nTIPERs Project – Physics Tools for Learning and Assessment in Newtonian Mechanics

Supported by NSF CCLI collaborative grants
0632963 (Joliet Junior College) & 0633010 (New Mexico State University)

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Tasks Inspired by Physics Education Research (TIPERs)

- Focused on the development of conceptual understanding and reasoning in targeted areas.
- Designed to promote sense making and help students build a base to solve problems with understanding.
- Many tasks are taken directly from research questions.
- Variety of task formats provide alternative ways of focusing students on important or confusing ideas and concepts.
- Multiple approaches or task formats help build a stronger and more robust understanding for students.
- Can be used to do pre-topic assessment, reinforce instruction, post-topic assessment, topic extension, bridge to new ideas, or review work.
- Can be used in individual activities, peer-share instruction, small group work, homework, review work, and exam/quiz tasks.
- Can be adopted incrementally.
- Tasks encourage and support active learning along with reasoning skills.
Use of standard quantitative problems for student practice and subsequent use for evaluation of student achievement does little to promote conceptual understanding of physics concepts.

The workbook developed during this project provides a variety of alternative task formats that emphasize conceptual understanding and can be used in a variety of teaching activities.

The goal of the nTIPERs project is to improve student understanding of physics by

- providing college teachers with a published collection of high quality conceptual (qualitative) exercises in mechanics with solutions,
- based on task formats related to work in Physics Education Research (PER),
- materials are intended to provide an easy migration for teachers with heavy demands in the adoption of PER-connected materials,
- and are effective in improving learning.
Evaluation strategies, methods, and impact

Several retired and sabbatical leave CC teachers volunteered to review parts of the first stage early work.

Extensive reviews of all first stage materials by two nationally known HS physics teachers before field testing the materials.

External evaluator from Chicago State University worked with 5-10 CC faculty in the evaluation of selected second stage materials for two years.

Many (70+) field testers/teachers from universities, CCs, and HSs tried the materials in their classes.

Over thirty workshops during this period were provided to inform the physics teaching community about the project and its implementation.

Final edit was done by an expert CC physics teacher from Joliet Jr College.

Publisher provided the design for the book covers and copy-edited the materials.

Project reaching a new level by adapting and modifying published materials along with developing new tasks for a new student workbook for the regular high school physics course.
Unexpected challenges and/or lessons learned

The time it takes to rewrite, edit, review, correct, format, write solutions, etc, for publication after you think it is finished.

The difficulty in cutting from 600+ tasks/pages to 339 pages for publication and the time required to prepare the solutions guide for each task.

The complexity of dealing with comments and issues such as notation from users at various institutions.

The limited institutional support for projects with a national scope/impact directed by retired/adjunct CC PIs.

The strong support by so many physics teachers for the project across the country.

The impact of change in plans and responsibilities of PIs and Co-PIs during the project.

The impact and need to deal with new CC administrators (President, Vice-President, Dean, Department Chair over five years).

The difficulty in trying to adapt to new technical developments and devices such as the iPad to deliver the materials to students.
**TIPERs formats**

- What (if anything) is Wrong Tasks (WWT)
- Working Backwards Tasks (WBT)
- Troubleshooting Tasks (TT)
- Ranking Tasks (RT)
- Qualitative Reasoning Tasks (QRT)
- Linked Multiple Choice Tasks (LMCT)
- Comparison Tasks (CT)
- Changing Representations Tasks (CRT)
- Conflicting Contentions Tasks (CCT)
- Bar Chart Tasks (BCT)
- Predict and Explain Tasks (PET)
Newtonian Tasks Inspired by Physics Education Research: nTIPERs

Student workbook published January 2011 by Pearson Addison-Wesley
339 pages with 398 tasks
Ten task formats in nine areas of introductory mechanics.
Five years in development
Supported by formal NSF CCLI collaborative grants to JJC and NMSU
“nTIPERs: Tasks to Help Students ‘Unpack’ Aspects of Newtonian Dynamics”
David P Maloney, Curtis Hieggelke, and Steve Kanim, paper published in the proceedings and featured at the Physics Education Research Conference 2010 at the 2010 AAPT Summer Meeting, Portland, OR

Companion product to E & M TIPERs: Electricity & Magnetism Tasks
- C. J. Hieggelke, D. P. Maloney, T. L. O'Kuma, & S. E. Kanim,
- published by Pearson Addison-Wesley (2006),
- 256 page student workbook with 186 electrostatics tasks in 16 categories and 128 magnetism tasks in 8 categories,
- development supported by two NSF CCLI grants on magnetism and electrostatics
nTIPERs Distribution Chart by Physics Task Area

Distribution of nTIPER Tasks by Area (Jan 2011)

- nT9 Oscillation
- nT8 Rotation
- nT7 Momentum
- nT6 Energy
- nT5 Newton's Laws
- nT4 2D Motion
- nT3 1D Motion
- nT2 Vectors
- nT1 Preliminaries

Broadening Impact: NSF-funded Projects at TYCs Conference
June 16-17, 2011 in Washington, D.C.

nTIPERs - Physics Tools for Learning and Assessment
CCLI Collaborative Project of Joliet Junior College & NM State University
**RTpractice: Stacked Blocks—Number of Blocks**

Shown below are stacks of various blocks. All masses are given in the diagram in terms of $M$, the mass of the smallest block.

![Stacked Blocks Diagram]

Rank the total number of blocks in each stack.

Greatest 1 ______ 2 ______ 3 ______ 4 ______5 ______ Least

OR, The total number of blocks in each stack is the same. ___

OR, The ranking for the total number of blocks in these stacks cannot be determined. ____

**Explain your reasoning.**
**nT6H-BCT1: Box Lifted Up Moving Upward I—Energy Bar Chart for the Earth-Box System I**

A 100 N box is initially moving upward at 4 m/s. A man is applying a vertical force of 80 N with his hand to the box as shown. (use $g = 10 \text{ N/kg}$)

Draw an energy bar chart below for the earth-box system as it moves upward a distance of 1 m with the zero point for the gravitational (potential) energy set at the initial height.

<table>
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**Bar chart graph key**

- KE: Kinetic energy
- $E_{\text{int}}$: Internal energy
- PE$_{\text{grav}}$: Gravitational potential energy
- PE$_{\text{spring}}$: Spring potential energy
- $W_{\text{ext}}$: Work done by external forces
- Q: Heat added to system

Use $g = 10 \text{ m/s}^2$ for simplicity
Three 4-Newton forces act on a plywood hexagon as shown in the diagram. The sides of the hexagon each have a length of 1 meter.

Rank the magnitude of the torque applied about the center of the hexagon by each force.

Greatest 1 _______ 2 _______ 3 _______ Least

OR, The magnitude of the torque due to each force is the same, but not zero. ___

OR, The magnitude of the torque due to each force is zero. ___

OR, We cannot determine the ranking of the magnitude of the torques. ___

Please explain your reasoning.
**nT5B-CT20: Ropes Pulling Boxes III—Rope Tension**

Shown below are boxes that are being pulled by a force $F$ along frictionless surfaces, accelerating toward the left. The masses of the boxes are indicated in each figure.

![Diagram](image)

Will the tension in rope A on the top be (a) **greater than**, (b) **less than**, or (c) **equal to** the tension in rope B on the bottom?

**Explain.**
**nT5G-WBT1: Equations Describing a Situation—Physical Situation**

Given below are two equations resulting from the application of Newton’s Second law to two objects in a system.

\[ Mg - T = Ma \]
\[ T + \mu mg = ma \]

Describe and draw a physical situation that could have produced these equations.
The graph shown is for an object in one-dimensional motion. The vertical axis is not labeled.

If the vertical axis is *position*, does the object ever change direction? If so, at what time or times does this change in direction occur?

If the vertical axis is *velocity*, does the object ever change direction? If so, at what time or times does this change in direction occur?
A student has obtained a graph of an object’s velocity versus time and then draws the graph of the acceleration versus time for the same time interval.

What, if anything, is wrong with the graph of the acceleration versus time? If something is wrong, identify it and explain how to correct it.
**nT1A-CCT1: Breaking up a Block—Density**

A block of material with a width $w$, height $h$, and thickness $t$ has a mass of $M_o$ distributed uniformly throughout its volume. The block is shown cut into two pieces A and B.

Andy: “The density is the mass divided by the volume, and the volume of B is smaller. Since the mass is uniform, and the volume is in the denominator, the density is larger for B.”

Badu: “The density of piece A is larger than the density of piece B since A is larger, thus it has more mass.”

Coen: “They both have the same density. It’s still the same material.”

Which, if any, of these three students do you agree with?

Andy _____ Badu _____ Coen _____ None of them_____

Please explain your reasoning.
**nT5C-TT38: Thrown Baseball—Force Diagram**

A baseball is thrown from right field to home plate, traveling from right to left in the diagram.

![Force Diagram](image)

A student watching the game sketches the force(s) on the baseball at the top of its path. He ignores air friction and notes that the forces are not drawn to scale in his sketch. He produces the following diagram for the forces on the ball at the top:

![Student's Force Diagram](image)

The student states:

“*A is the horizontal component of the initial applied force, B is the vertical component of the initial applied force, and C is the force of gravity.*”

There is a problem with the student’s description. Explain what is wrong, and correct it.
Sketch an angular acceleration versus time graph given the angular velocity versus time graph shown for the same time interval.

Explain.
**nT8H-LMCT: Horizontal Pivoted Board with Load — Force to Hold**

A 100-N weight is placed on a massless board a distance \( L_1 \) from a frictionless pin. A force \( F \) is applied vertically to the end of the board, a distance \( L_2 \) from the pivot.

Identify from choices (a)-(e) how each change described below will affect the magnitude of the support force \((F)\) at the end of the board needed to keep the system in equilibrium.

Compared to the case above, this change will:

(a) *increase* the magnitude of the support force \((F)\) at the end of the board.

(b) *decrease* the magnitude of the support force \((F)\) at the end of the board but not to zero.

(c) *decrease* the magnitude of the support force \((F)\) at the end of the board to zero.

(d) *have no effect* on the magnitude of the support force \((F)\) at the end of the board.

(e) *have an indeterminate* effect on the magnitude of the support force \((F)\) at the end of the board.

Each of these modifications is the only change to the initial situation shown in the diagram above.

1) The 100-N weight is moved to a position closer to the support force \((F)\) at the right end of the board.

   Explain.

2) The 100-N weight is moved to a position closer to the frictionless pin at the left end of the board.

   Explain.
**RTpractice: Stacked Blocks—Number of Blocks—Answer**

Shown below are stacks of various blocks. All masses are given in the diagram in terms of $M$, the mass of the smallest block.

```
\begin{array}{cccc}
  & M & 5M & \\
A & M & M & \\
  & 3M & 4M & M \\
B & M & M & M \\
  & 4M & 2M & M \\
C & M & M & M \\
  & M & M & M \\
D & \\
  & E & \\
\end{array}
```

**Rank the total number of blocks in each stack.**

Greatest 1 _AD___ 2 ________ 3 _BCE__ 4 ________5 ________ Least

\[ A = D > B = C = E \]

Greatest 1 ___A____ 2 ___D___ 3 __B____ 4 ___C______5 ___E___ Least
**nT6H-BCT1: Box Lifted Up Moving Upward I—Energy Bar Chart for the Earth-Box System I-Answer**

A 100 N box is initially moving upward at 4 m/s. A man is applying a vertical force of 80 N with his hand to the box as shown.

Draw an energy bar chart below for the earth-box system as it moves upward a distance of 1 m with the zero point for the gravitational (potential) energy set at the initial height.

![Energy Bar Chart](image)

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Arbitrary height, same for both (can be zero)
Three 4-Newton forces act on a plywood hexagon as shown in the diagram. The sides of the hexagon each have a length of 1 meter.

Rank the magnitude of the torque applied about the center of the hexagon by each force.

Greatest 1 ___ A ___ 2 ___ C ___ 3 ___ B ___ Least

The magnitude of the torque due to each force is equal to the magnitude of the force times the perpendicular distance between the line of action of that force and the pivot point. The line of action of force B passes through the center of the hexagon, so the torque due to force B is zero. The perpendicular distance between the line of action and the pivot point is equal to the height of one of the triangles shown for force C, and is equal to the side of a triangle for force A. The side of the triangle is longer than the height, and so the torque due to force A is greatest.
Shown below are boxes that are being pulled by a force $F$ along frictionless surfaces, accelerating towards the left. The masses of the boxes are indicated in each figure.

Will the tension in rope A on the top be (a) greater than, (b) less than, or (c) equal to the tension in rope B on the bottom?

(b) The tension in rope A is less than the tension in rope B.

Since the surface is frictionless, the tension in all ropes is the net force on the system of all blocks to the right of that rope. So the tension is equal to the mass of all blocks to the right of that rope times the acceleration. Since the tension in the leftmost rope is $F$ and the mass of the two blocks is $3m$ in each case, the acceleration of both systems is the same. For rope A, the tension is the acceleration times $m$. For rope B the tension is the (same) acceleration times $2m$, twice the tension of rope A.
**nT5G-WBT1: Equations Describing a Situation—Physical Situation—**

**Answer**

Given below are two equations resulting from the application of Newton’s Second law to two objects in a system.

\[
\begin{align*}
Mg - T &= Ma \\
T + \mu mg &= ma
\end{align*}
\]

Describe and draw a physical situation that could have produced these equations.

*A hanging mass \( M \) connected to a string with a tension \( T \) that is connected also to a block \( m \) on a rough horizontal surface with a coefficient of kinetic friction \( \mu \). The hanging mass \( M \) is initially moving upward and the block is moving away from the edge.*
The graph shown is for an object in one-dimensional motion. The vertical axis is not labeled.

If the vertical axis is \textit{position}, does the object ever change direction? If so, at what time or times does this change in direction occur?

\textit{Answer}: The velocity of the object is given by the slope of the graph, and the object has a negative velocity from time zero to 5 seconds. After 5 seconds, the object has a positive velocity. So the object \textbf{changed direction at 5 seconds}.

If the vertical axis is \textit{velocity}, does the object ever change direction? If so, at what time or times does this change in direction occur?

\textit{Answer}: The velocity of the object is given by the value of the graph, and the object has a positive velocity from time zero to 2 seconds. From 2 seconds to 8 seconds, the object has a negative velocity. After 8 seconds, the object has a positive velocity. So the object \textbf{changed direction at 2 seconds, and again at 8 seconds}. 

\textbf{nT3A-QRT1: Kinematics Graphs—Change Direction—Answer}
**nT3A-WWT1: Velocity vs. Time Graph I—Acceleration vs. Time Graph—Answer**

A student has obtained a graph of an object’s velocity versus time and then draws the graph of the acceleration versus time for the same time interval.

What, if anything, is wrong with the graph of the acceleration versus time? If something is wrong, identify it and explain how to correct it.

*The acceleration is the slope of the velocity graph. Thus, the third and fourth peaks should be reversed as shown below because the sign of the acceleration is the same as the sign of the slope of the velocity-time graph.*
nT1A-CCT1: Breaking up a Block—Density -Answer

A block of material with a width \( w \), height \( h \), and thickness \( t \) has a mass of \( M_o \) distributed uniformly throughout its volume. The block is shown cut into two pieces A and B.

Andy: “The density is the mass divided by the volume, and the volume of B is smaller. Since the mass is uniform, and the volume is in the denominator, the density is larger for B.”

Badu: “The density of piece A is larger than the density of piece B since A is larger, thus it has more mass.”

Coen: “They both have the same density. It’s still the same material.”

Which, if any, of these three students do you agree with?

Andy_____ Badu _____ Coen __X__ None of them______

Please explain your reasoning.

Coen is correct. Density is the ratio of mass to volume. The larger piece has twice the mass, but also twice the volume of the smaller piece, so the ratio of mass to volume is the same for both, and the same as the density of the unbroken block.