Tutorial Letter 102/3/2016

Mechanics

PHY1505

Semesters 1 & 2

Department of Physics

IMPORTANT INFORMATION:

This tutorial letter contains important information about your module.

BAR CODE

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1 Module Purpose

The purpose of this module is to teach you the concepts, principles and laws of mechanics as well as problem-solving skills required to enable you to solve word problems involving these concepts, principles and laws. This module deals with the following concepts in mechanics:

- Concepts of motion
- Kinematics in One and Two dimensions
- Newton's Laws of Motion
- Conservation of Mechanical Energy and Momentum
- Newton's Law of Universal Gravitation
- Circular Motion and Rotation
- Oscillations
- Fluids and Elasticity

One of the primary goals of this module is to assist you to develop a conceptual understanding of these concepts.

2 Desired Learning Outcomes

After successful completion of this module you should be able to

- describe the motion of objects in terms of their position, velocity and acceleration using words, graphs and equations.
- state and explain Newton's three laws of motion and Newton's Law of Universal Gravitation.
- state and explain the principle of Conservation of Mechanical Energy and the principle of Conservation of Momentum.
- derive expressions for the moment of inertia of regular shaped objects of uniform mass density. (thin rod, circular disc, rectangular plate, cylinder, sphere)
- state and explain the Equation of Continuity and Bernoulli equation for incompressible fluids.
- integrate the concepts, principles and laws of mechanics (indicated above) to solve word problems in mechanics.

These learning outcomes will be assessed through written formative assignments and a written summative examination. You are, therefore, expected to be able to remember, explain and apply the concepts, principles and laws of mechanics.

3 Module Schedule

This module is a semester module. Therefore, will need at least fifteen (15) weeks to cover all the prescribed module materials. The table below shows a possible distribution of your work.

Pace	**Concepts**
week 1 to week 3	- Concepts of motion - Kinematics in One and Two dimensions
week 4 to week 6	- Newton's laws of motion - Circular motion
week 8 to week 10	- Mechanical energy and momentum - Newton's law of Universal Gravitation
week 12 to week 14	- Oscillations - Fluids and Elasticity

You are encouraged to frequently visit the Discussion Forum on the module website on *myUnisa*. You are welcome to discuss the module content with the lecturer.

4 Effective Learning

The learning tips indicated in this section are derived from long-time careful observation and years of research on successful students. Almost all the students who succeed use these tips when studying.

- **Learning is voluntary**: you are the one who decides what to learn and when to learn it.
- **Effective learning occurs in less than one hour**: you are advised to take short breaks after every one hour of active learning.
- **Little learning occurs when multi-tasking**: when you are studying, you must minimize disruptions and interruptions, and focus only on learning.
- **Long-term memory is built through repetition**: you must regularly (every week) revise everything you have studied and leaned. Rewrite definitions, descriptions and derivations without referring to the book. Then check the correct definitions, descriptions and derivations in the book and correct your mistakes.

It helps to start by guessing the definitions, descriptions and derivations of concepts before you study them. Reading the same thing again and again does not help you remember it. Trying again and again to remember something helps you memorize the thing. Therefore, put more effort in trying to remember what you have studied, and genuinely try to recall what you have studied.

4.1 Knowledge Construction

You are required to know, understand and apply the concepts, principles and laws of mechanics. Try to memorize definitions and descriptions (not explanations) of concepts, principles, and laws as well as derivations of useful equations. The *Read-Recite-Review* strategy may help you to memorize what you study.

- **READ**: Survey the module material and identify important concepts, principles and laws, and make a list of these concepts, principles and laws. A good textbook has a list of important concepts, principles and laws as a summary at the end of every chapter.
- **RECITE**: Explain to yourself again and again (several times) the definitions, descriptions and derivations of the concepts, laws and the principle vocally or write them several times.
- **REVIEW**: Try to remember, without assistance, what you have studied. Write down definitions, descriptions and derivations in your own words without referring to the book. Then, compare you version with the correct one in the book, and correct your mistakes.

After learning the concepts, principles and laws of motion you can then learn how to apply these concepts, principles and laws to solve related problems.

4.2 Worked-out Examples

Use worked-out examples in the textbook to learn and practice problem solving. Analyze and explain the problem statement as well as the solution of the example.

- Rework the solution and construct a shorter, yet complete, solution of the example in less than 10 minutes.
- Use the rubric to evaluate your solution and award a mark out of 20.

Practice solving problems for which you do not know the solution. A problem-solving strategy helps present a solution in the shortest and clearest manner. Always evaluate your solutions using the rubric.

5 Problem-solving Strategy

Step 1. **Analyze the problem**: Carefully read and understand the problem statement. Translate the words of the problem statement into a visual representation.

- Identify known quantities, unknown quantities and constraints.
- Identify the physics concepts and principles appropriate for the problem situation.

Step 2. **Describe the problem in physics concepts**: Translate the sketches into a physical representation of the problem.

- Use appropriate physics principles to construct relevant diagrams for the problem situation.
- Represent each relevant quantity (known and unknown) with a symbol and assign the given the known values.

Step 3. **Plan a solution**: Translate the physics description into a mathematical representation of the problem.

- Express the identified physics concepts and principles in equation form.
- Incorporate the specified constraints in the equations.

Step 4. **Construct the solution**: Translate the plan for the solution into a series of appropriate mathematical procedures.

- Use correct mathematical rules and procedures to express the unknown quantity in terms of the known quantities.
- Substitute the given values of the known quantities to determine the value of the unknown quantity.

Step 5. **Evaluate the solution**: Determine if the answer makes sense.

- Check if the signs and units are correct in all the solution steps.
- Check if the magnitude of the answer is reasonable.

6 Solution Rubric

Solutions to problems in the assignments and examination will be evaluated using this rubric.

Criterion	**5**	**4**	**3**	**2**	**1**	**0**
PROBLEM DESCRIPTION	useful and complete	useful with minor omissions/errors	parts not useful, missing or contain errors	most not useful, missing or contain errors	all not useful or contain errors	no description provided
PHYSICS APPROACH	appropriate and complete	appropriate with minor omissions /errors	parts not appropriate , missing or contain errors	most not appropriate , missing or contain errors	all not appropriate	no approach provided
MATHEMATICS PROCEDURES	appropriate and complete	appropriate with minor omissions /errors	parts not appropriate , missing or contain errors	most not appropriate , missing or contain errors	all not appropriate	no approach provided
LOGICAL PROGRESSION	clear, focused and consistent	clear and focused with minor omissions /errors	parts not clear, not focused or not consistent	most not clear, not focused or not consistent	all not clear, not focused or not consistent	no evidence of logical progression

7 Worked-out Examples

Example 1: A rock is released from rest at a height of 100 m above the ground. How long does the rock take to fall to the ground and what is its impact velocity? [20]

SOLUTION

Useful information

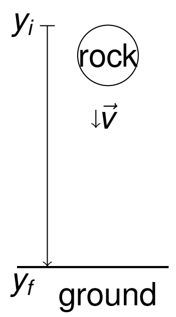
Known quantities

Initial position	$y_i = 100\,\text{m}$
Final position	$y_f = 0\,\text{m}$
Initial velocity	$v_i = 0\,\text{m/s}$
Acceleration	$a = -g = -9.8\,\text{m/s}^2$

Unknown quantities

Time to reach the ground	t
Final velocity	v_f

Illustrations



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Physics approach

Free fall is motion with constant acceleration $a = -g$. The equation that relates time, distance and acceleration is

$$y_f = y_i + v_i\Delta t + \frac{1}{2}a(\Delta t)^2\,.$$

The equation that relates final velocity, distance and acceleration is

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$$v_f^2 = v_i^2 + 2a(\Delta y)\,.$$

Logical mathematical procedures

a) The time is calculated from the equation

$$y_f = y_i + v_i\Delta t + \frac{1}{2}a(\Delta t)^2 = y_i + \frac{1}{2}a(\Delta t)^2$$

to obtain

$$t = \sqrt{\frac{2(y_f - y_i)}{g}} = \sqrt{\frac{2(100\,\text{m} - 0\,\text{m})}{9.80\,\text{m/s}^2}} = \pm 4.52\,\text{s}\,.$$

Check answer: The $-t$ refers to the time before the ball was dropped. Therefore, the correct time is $+4.52\,\text{s}$.

b) The final velocity is calculated from the equation

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$$v_f^2 = v_i^2 + 2a(\Delta y)$$

to obtain

$$v_f = \sqrt{v_i^2 + 2a(\Delta y)} = \sqrt{(0\,\text{m/s})^2 + 2\cdot(-9.80\,\text{m/s}^2)\cdot(-100\,\text{m})} = \pm 44.3\,\text{m/s}\,.$$

Check answer: The velocity is downwards in the direction of the acceleration. Therefore, the velocity of impact is $-44.3\,\text{m/s}$.

Example 2: A stunt man drives a car off a 10.0 m high cliff at a speed of 20.0 m/s. How far from the base of the cliff does the car lands? [20]

SOLUTION

Useful information

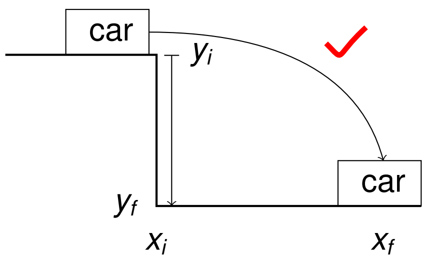
Known quantities

Initial horizontal position	$x_i = 0.0\,\mathrm{m}$
Initial vertical position	$y_i = 10.0\,\mathrm{m}$
Final vertical position	$y_f = 0.0\,\mathrm{m}$
Initial horizontal velocity	$u_x = 20.0\,\mathrm{m/s}$
Final horizontal velocity	$v_x = 20.0\,\mathrm{m/s}$
Initial vertical velocity	$u_y = 0.0\,\mathrm{m/s}$
Horizontal acceleration	$a_x = 0.0\,\mathrm{m/s^2}$
Vertical acceleration	$a_y = -g = 9.80\,\mathrm{m/s^2}$

Unknown quantities

Final horizontal position	x_f

Illustrations



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Physics approach

The horizontal and vertical motions are at constant acceleration. The equations that relate time, distance and acceleration are

$$x_f = x_i + u_x \Delta t + \frac{1}{2} a_x (\Delta t)^2 \quad \text{and} \quad y_f = y_i + u_y \Delta t + \frac{1}{2} a_y (\Delta t)^2 .$$

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The time is the same for both equations.

Logical mathematical procedures

The vertical motion is used to determine the time. Therefore,

$$-\Delta y = u_y \Delta t + \frac{1}{2} a_y (\Delta t)^2 = -\frac{1}{2} g (\Delta t)^2$$

leads to

$$t = \sqrt{\frac{2\Delta y}{g}} = \sqrt{\frac{2(10.0\,\mathrm{m})}{9.80\,\mathrm{m/s^2}}} = 1.43\,\mathrm{s} .$$

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Substitute this value of time in the horizontal motion to obtain

$$x = u_x t + \frac{1}{2} a_x t^2 = (20.0\,\mathrm{m/s})(1.43\,\mathrm{s}) = 28.6\,\mathrm{m} .$$

Example 3: Blocks A and B are connected by a massless string 2 and pulled across a frictionless table surface by a massless string 1. Block B has a larger mass than block A. Is the tension in string 2 larger than, smaller than, or equal to the tension in string 1? [10]

SOLUTION

Useful information

Known quantities

Difference in mass $m_A < m_B$

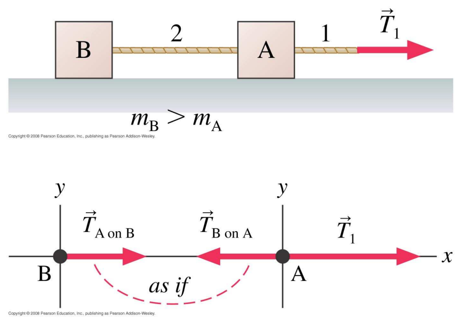
Tension in string 1 $\vec{T}_1$

Kinetic friction force $\vec{f}_k = 0\,\text{N}$

Unknown quantities

Tension in string 2 $\vec{T}_2$

Illustrations



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Physics approach

The net force on block B is $\vec{T}_2$. The net force on block A is

$$\vec{F}_{\text{net}} = \vec{T}_1 - \vec{T}_2 = m_A \vec{a}_A\,.$$

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Because there is no friction to oppose the motion, the blocks are accelerating to the right, so that $a_A > 0\,\text{m}/\text{s}^2$. Therefore,

$$T_1 > T_2\,.$$

Check answer: String 1 pulls both blocks of a combined mass $m_A + m_B$ with tension $\vec{T}_1$ and string 2 pulls only block B of mass m_B with tension $\vec{T}_2$. Therefore, T_1 should be greater than T_2.

<u>General Comments</u>

- It is not necessary to include a diagram in *Example 1* and *Example 2*, however, it is necessary to include a diagram in *Example 3*. Therefore, it is not always necessary to include a diagram in your solution.
- Marks are reduced/deducted when your solution has mistakes and/or some useful information is missing.
- *Logical Progression* means your argument, including mathematical procedures, should be structured.
- The number of tics in the marked solution is not related to marks.