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, STANDARD PENDULUM

The goal of this experiment is to test whether Newton's laws apply to an object in circular motion.

Available equipment: Digital scale, pendulum, spring scale, string, ring stand, clamp

a) Attach the pendulum to the spring scale. Let it hang freely and notice the reading of the spring scale. Explain the reading using a force diagram for the pendulum bob (a 'bob' is what the object attached to the end of the pendulum string is called). Which force is the spring scale measuring? Explain.
b) Now imagine that you pull the bob to the right and let it swing (do not do this yet). Draw a motion diagram for the pendulum bob from just before it reaches its lowest point to just after it passes its lowest point. Next, draw a force diagram for the pendulum bob right at the moment it is at its lowest point. Make sure that the two diagrams are consistent with each other. Hint: What's the connection between the motion diagram and the force diagram?
c) Think about the moment when the pendulum bob is at the bottom of its swing. Use the diagrams to predict whether the scale will read a greater value, smaller value, or the same value compared to when the pendulum is at rest.
d) How is a hypothesis different from a prediction?
e) Why is it important to make the prediction before performing the experiment?
f) What assumptions did you make when you made the prediction?
g) Now perform the experiment and record the result. Was the outcome consistent with the prediction? If not, was it because 1) the hypothesis needs revision so it applies in this situation, 2) there was a problem with the way you made your prediction, or 3) one of the assumptions you made in making the prediction wasn't reasonable? Explain.

II: APPLICATION EXPERIMENT: CONICAL PENDULUM

A conical pendulum is different from the 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. Another way of visualizing this is the string sweeps out a cone.

RUBRIC D: Ability to design and conduct an application experiment					
Scientific Ability		Missing	Inadequate	Needs some improvement	Adequate
D4	Is able to make a judgment about the results of the experiment	No discussion is presented about the results of the experiment	A judgment is made about the results, but it is not reasonable or coherent.	An acceptable judgment is made about the result, but the reasoning is flawed or incomplete.	An acceptable judgment is made about the result, with clear reasoning. The effects of assumptions and experimental uncertainties are considered.

D8	Is able to identify the assumptions made in using the mathematical procedure	No attempt is made to identify any assumptions.	An attempt is made to identify assumptions, but the assumptions are irrelevant or incorrect for the situation.	Relevant assumptions are identified but are not significant for solving the problem.	All relevant assumptions are correctly identified.
D9	Is able to determine specifically the way in which assumptions might affect the results	No attempt is made to determine the effects of assumptions.	The effects of assumptions are mentioned but are described vaguely.	The effects of assumptions are determined, but no attempt is made to validate them.	The effects of the assumptions are determined and the assumptions are validated.

RUBRIC G: Ability to collect and analyze experimental data					
Scientific Ability		Missing	Inadequate	Needs some improvement	Adequate
G2	Is able to evaluate specifically how identified experimental uncertainties may affect the result	No attempt is made to evaluate experimental uncertainties.	An attempt is made to evaluate experimental uncertainties, but most are missing, described vaguely, or incorrect. Or only absolute uncertainties are mentioned. Or the final result does not take the uncertainty into the account.	The final result does take the identified uncertainties into account but is not correctly evaluated.	The experimental uncertainty of the final result is correctly evaluated.
G3	Is able to describe how to minimize experimental uncertainty and actually do it	No attempt is made to describe how to minimize experimental uncertainty and no attempt to minimize is present.	A description of how to minimize experimental uncertainty is present, but there is no attempt to actually minimize it.	An attempt is made to minimize the uncertainty in the final result is made but the method is not the most effective.	The uncertainty is minimized in an effective way.

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

Available equipment: Ring stand and accessories, masking tape, clamp, pendulum, a meter stick, a spring scale, stopwatch, sugar packets, motion sensor, computer w. Logger Pro software, digital scale

Include the following in your writeup (c-i are for each experiment. J-k are for after you have performed both experiments):

Getting ready for the symposium: As you work through this experiment create a condensed version of your lab writeup on the whiteboard (you will hand in the full version along with the rest of your work). Be as neat and organized as you can since later on other groups will need to understand your work.

a) What is meant by 'independent'? Why is it important for the two experiments to be independent? Why is it important to perform two experiments in the first place?

b) Brainstorm several possible experiments and write describe each in a few sentences. Describe the pros and cons of each. Consider these pros and cons and choose the two experiments you will perform. Call your TA over and discuss your experiments with them.
c) Describe your experimental design. Include a labeled diagram.
d) Explain the mathematical procedure that you will use to determine the net force exerted on the pendulum bob.
e) What physical quantities will you 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.
f) What additional assumptions are you making in your mathematical procedure? Explain in detail how each assumption might affect the result. (Meaning, will the assumption cause the result to be larger than the actual value, smaller than the actual value, or have a random effect? Explain how you decided.)
g) List sources of experimental uncertainty and describe how you will minimize them.
h) Perform the experiment and record the data. Make sure you take steps to minimize experimental uncertainties.
i) Use your mathematical procedure to determine the net force. Use the weakest link rule to estimate the uncertainty in your result.
j) After you have performed both experiments, compare the two values you've obtained. Decide if these values are consistent or not. If they are not consistent, discuss possible reasons. *Hint: Think about the assumptions you made.* Why can't you use experimental uncertainty to explain why two values aren't consistent?
k) In one of the experiments you probably tried to get the bob to move in circle. However you probably 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. This requires a fairly challenging bit of reasoning. Once you think you have given it your best shot, call your TA over and discuss it with them.

Symposium

Once your TA gives the signal, choose half of the table to get up and move around to the other tables. Their goal is to see what other groups have done and to get in discussions when what they did differs from what you did. The goal of the other half of the table (the half that stays behind) is to have discussions with people from the groups as they visit.

Once you have visited the other tables and given/received help get back together with your group and discuss what you learned and make revisions to your work.

III. WHY DID WE DO THIS LAB?

1. Explain how your understanding of physics and scientific abilities is different now compared to before the lab. Be specific.
2. Why is it important to determine the specific effect that making an assumption will have on the outcome of your experiment?
3. What could you do to improve your design for experiment II?

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.

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/

> 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."

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?