PHYS 121: Homework #01 and Reading Assignment

16 January 2024

This Written Homework is due Monday, January 29, at 11 PM and must be submitted online as a SINGLE CLEARLY LEGIBLE PDF file via Canvas.

Physics 121: Spring 2023: Week 1 Reading assignment:

REQUIRED: Read P121 Course Documents #01, #02, #03, #04, and #05 which you can find in the Modules section of the PHYS 121 Canvas Page.

- These five documents are packed with important information so I am asking all students to take some time to at least look through each of these by tonight. Make yourself a cup of tea. Don't put it off!

REQUIRED: ***Physics 121 Online Class Notes*** **Cycle 1, Chapters 0 through 5 and 9, posted on the Canvas, as follows:**

- **Read Chapter 0:** This is the whole course in a nutshell. Newton's Second Law governs everything we do for the whole semester.
- **Read Chapter 1:** Read pages 1-1 to 1-6 fairly carefully. Skim pages 1-7 to 1-9, since we will be going back to relative velocity later in the semester. Note that we will assign *some* but not *all* problems that you find in the notes.
- **Read Chapter 2:** This idea is of the relationship between position, velocity and acceleration in 1-D is the most important idea of the whole week.
- **Read Chapter 3:** This is good stuff! Conceptually it's very important to understand projectile motion as a *kinematic* concept.
- **Read Chapter 4:** We will be looking gravity as a thread, so it's good to see it so early in the course. Skim page 4-4 since we will contend with Kepler's Laws at a later time.
- **Read Chapter 5:** Okay, now we look at Newton's Second Law in some detail using the idea of pushes, pulls, and weights. This is the heart of inc Newtonian Mechanics and at some level, having learned how to do this, everything else in the course follows as a logical consequence.
- **Finally slightly "out of order" Read Chapter 09:** We want to get an "early look" at the concepts of Work, Kinetic and Potential Energy, and the Conservation of Mechanical Energy

Physics 121: Spring 2024: Homework #01

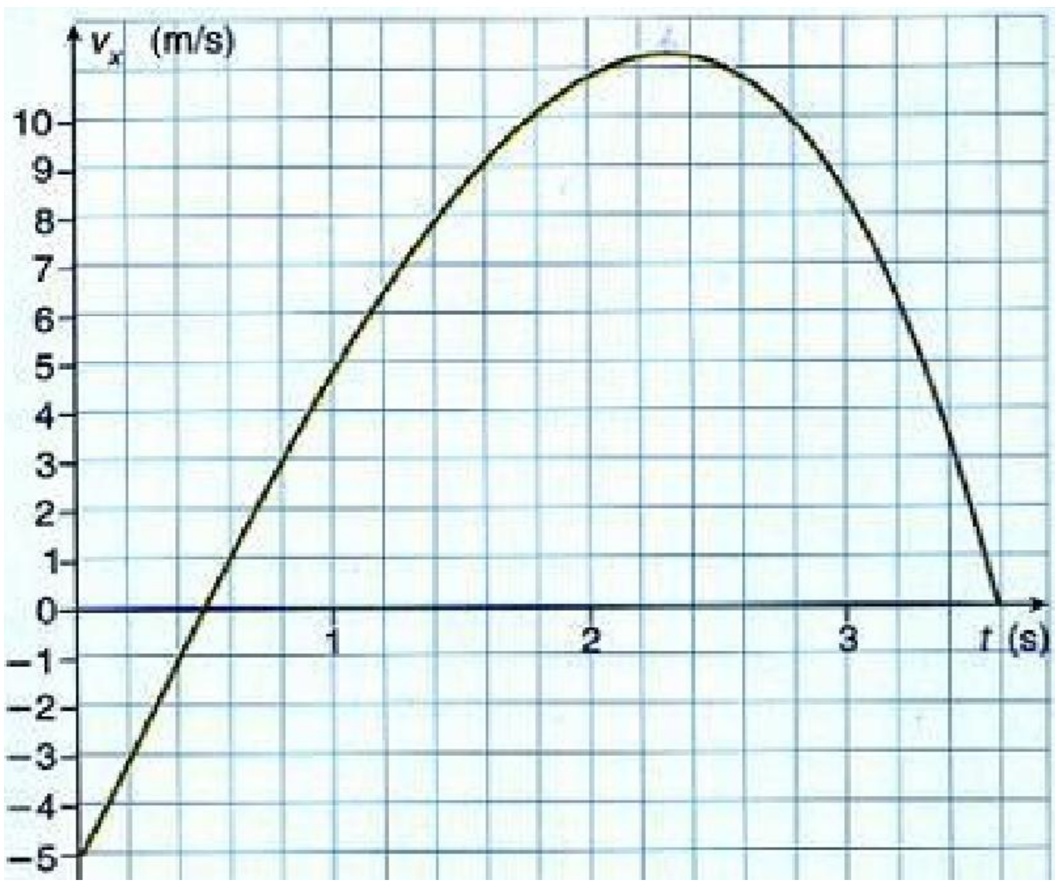
The Homework is due as as scanned PDF file via Canvas by
11 PM Monday January 29, 2024

Important! Read Course Document #03: Homework Guidelines before you start this homework assignment!

Important note: The Written Homework will be graded on a scale of 0 to 15 points. **Not all problems will be graded. Only a subset of the assigned problems will be graded.**

Homework continues next page....

Problem 1. The 1-D velocity of a particle is graphed in the figure below as a function of time. Answer each of these questions. **Explain carefully and completely** your answer for each part. Important: You are **obligated to explain** how and when you use detailed information from the graph. For example, if you you use the slope of the graph at some point, you need to explain which point(s) you are measuring the slope at and you need to show your **calculations** for determining the value of the slope.



Important: *You must* **not** *assume any specific analytical functional form for this graph.* Maybe this curve sort of looks like a parabola perhaps. Maybe not. But you cannot rely on this being true to solve this problem. This means that you must use graphical – and not analytical – methods to solve this problem.

Problem 1 continues....

Please answer **all** of the following questions regarding the graph shown on the previous page. **Important! You must explain your answers with a sentence or two telling the grader how and why you got the answer you have. Also, if you use information from the graph to answer the question, you must show a sketch or a marked copy of the graph that indicates how you used the graph. For example, if you calculate a slope, you need to show us a sketch that indicates how you measured (ideally with a ruler) the quantities that go into your calculation for the slope.**

- **Part (a):** Three students make statements:

  Student 1: *"At time $t = 0$ we know the particle has zero velocity because particles must start at rest."*

  Student 2: *"No, you are wrong. In fact at time $t = 0$ we know the particle is already moving in the negative direction. In fact the particle is slowing down."*

  Student 3: *"No, you are both wrong. At time $t = 0$ the particle is speeding up. We know this because the slope is positive."*

  Only one of these three students is correct. Which student is correct and why? Explain your answer.

- **Part (b):** Is the acceleration of the particle constant during this the entire interval shown here? How do you know this? Explain your answer.

- **Part (c):** Consider the following equation:

  $$x(t) = x_0 + v_0 t + \frac{1}{2}at^2$$

  In principle, can we apply this equation to describe the motion of the particle during this entire interval? Yes or No? How do you know this? Explain your answer.

- **Part (d):** Are there one or more instants in time that corresponds to **zero acceleration** of the particle? If so, indicate the time(s) (in seconds) and explain: How do you know that the indicates time(s) corresponds to zero acceleration? Very important: Explain your answer.

- **Part (e):** Is there any single instant in time that corresponds to the **minimum position** of the particle? If so, what time is this and how do you know that this is the minimum position? Explain your answer.

- **Part (f):** Estimate the acceleration of the particle at the instant corresponding to $t = 1.0$ seconds. Important: You **must** explicitly show your numerical calculations in a complete way and you must explicitly reference the graph to explain **how in terms of some graphical method** you used the graph to calculate this. Be careful with the units!

- **Part (g):** Harder and more time consuming: Estimate the *final position* of the particle $x(t)$ at time $t = 3.6$ seconds relative to the initial position $x = 0$ at $t = 0$ seconds. There are several approximately correct graphical ways to do this. As long as you are consistent, any method that gives reasonable accurate results is acceptable. Again, you must use words and **use the graph** to explain **how in terms of some graphical method** you you calculate this. Clearly demonstrate to the grader how you obtained your answer. Be careful with the units!

(Homework assignment continues next page...)

Problem 2.

A heavy package of given mass M is released at rest to fall straight down from a hovering helicopter located at a given height H meters from the ground.

- **Part (a): –** How much time t will pass from when the package is released to when it hits the ground? Important: use the equations of Free-Fall Kinematics to solve this problem *symbolically* in terms of the given parameters. Here the given parameters are M and H. You can also always assume that any physical constants such as g are also given). Assume you an ignore air resistant. Explain what you are doing. Show your work.
  $\boxed{\text{Put a box around your final symbolic answer.}}$

- **Part (b): –** How fast will it be moving at the instant just before it hits? Again, use the equations of Free-Fall Kinematics to solve this problem *symbolically* in terms of the given parameters. Explain your work.
  $\boxed{\text{Put a box around your final symbolic answer.}}$

- **Parts (c): –** Now suppose you are told that the mass of the heavy box is specified as M=47.84 kilograms and the release height of the helicopter is given as $H = 52.8$ meters. Plug these numbers into the symbolic answer you just obtained above to calculate the speed of the box *numerically*. Be sure to take care with significant digits and physical units.
  $\boxed{\text{Please put a box around your numerical answer.}}$

Important! The method outlined here is how we want you to solve every "story problem" in this course. Specifically:

- Use *symbolic variables* (such as M and h to represent given parameters. Always solve in terms of symbolic variables. Do not plug in numbers. Do this even if you are only given numerical values.

- Solve the problem in terms of given symbolic parameters and any known physical constants, such as g. Your answer should be an equation where time is given in terms of the given symbolic parameters only: $t = f(M, h, g)$. Put a $\boxed{\text{box}}$ around your symbolic solution. Note that it is possible that the final solution will not explicitly depend on all of the given parameters.

(Problem 2 continues next page...)

(Problem 2 continues:)

- Once you have solved the problem symbolically, *then and* **only** *then* should you go ahead and plug in numerical values for the given parameters. Be sure to include appropriate units, and present your answer in terms of an appropriate number of significant digits. Put a $\boxed{\text{box}}$ around your final numerical solution (with units).

Very important Reminder: Put a $\boxed{\text{box}}$ around your symbolic solutions. Put a $\boxed{\text{box}}$ around your final numerical solutions (with appropriate SI units). You must always put a box around both your final symbolic and/or numeric solutions.

(Homework assignment continues next page...)

Problem 3. José Ramírez swings the bat, but hits a pop-up. The baseball has a vertical upward velocity of $V_0 = 23.7$ meters per second when the ball leaves his bat. Relative to his bat, how high in the air will the baseball travel? How much total time will elapse before the ball is caught by the opposing catcher? Assume the ball is caught at the same vertical location that it was hit. Ignore air resistance.

- As always, **first** solve the problem symbolically. You want expressions for both the height and the time in terms of the given parameters (here just v_0) and and relevant physical constants (here just g). Put a $\boxed{\text{box}}$ around your symbolic solution.
- Now that you have solved the problem symbolically, *then and* **only** *then* should you go ahead and plug in numerical values (with appropriate units) for the given parameters and constants. Put a $\boxed{\text{box}}$ around your numerical solution.

As always, **explain your work.**

Very important Reminder: Put a $\boxed{\textbf{box}}$ around your symbolic solutions. Put a $\boxed{\textbf{box}}$ around your final numerical solutions (with appropriate SI units). You must always put a box around both your final symbolic and/or numeric solutions.

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Problem 4. The dwarf planet Sedna is at a distance $D = 85$ AU (Astronomical Units) from the Earth. You want to fly a space-ship to Sedna. Suppose you have a space-ship that is able to linearly accelerate in either a positive or a negative direction at exactly $A = 0.238$ m/s^2. You plan a trip where you move with constant *positive* acceleration in a straight line toward Sedna, speeding up the whole time, and then, at precisely the half-way point, you turn the ship around and accelerate in the opposite direction *e.g., with negative acceleration* of the same magnitude so that you are now slowing down. **By symmetry**, if you reverse acceleration at the half-way point, you should arrive at your destination with zero velocity (right?). Note: in this problem we are completely ignoring the practical reality of how one might build a spaceship that can sustain constant acceleration for an arbitrary period of time. We are also ignoring the motion of the Earth and of Sedna during the trip.

- **Part (a): –** How long will the trip take? Important: You must given a **symbolic** answer in terms of the given parameters (here a and D corresponding to the acceleration of the spaceship and the distance traveled to Sedna. $\boxed{\text{Box}}$ your symbolic answer. Also give a numerical answer in terms of seconds. Be sure that the answer has an appropriate number of significant digits. $\boxed{\text{Box}}$ your numerical answer. Also convert your answer in seconds to an answer in units that are most appropriate to actual length of the trip (days, years, etc.) Again box your answer. Show your work. Hint: you will need to convert from “AU” to meters.

- **Part (b): –** What is the maximum velocity of the spaceship during the trip? Again, present your answer symbolically in terms of given parameters, $\boxed{\text{box}}$ this, and then plug in to get a numerical answer in terms of appropriate SI units, and then $\boxed{\text{box}}$ this. Be sure to explain your work.

- **Part (c): –** Draw a qualitative but clear **sketch** showing plots of the acceleration, the velocity and the position of the spacecraft as a function of time during the entire trip from Earth To Sedna. For each plot, explain in a sentence or two how you determined the shape of the plot.

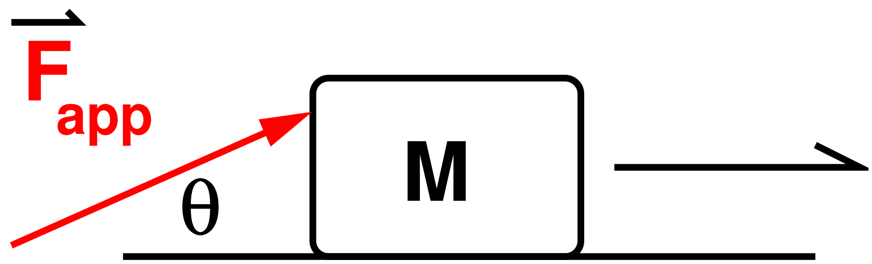
Problem 5. An apple sits at rest on top of a book which in turn sits on a table that sits on the floor. The mass of the apple is given as $m_A = 76$ grams and the mass of the book is $m_B = 1.07$ kg and the mass of the table is $m_T = 13.4$ kg.

- **Part (a): –** Determine the **net force** on the book. Hint. This is a *conceptual question*. Literally: no calculations are required, whatsoever. Just apply **Newton's Second Law.**
- **Part (b): –** Draw complete and proper **Free Body Diagrams** for both the apple and the book. Include only forces that are listed on the "Force Menu" (see Course Document #04, page 7) Each and every force on each object must be consistently and properly labeled. For example, if you want to indicate the force of **Weight** on the apple then you should label such a force as $\vec{W}_A$ which means "the Weight force on Body A." Likewise if you want to label the Normal force on the book *due to* the apple you would label this $\vec{N}_{BA}$.
- **Part (c): –** Apply **Newton's Second Law** together with your two **Free-Body Diagrams** to calculate the magnitude of each and every individual force on each of the two object (apple and book). Ignore air resistance and friction. Explain your work. Note that you must invoke and then apply Newton's Second Law to receive proper credit. Note: you **must** first set up and solve this problem ***symbolically***, not numerically. In other words, give your answers in terms of the given parameters m_A, m_B and perhaps m_T, and the physical constant g. Only after you have done this, should you plug in the numbers to your answer in terms numbers with appropriate units at the very end. ***Answers that are solved numerically and not symbolically will not receive full credit.***

(Problem 5 continues next page...)

(Problem 5 continues:)

- **Parts (d), (e) and (f)): –** Repeat parts (a), (b) and (c) for Problem 5 above except now assume that table is sitting in an elevator that is accelerating *upward* with a given acceleration of precisely $A_0 = 6.96$ m/s^2. Be sure to explain your work. Note that you must explicitly invoke and then apply Newton's Second Law to receive proper credit. Note that students are specifically disallowed from invoking "fictitious" forces of any kind. Students are disallowed from "changing the value of g" or anything like this. Students **must** solve the problem using **Newton's Second Law** and they must solve the problem using kinematic variables as defined in an *inertial reference frame* only. Note: again you **must** set up and solve this problem *symbolically*, first, not numerically. **Plug in numbers only at the very end.**



Problem 6. An force of given magnitude F_{app} is applied to a block of a given mass M. The force is applied to the right and upward at a given angle θ relative to the horizontal as shown. There is a given force of friction with magnitude f that acts on the block to the left. As a result of these forces, the block is observed to move to the right a given distance D. .

Important: For each question: give your answer in terms of the **given parameters**:

Part (a) – What is the **Work** done by the *Normal* force on the block? Explain your answer.

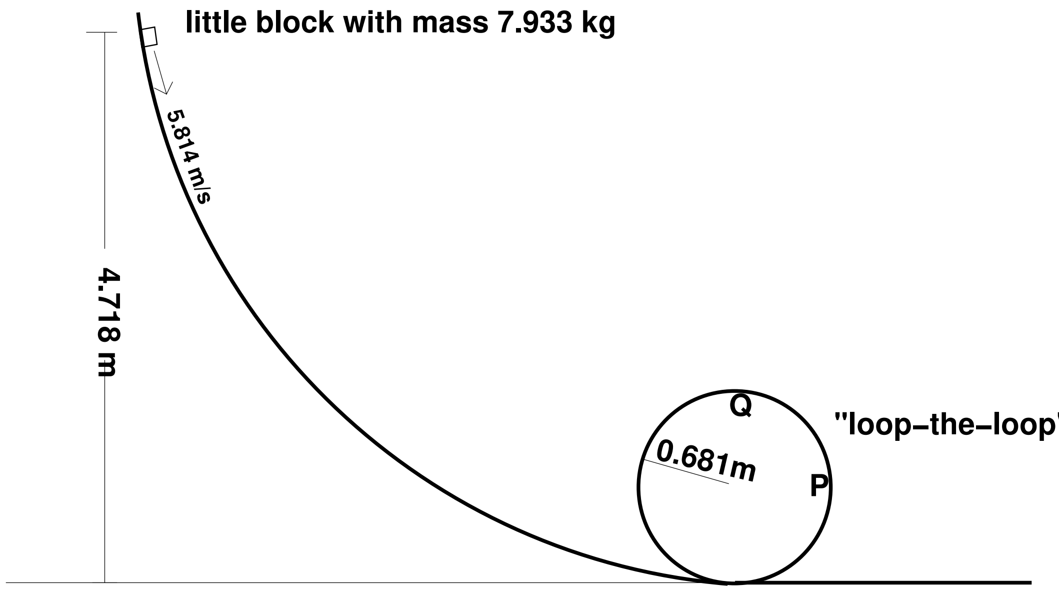
Part (b) – What is the **Work** done by the *Weight* force on the block? Explain your answer.

Part (c) – What is the **Work** done by the *Applied Force* force on the block? Explain your answer.

Part (d) – What is the **Work** done by the *Friction Force* force on the block?

Part (e) – What is the **Total Work** done on the block? Explain your answer.

Part (e) – Assuming that the block starts at rest, what is the **final speed** block when it has traveled a distance D?



Problem 7. A small block of metal with a given mass of $m_b = 7.933$ kg is provided given initial speed $V_i = 5.814$ at the top of a curved **frictionless** surface as shown above. The block moves down the track and then does a "loop-the-loop". The height of the track h and the radius of the loop R are given as shown in the figure.

Important: you must work the following problems symbolically first, (giving your answer in terms of given parameters) and then numerically, part-by-part:

Part (a) – What is the **Work** done by the *Normal* force on the block due to the track as it moves from the top of the track to point P (precisely half-way up the "loop-the-loop")? Explain your answer.

Part (b) – What is the **Work** done by the force of *Weight* on the block as it moves from the top of the track to point P? Is this positive work or negative work? Explain your answer.

Part (c) – What is the ***speed*** of the block at point P? Show how you determined this. Explain what physics concept(s) and/or Laws you used to determine this. Explain your work.