Physics 7B

DLM 18 Overview

Model: Simple Harmonic Motion

Act 7.2.4 The Physics of Simple Harmonic Motion (~ 60 min)

Learning Goals:

- Develop understanding of how position, velocity, and acceleration are related in SHM
- Understand the defining equation for SHM
- Understand how force and displacement are related if there is SHM
- Know how the period of SHM is related to the physical properties of a mass-spring system
- Understand why SHM is so universal

Act 7.2.5 The Physics of a Pendulum (~ 60 min)

Learning Goals:

- Develop understanding of how position, velocity, and acceleration are related in a pendulum.
- Understand the defining equation for SHM of a pendulum
- Understand how force and displacement are related for a pendulum
- Understand why SHM is so universal

End of quarter evaluations (~20mins)

Announcements

- **Final exam will be given at 10:30 am on Monday March 19**. You must bring a picture ID. Show up at least 20 minutes earlier, so you can get a good seat and start on time and not wait in line.
- **The exam rooms will be:**
  DL sections 1-3 Chem 179
  DL sections 4-11 Chem 194

The Physics of Simple Harmonic Motion (FNTs 1, 2 & 3)

A) The mathematical description of the velocity and acceleration of an object in SHM

In your small group

1) Put up on the board your responses to FNTs 1 and 2. **But don't put up the graphs:** see 2) below

2) a) Make a separate graph of *y*(t), *v*(t), and *a*(t). Stack them with the position on top, then the velocity in the middle and the acceleration at the bottom. Make the time axes exactly the same, and mark the time axes off and label every quarter of a period (how much does $(2\pi t/T + \phi)$ change during one quarter of a period?).

   b) In your own words, describe on the board the motion at each quarter of the period for each of the three graphs.

   c) How is it that the mass can have no acceleration at the equilibrium point yet still be moving in a particular direction?

Whole class discussion

B) The defining equation for SHM

In the last part of FNT 2 you found that the acceleration is directly proportional to the displacement from equilibrium, but points in the opposite direction. But we also know that the acceleration is the second derivative of the position. So we can write this expression as

$\boxed{d^2y/dt^2 = - \text{constant } y(t)}$ This is the defining equation for SHM. A general solution that gives the position as a function of time is what we have been working with: $y(t) = A\sin\left(\frac{2\pi t}{T} + \phi\right)$

1) Compare and contrast the defining equation for SHM with the defining equation for exponential behavior. What is similar and what is different? Write out a sentence that gives the meaning of the defining equation for SHM and put it on the board.
2) In terms of the parameters appearing in the solution, the expression for *y*(t) above, what is the constant (in the equation above for d^2y/dt^2) equal to? Write this on the board.

Whole Class Discussion

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C) Connecting to real oscillations

Using the symbol a(t) for the acceleration as a function of time and the expression found above for the constant , the defining equation for SHM can be written

$$a(t) = -(2\pi/T)^2\, y(t)$$

1) Come to a consensus in your group on what the above equation means in words. Put this statement the board.

2) Re-write the defining equation above using Newton's 2nd law, substituting an appropriate expression involving ΣF and m for a(t). What does this relation tell you about the net force if the motion is going to be SHM. Write your response on the board.

3) Physically examine the mass-spring system. Does the net force acting on the mass "obey" the requirement in (2)? Explain.

4) Newton's 2nd law applied to the mass-spring system is $\Sigma F = -kx = ma$, where k is the spring constant. What is the period equal to in terms of k and m for a mass spring system?

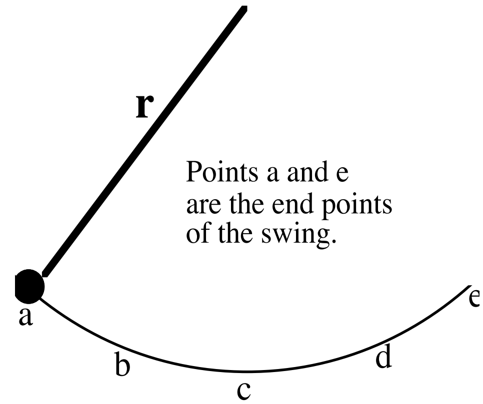
5) Is your expression for the period from part 4 consistent with your observations from 7.2.1?

Whole Class Discussion

The Physics of a Pendulum (FNT4 and Course Review)

Phenomenon:

Set up a simple pendulum using the ball and string. Observe its motion as it swings back and forth



Describe the Motion

A. Describe what the pendulum bob is doing in general everyday words as it makes a complete swing back and forth. Be specific. Refer to the five labeled points.

B. Write on the board your group's answer to FNT 4 part a. At which of the five labeled points did you assume you started your clock?

C. Determine what ϕ would be for each of the other labeled points.

Whole class discussion

D. Now describe the motion of the pendulum bob (ball) at the five labeled points. Draw on the board velocity vectors on a diagram of the motion as the ball moves from point *a* to point *e*. Describe in words how they change as the ball goes from point a to point e.

E. Elsewhere on the board draw two separate force diagrams of for the bob at position c and e. Also find the net force.

F. Compare your responses to FNT4 part f. Can you think of more than one way to determine acceleration vectors?

G. On the diagram of the motion draw the radial and tangential components of the acceleration, $\mathbf{a}_r$ and $\mathbf{a}_t$ at each of the five points. Make sure the lengths of your vectors are appropriately scaled from point to point. Does $\mathbf{a}_r$ and $\mathbf{a}_t$, or $\mathbf{a}$ follow the pattern of oscillations we just discussed in 7.2.4?

Whole class discussion

G. Is momentum conserved for this system? Create a momentum chart with at least three rows labeled a-b, b-c, c-d. Be able to explain what directions your vectors point in relation to you motion diagrams.

H. Is angular momentum conserved for this system? What direction does it point from a-c, c-e, and e-c?

Whole class discussion

A Combination of the two time-dependences of Unit 7. (If time permits)

I. As you surely noticed the pendulums in DL eventually stop swinging: the amplitude decays to zero.

i) If the amplitude becomes 37% as great from time $t = 0$ to $t = \tau$ and then dwindles to 13% when $t = 2\tau$ what type of behavior is this?

ii) Using $E(t) = E_0 e^{-t/\tau}$ solve for E_0 and plot amplitude versus time labeling τ and 2τ.

iii) Refer back to your previous oscillatory graphs and plot the pendulum's oscillation till time $t = 2\tau$.

iv) What properties do you think τ depends on?

v) How would the decay curve change if the time constant were doubled, or halved?

Physics 7B

Exit Handout

Check the 7B web page for updates & announcements.

Review Session (Extra) Office Hours

Normal office hours will continue through Monday, Dec. 11th. The review session office hours will be posted on the 7B webpage, and are listed below. Review sessions are for you to ask questions and get help problem solving. You can ask about material seen in lecture, DLMs, FNTs, and quizzes.

All Review Sessions will be held in the DL room (166 Roessler) according to the schedule below: (also check web page for updates)

Thur, Mar. 15th	**Rm 166**
10:30 am – 12:30 pm	John Terning
4:30 – 6:00 pm	Daniel Phillips
7:00 – 8:30 pm	John McRaven

Fri, Mar. 16th	**Rm 166**
9:00 am – 10:30 am	Jim Ma
10:30 am – 12:00 pm	Donna Joliff
2:00 – 3:30 pm	Marcus Afshar
3:30 – 5:30 pm	John Conway

<u>Picking up quizzes</u>

Quizzes and re-grades will be available for you to pick up in the DL room during the extra office hours starting on Friday, Dec. 12th. They will be sorted by section number.

<u>Check your quiz grades</u>

Quiz grades (and updates) are be posted on the Physics 7B web page. You should check ASAP and make sure your scores listed there have been correctly recorded.

<u>Quiz re-evaluation requests</u>

Re-evaluation requests for quizzes can be turned in before the final.

****Final Exam****

Monday March 19, 10:30 am to 12:30 pm in Chem 179 (DL sections 1-3) or Chem 194 (DL sections 4-11)

Arrive early---by 10:10 am and bring a picture ID so that we can check you in at the doors.