignaz Philipp Semmelweis studied medicine at the University of Vienna where in 1844, at the age of 25 he received the degree of Doctor of Medicine. Later in the same year he qualified for the degree of Master of Midwifery, and from that time forward devoted the remainder of his life to the science and practice of Obstetrics. Upon receiving his Master's degree he at once applied for the position of Assistant in the Lying-In Division of the huge Vienna General Hospital, and was eventually appointed to that post.

The General Hospital's Lying-In Division was the largest of its kind in the world. It was also one of the most deadly due to prevalence among its post-partum patients of what was known as "the endemic puerperal fever of Vienna."

The sensitive and deeply humanitarian Semmelweis was appalled by the death rate from puerperal fever in the Lying-In Division, and searching for the cause and control of this pitiless disease became his life's work. For a laboratory he had the First and Second Obstetrical Clinics, each averaging about 3000 deliveries per year. When he tabulated the deliveries and deaths by month and year in each of the Clinics for the six-year period from 1841 to 1846, he found that the First Clinic, where medical students were trained, had a death rate from puerperal fever of 9.9%; whereas, the death rate in the Second Clinic where midwives did the deliveries was 3.3% - only one-third that of the First Clinic. It would be too chilling to list the grotesque explanations offered by the medical "authorities" and a government commission in Vienna to account for the evil reputation of the First Clinic where patients were in mortal fear to go because they believed that a doctor's interference was always the precursor of death.

These circumstances were especially troubling to Semmelweis for he himself had been in charge of the First Clinic since February of 1846, and the high death rate persisted in spite of all his efforts. He had studied the problem from every angle in the wards. He also frequented the pathology department where he participated in the post mortem examinations of the many victims, becoming increasingly mindful of the nauseous fetor that clung to his hands and clothes long after an autopsy. By 1847 there was no one in Vienna with greater knowledge of endemic childbed fever than Semmelweis, and his mind was prepared to grasp the solution to the mystery of its cause when chance provided the clue - as it soon did in the sad loss of a dear friend, Dr. Kolletschka, who died of infection.

Jakob Kolletschka, a 43 year-old Professor of Forensic Medicine, was a former teacher and friend whom Semmelweis held in the highest esteem. Kolletschka's death early in 1847 from a scalpel wound, incurred during an autopsy, and had a profound effect upon Semmelweis who assuaged his anguish by studying in detail the reports of his friend's fatal illness and autopsy. These records disclosed that after a puncture wound in his finger from the knife of one of his pupils, Kolletschka developed

lymphangitis and phlebitis in the same upper extremity. From there the infection spread. He developed pleurisy, pericarditis, peritonitis, and meningitis; and a few days before his death an abscess occurred in one of his eyes. This generalized dissemination of infection was exactly the same that Semmelweis had seen at autopsy in women who died of puerperal fever. A new thought was forced upon his mind with irresistible clarity - the disease from which Kolletschka died was identical with that from which he had seen so many hundred women die.

Semmelweis recognized the similarities between this accidentally acquired infection and puerperal fever. From time immemorial, pyemia had stalked the deadhouses as a dreaded foe of all anatomists, pathologists, surgeons and others who dissected. It was well known that a swiftly fatal infection might follow even the slightest prick of a knife or needle during anatomical dissection, autopsy, or an operation such as amputation of a gangrenous limb. It was the genius of Semmelweis to derive from this observation a new principle of prophylaxis and, by experiment, to demonstrate its validity.

Semmelweis designated the causative agent as "cadaveric particles" that enter the circulation after being introduced by the knife in the case of pathologist's pyemia. In puerperal fever, the particles are introduced into women in labor by students and others who do vaginal examination with hands contaminated by such particles during autopsy or anatomical dissections, or during examination of patients with puerperal fever or other infections. Contaminated instruments and bedclothes might also transfer the causative agent. He also observed:

Owing to a filthy discharge from an ulcer on the leg in one of the patients, several women who were confined at the same time were infected. Thus, therefore, the conveyance of a foul exudation from a living organism may be one cause which produces the puerperal process.

By this conjecture Semmelweis is thought by some to have foreshadowed the germ theory by proposing that, while puerperal fever is in most cases a cadaveric infection, it is sometimes traceable to other sources, i. e., to a "living organism."

Now the explanation for the higher mortality from puerperal fever in First Clinic became obvious to Semmelweis - medical students and doctors carried cadaveric particles to the patients on hands contaminated at post mortem dissections. In Second Clinic the midwives, who did no dissections, were not thus contaminated.

Semmelweis knew that soap and water would not dispel it. However, he found a solution of chlorinated lime to be effective and therefore chose it as the decontaminant. Placards with the following directions were posted conspicuously in the wards:

All students or doctors who enter the wards for the purpose of making an examination must wash their hands thoroughly in a solution of chlorinated lime which will be placed in convenient basins near the entrance of the wards. This disinfection is considered sufficient for this visit. Between examinations the hands must be washed in soap and water.

The experiment was successful. Within a few months, the mortality rate in First Clinic was no greater than in Second Clinic, and remained so as long as Semmelweis's directions were strictly followed. In 1848, the first full year in which the chlorine-washing was carried out assiduously, 45 out of 3556 women died of puerperal fever in the First Clinic for a mortality of 1.27 %. In the Second Clinic, during the same period, 43 died out of 3219 died, or 1.34%. These results were a clear validation of the concept and method of prophylaxis which became known as the Semmelweis "doctrine."

Extracts from John L. Wilson, M.D. *Stanford University School of Medicine and the Predecessor Schools: an historical perspective*. (Chapter five.) John L. Wilson, M.D.
<http://elane.stanford.edu/wilson/>

Reread the passage and answer the following questions.

- 1) What was Dr. Semmelweis' first step in his quest for a way to reduce the large postpartum rate?
- 2) What observations did Dr. Semmelweis conduct? Were they qualitative or quantitative?
- 3) Did Dr. Semmelweis find any patterns?
- 4) How did Dr. Semmelweis explain his observations?
- 5) How did he check the correctness of his explanation?
- 6) What did Dr. Semmelweis' hypothesis predict that would happen if medical students would wash their hands with a chlorinated lime solution before helping deliver babies?
- 7) What outcome of the experiment would have ruled out Semmelweis' explanation?
- 8) The passage illustrates the construction of scientific knowledge, but only part of the cycle of scientific research was reproduced. What elements of cycle can you identify?