

## **Assessment Third Year Review Report of the Department of Physics and Astronomy**

**Assessment contact:** Jerry Hinnefeld, Professor of Physics, Department Chair

**Attachments:** 2006 and 2007 assessment reports; current assessment plan; Fall 2007 faculty assessment survey; Force Concept Inventory

**Changes to educational goals, and rationale:** The educational goals in the departmental assessment plan adopted in September 2005, while identifying the same desired outcomes as those in the 2005 Third Year Review report, are stated in terms that make them more amenable to assessment. For example, in the 2005 Third Year Review one of the stated goals was, "Students majoring in physics should learn to apply fundamental physical principles to the solution of complex problems." In the current assessment plan this sentiment is recast as a measurable outcome -- "Students completing the major in physics will be able to apply fundamental physical principles to the solution of complex problems."

**Assessment techniques added or discontinued, and rationale:** A simple end-of-semester survey has been implemented to assist in the documentation of assessment data collected through the activities we identify as "faculty inventory." All active faculty in the department are invited to complete the survey after each semester. A copy of the survey is appended to this report.

**Assessment instruments used:** We continue to use the Force Concept Inventory (FCI), a nationally normed instrument for determining the extent to which students of mechanics have overcome common Aristotelian misconceptions in favor of a Newtonian understanding of force and motion, in selected courses. Results are included in our internal assessment report and discussed within the department. A copy of the FCI is appended to this report.

**Analysis performed and conclusions drawn:** Each spring the department's assessment coordinator prepares and distributes an internal assessment report, which serves as the basis for discussion at a department meeting. The report includes results of the FCI, Faculty Assessment Surveys, selected items on course evaluations, assessments of students' oral and written presentations, reports on graduates' success in graduate school admission and completion, and descriptions of student research projects.

We have concluded, based on the experience of recent graduates, that we could do more to help our senior students prepare for the Physics Graduate Record Exam (GRE). We have also noted that some of our students carry out very successful research projects, and that these research experiences help them to strengthen their understanding of a particular set of physics concepts.

Some of our faculty members have noticed a larger percentage of students in our general education courses who are ill-prepared or disinterested. This correlates with the replacement of our traditional courses for non-science majors with versions of PHYS/AST/GEOL-N190 The Natural World, a Common Core course of the campus-wide general education curriculum.

**What changes have been made to the program? How did assessment data and analysis support these changes?** We have added an introductory seminar course, PHYS-S106 Contemporary Physics Seminar, aimed primarily at students who are either in the introductory physics sequence, PHYS-P221/P222, or are not yet in PHYS-P221/P222 because they are not yet ready to take the co-requisite, MATH-M215 Calculus I. Our hope is that this course will improve the retention of students who arrive at IUSB self-identified as physics majors or pre-engineering students. The course was taught for the first time in Fall 2007. The format of the course was altered modestly for Spring 2008, based on the Fall 2007 experience. Specifically, student feedback on Fall 2007 course evaluations indicated that the enrolled students were often intimidated, and so disinclined to ask questions of the speaker, by the presence of advanced physics students and physics faculty members. For the Spring 2008 offering the first several presentations, which were by faculty members within the department, were open only to enrolled students.

Some faculty members are now requiring student presentations in upper-level courses for our majors. This is at least partially in response to the observation, noted in the department's 2007 internal assessment report, that our majors would benefit from more experiences with written reports and oral presentations.

**What changes are planned in the coming years to the program and to assessment techniques, and why?** We plan to take steps to prepare our majors better for the Physics GRE. Some of these steps will be taken within existing courses -- for example, by including problems or questions on homework assignments that are of the type commonly seen on the GRE. This will require those of us teaching upper-level courses for majors to become better acquainted with the coverage and the style of question found on the Physics GRE. We will need to be careful, of course, not to let the content of our courses become narrowly focused on the content of this standardized test.

While our current assessment plan identifies alumni surveys as one of our assessment techniques, we have not yet utilized this tool. We plan to do so in the coming year, as we feel recent alumni are in a unique position to identify the strengths and shortcomings of their IUSB physics education.

**How were faculty, students, administration, alumni and other groups involved in assessment?** Student involvement in assessment has been primarily through selected items on course evaluations. Faculty involvement includes responding to the end-of-semester surveys and participating in the discussion of the internal assessment report. Alumni will be brought into the assessment process with the alumni surveys mentioned above.

**How were assessment data and results shared with these groups?** The internal assessment report prepared by the assessment coordinator is the primary vehicle for sharing assessment data and results with the department faculty. The annual reports are available to students, alumni, and anyone else on the web site of the campus Assessment Committee.

**Summarize the most important impacts:** The most important impacts of our assessment efforts to date have been the modifications to our curriculum – the expansion of our modern physics course to a two-semester sequence, greater attention to the sequencing of courses and to coordinating the content of courses to match this sequence, the commitment to offering a major

elective course in each semester, and the creation of the introductory seminar course. These seem to be the factors behind our recent improvements in retention of majors, which is reflected in our solid enrollments in upper-level courses in the major.

## 2006 Assessment Report Department of Physics and Astronomy

- a. Program Name - Department of Physics and Astronomy
- b. Report prepared by – Jerry Hinnefeld, Chair
- c. Who is the current assessment contact for your program? Jerry Hinnefeld
- d. Should assessment information be sent to anyone else in your department? no

### 1. What are the program's educational goals? (Please take goals directly from your program's assessment plan, and highlight any changes made this year.)

#### Physics majors

- 1) Students completing the major in physics will know and understand in detail many of the concepts that are used to describe the physical world, including the structure of matter, the fundamental interactions of nature, the relationship between force and motion, and the concept of energy.
- 2) Students completing the major in physics will be able to apply fundamental physical principles to the solution of complex problems.
- 3) Students completing the major in physics will be able to communicate results of their experimental or computational work clearly, both orally and in written form.

#### Students majoring in other natural sciences or mathematics

- 4) Students completing physics courses as cognate requirements will know and understand physics concepts that will help them to better understand concepts in their own major areas of study.
- 5) Students completing physics courses as cognate requirements will understand the relevance of their studies in physics to their own major areas of study.

#### Students studying physics, astronomy, or geology for general education purposes

- 6) Students completing courses in these areas as part of their general education curriculum will know and understand a limited set of concepts that illustrate a scientific approach to explaining the physical world.
- 7) Students completing courses in these areas as part of their general education curriculum will have gained an appreciation of the scientific approach to understanding the physical world.

### 2. What assessment techniques did the program use? (Please take assessment techniques directly from your program's assessment plan and highlight any changes made this year.)

- Classroom assessment
- Students' oral and written reports
- Research experience
- Pre-/post-testing
- Success in graduate school admission
- Faculty end-of-semester surveys

### 3. What has your program done with assessment information this year? (i.e. communicated results to faculty, staff, alumni and students, made changes in the curriculum, made changes in the budget, added new courses. . .)

The department's assessment coordinator presented an internal assessment report to department faculty and staff at a department meeting in May 2006. Faculty members expressed interest in expanding the use of pre-/post-testing with the Force Concept Inventory (FCI) to courses other than PHYS-P221 (Physics 1). We noted that our graduates typically take more than the required 35 cr. hrs. in physics, and that strong enrollments in our major electives -- PHYS-P321 Techniques of Theoretical Physics in Fall 2005 and PHYS-S405 Readings in Physics: General Relativity (cross-listed with MATH-M435 Differential Geometry) in Spring 2006 -- indicate strong student interest in major electives in each semester. The assessment report also afforded another opportunity to discuss creation of a colloquium course aimed at beginning students, in which current physics topics would be presented. The department chair is supposed to have this 1-cr. course ready for the Spring 2007 semester.

#### **4. What are two concerns about student learning you identified this year?**

- There is some concern that class sizes may in some cases be too large to allow the instructor to ascertain the quality and accuracy of conceptual understanding. This concern was explicitly expressed in connection with our course for elementary education majors, PHYS-T105 Physical Science for Elementary Teachers; but it might also apply to the introductory sequence, PHYS-P221/P222 Physics 1/2, which has grown considerably in enrollment in recent years.
- We feel some of our strongest students could be getting more out of their research requirement, and to that end we are exploring the possibility of creating a "departmental honors" designation for students who, among other thing, complete a senior thesis as part of the required PHYS-S406 Research. A recently developed policy for establishing notations on IU transcripts may aid us in this effort.

**2007 Assessment Report**  
**Department of Physics and Astronomy**

- a. Program Name - **Department of Physics and Astronomy**
- b. Report prepared by - **Jerry Hinnefeld, Chair**
- c. Who is the current assessment contact for your program? **Jerry Hinnefeld**
- d. Should assessment information be sent to anyone else in your department?  
**no**

1. What are the program's educational goals? (Please take goals directly from your program's assessment plan, and highlight any changes made this year.)

Physics majors

- 1) Students completing the major in physics will know and understand in detail many of the concepts that are used to describe the physical world, including the structure of matter, the fundamental interactions of nature, the relationship between force and motion, and the concept of energy.
- 2) Students completing the major in physics will be able to apply fundamental physical principles to the solution of complex problems.
- 3) Students completing the major in physics will be able to communicate results of their experimental or computational work clearly, both orally and in written form.

Students majoring in other natural sciences or mathematics

- 4) Students completing physics courses as cognate requirements will know and understand physics concepts that will help them to better understand concepts in their own major areas of study.
- 5) Students completing physics courses as cognate requirements will understand the relevance of their studies in physics to their own major areas of study.

Students studying physics, astronomy, or geology for general education purposes

- 6) Students completing courses in these areas as part of their general education curriculum will know and understand a limited set of concepts that illustrate a scientific approach to explaining the physical world.
- 7) Students completing courses in these areas as part of their general education curriculum will have gained an appreciation of the scientific approach to understanding the physical world.

2. What assessment techniques did the program use? (Please take assessment techniques directly from your program's assessment plan and highlight any changes made this year.)

- **Classroom assessment**
- **Students' oral and written reports**

- Research experience
- Pre-/post-testing
- Success in graduate school admission
- Faculty end-of-semester surveys

3. What has your program done with assessment information this year? (i.e. communicated results to faculty, staff, alumni and students, made changes in the curriculum, made changes in the budget, added new courses...)

The department's assessment coordinator presented an internal assessment report to department faculty and staff at a department meeting.

We reaffirmed our commitment to offering an elective majors' course in each semester.

We created an introductory seminar course, PHYS-S106 Contemporary Physics Seminar, offered for the first time in Fall 2007.

4. What are two concerns about student learning you identified this year?

There seems to be a larger proportional of poorly prepared or unmotivated students in the Common Core courses, AST/GEOL/PHYS-N190, than has been typical in the 100-level courses they replaced. For example, versions of AST-N190 have replaced AST-A100 The Solar System and AST-A105 Stars and Galaxies. We suspect that students may be taking the N190 courses at earlier points in their careers than they took the older courses. We may need to come up with ways to convince students of the value and importance of the quantitative reasoning they're asked to learn in these courses.

Our majors who wish to go on to graduate school could be better prepared for the discipline-specific GRE. We should become more familiar with this instrument, so that we are in a better position to assist these students in their preparation.

# Department of Physics and Astronomy

## Assessment Plan Adopted October 6, 2005

The department offers courses of study leading to a B.S. or B.A. in physics, physics courses aimed at majors in other natural sciences or mathematics, and physics, astronomy, and geology courses aimed at a general education audience.

### I. Educational Goals

#### Physics majors

- 1) Students completing the major in physics will know and understand in detail many of the concepts that are used to describe the physical world, including the structure of matter, the fundamental interactions of nature, the relationship between force and motion, and the concept of energy.
- 2) Students completing the major in physics will be able to apply fundamental physical principles to the solution of complex problems.
- 3) Students completing the major in physics will be able to communicate results of their experimental or computational work clearly, both orally and in written form.

#### Students majoring in other natural sciences or mathematics

- 4) Students completing physics courses as cognate requirements will know and understand physics concepts that will help them to better understand concepts in their own major areas of study.
- 5) Students completing physics courses as cognate requirements will understand the relevance of their studies in physics to their own major areas of study.

#### Students studying physics, astronomy, or geology for general education purposes

- 6) Students completing courses in these areas as part of their general education curriculum will know and understand a limited set of concepts that illustrate a scientific approach to explaining the physical world.
- 7) Students completing courses in these areas as part of their general education curriculum will have gained an appreciation of the scientific approach to understanding the physical world.

### II. Methodology for Measuring Attainment of Educational Goals

Classroom assessment: For all three groups of students, knowledge and understanding of course-specific content is assessed primarily through exams, quizzes and homework. (Goals 1, 2, 4, 6)

Oral and written reports: Written communication of observations and conclusions is a central emphasis of the laboratory component of courses. Lab reports provide an opportunity for students to build written communication skills, as well as an opportunity for the instructor to evaluate students' understanding of the concepts involved and their success at communicating that understanding. In some courses, students are required to make oral presentations on topics

they have selected for individual study. Again, these oral presentations serve both instructional and evaluative purposes. (Goals 1, 3, 4, 6)

Research experience: Physics majors are required to complete a meaningful research experience, either under the direct supervision of a member of the department's faculty or as part of a structured summer research experience elsewhere (e.g., as a participant in the NSF-funded Research Experiences for Undergraduates [REU] program). They are also required to make public presentations of the results of their research. This serves as an integrative experience for our majors, in that they are called upon to apply knowledge and skills they have acquired through their earlier coursework to a real research task. Each member of the department's faculty evaluates the extent to which the student's presentation indicates success in the department's educational goals for majors. (Goals 1, 2, 3)

Pre-/post-testing: In courses that include a thorough introduction to the relationship between force and motion, specifically the courses PHYS P201 (General Physics 1) and PHYS P221 (Physics 1), we have performed pre- and post-testing using the Force Concept Inventory (FCI), an instrument in wide use for this purpose. (Goals 1, 4)

Success in graduate school admission and completion: For those students who aspire to graduate study in physics or a related field, we track their success in being admitted and in completing their intended course of study. (Goals 1, 3)

Items on student course evaluations: Our student course evaluations include items related to the fairness and effectiveness of exams and other classroom assessment techniques, items concerning the quality and effectiveness of our laboratory exercises, and items that measure students' perceptions of the relevance of our courses. (Goals 5, 7)

Faculty inventory: The department's faculty members are often in a position to identify program strengths and weakness that are not addressed by the other methodologies listed here. Faculty surveys following each semester provide an opportunity for bringing these observations to the attention of the rest of the department's faculty. (Goals 1, 2, 3, 4, 5, 6, 7)

Alumni survey: The department will survey physics major graduates approximately two years after their graduation, in order to solicit their current perceptions of the strengths and weaknesses of their undergraduate education. These surveys will also present an opportunity to collect direct measures of graduates' success in graduate study or employment. Surveys of all the department's alumni will be carried out periodically – perhaps every five years – for the same purposes. (Goals 1, 2 3)

### **III. Process for Using Assessment Information to Improve Programs**

Internal assessment report: Each February the department's assessment coordinator will prepare a report of the assessment measures collected during the previous year and distribute it to the department's faculty. The report will include:

- results of the end-of-semester faculty surveys from the past year
- results of pre-/post-testing using the FCI, as reported by the instructors administering these instruments
- summary results of relevant items on student course evaluations
- summary results of faculty evaluations of students' research presentations during the past year

- any available information concerning the success of recent graduates in securing suitable employment, admission to graduate study, or completion of graduate degrees
- results of alumni surveys completed during the past year

Department assessment meeting: The faculty will devote time at a department meeting in March to discussion of the department's internal assessment report. If the discussion identifies either shortcomings in the department's programs or strengths that could be capitalized on through programmatic changes, the faculty will attempt to identify measures that could be taken to accomplish this.

Departmental assessment report: The department's assessment coordinator will prepare the appropriate annual report for the campus Assessment Committee.

#### **IV. Participation of All Constituencies**

Faculty involvement will include participation in the department assessment meeting, as well as collection of direct assessment data via classroom assessment, pre- and post-testing and student course evaluations.

Course evaluation responses provide opportunities for student participation in the assessment process.

Alumni will be invited to participate in the department's assessment activities through alumni surveys.

#### **V. Record Keeping**

Department records of assessment activities will include these items:

- responses to end-of-semester faculty surveys
- detailed results of pre-/post-testing using FCI or other instruments
- results from relevant items on student course evaluations
- faculty evaluations of students' research presentations
- responses to alumni surveys
- internal assessment reports
- minutes of departmental assessment meetings
- assessment reports submitted to the campus Assessment Committee
- departmental assessment plans

**Faculty Assessment Survey  
Department of Physics and Astronomy  
Indiana University South Bend  
Fall 2007**

From the Dept. of Physics and Astronomy Assessment Plan, adopted in October 2005: “The department’s faculty members are often in a position to identify program strengths and weaknesses that are not addressed by the other methodologies listed here. Faculty surveys following each semester provide an opportunity for bringing these observations to the attention of the rest of the department’s faculty.”

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Our educational goals for physics majors are summarized in the following three statements:

- 1) Students completing the major in physics will know and understand in detail many of the concepts that are used to describe the physical world, including the structure of matter, the fundamental interactions of nature, the relationship between force and motion, and the concept of energy.
- 2) Students completing the major in physics will be able to apply fundamental physical principles to the solution of complex problems.
- 3) Students completing the major in physics will be able to communicate results of their experimental or computational work clearly, both orally and in written form.

*Based on your experiences in the last semester, is there evidence that we are meeting or exceeding these goals in some areas? Is there evidence that we are falling short of these goals in some areas? If so, please elaborate.*

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Our educational goals for students majoring in other natural sciences or mathematics are summarized in the following two statements:

- 4) Students completing physics courses as cognate requirements will know and understand physics concepts that will help them to better understand concepts in their own major areas of study.
- 5) Students completing physics courses as cognate requirements will understand the relevance of their studies in physics to their own major areas of study.

*Based on your experiences in the last semester, is there evidence that we are meeting or exceeding these goals in some areas? Is there evidence that we are falling short of these goals in some areas? If so, please elaborate.*

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Our educational goals for students studying physics, astronomy, or geology for general education purposes are summarized in the following two statements:

6) Students completing courses in these areas as part of their general education curriculum will know and understand a limited set of concepts that illustrate a scientific approach to understanding the physical world.

7) Students completing courses in these areas as part of their general education curriculum will have gained an appreciation of the scientific approach to understanding the physical world.

*Based on your experiences in the last semester, is there evidence that we are meeting or exceeding these goals in some areas? Is there evidence that we are falling short of these goals in some areas? If so, please elaborate.*

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*Are there any other observations about student learning that you would like to share with your department colleagues? If so, please elaborate.*

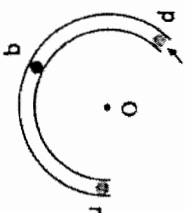
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- Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:
  - about half as long for the heavier ball as for the lighter one.
  - about half as long for the lighter ball as for the heavier one.
  - about the same for both balls.
  - considerably less for the heavier ball, but not necessarily half as long.
  - considerably less for the lighter ball, but not necessarily half as long.
- The two metal balls of the previous problem roll off a horizontal table with the same speed. In this situation:
  - both balls hit the floor at approximately the same horizontal distance from the base of the table.
  - the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
  - the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
  - the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.
  - the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.
- A stone dropped from the roof of a single story building to the surface of the earth:
  - reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
  - speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.
  - speeds up because of an almost constant force of gravity acting upon it.
  - falls because of the natural tendency of all objects to rest on the surface of the earth.
  - falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.
- A large truck collides head-on with a small compact car. During the collision:
  - the truck exerts a greater amount of force on the car than the car exerts on the truck.
  - the car exerts a greater amount of force on the truck than the truck exerts on the car.
  - neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
  - the truck exerts a force on the car but the car does not exert a force on the truck.
  - the truck exerts the same amount of force on the car as the car exerts on the truck.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (5 and 6).

The accompanying figure shows a frictionless channel in the shape of a segment of a circle with center at "O". The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at "p" and exits at "r".



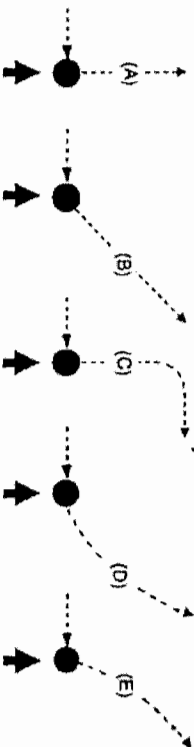
- Consider the following distinct forces:
  - A downward force of gravity.
  - A force exerted by the channel pointing from q to O.
  - A force in the direction of motion.
  - A force pointing from O to q.
 Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?
  - 1 only.
  - 1 and 2.
  - 1 and 3.
  - 1, 2, and 3.
  - 1, 3, and 4.
- Which path in the figure at right would the ball most closely follow after it exits the channel at "r" and moves across the frictionless table top?
- A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure. At the point P indicated in the figure, the string suddenly breaks near the ball. If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (8 through 11).

The figure depicts a hockey puck sliding with constant speed  $v_0$  in a straight line from point "a" to point "b" on a frictionless horizontal surface. Forces exerted by the air are negligible. You are looking down on the puck. When the puck reaches point "b," it receives a swift horizontal kick in the direction of the heavy print arrow. Had the puck been at rest at point "b," then the kick would have set the puck in horizontal motion with a speed  $v_k$  in the direction of the kick.



8. Which of the paths below would the puck most closely follow after receiving the kick?



9. The speed of the puck just after it receives the kick is:

- (A) equal to the speed " $v_0$ " it had before it received the kick.
- (B) equal to the speed " $v_k$ " resulting from the kick and independent of the speed " $v_0$ ."
- (C) equal to the arithmetic sum of the speeds " $v_0$ " and " $v_k$ ."
- (D) smaller than either of the speeds " $v_0$ " or " $v_k$ ."
- (E) greater than either of the speeds " $v_0$ " or " $v_k$ ," but less than the arithmetic sum of these two speeds.

10. Along the frictionless path you have chosen in question 8, the speed of the puck after receiving the kick:

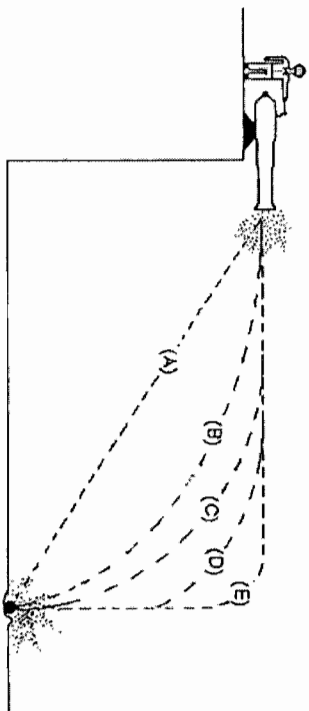
- (A) is constant.
- (B) continuously increases.
- (C) continuously decreases.
- (D) increases for a while and decreases thereafter.
- (E) is constant for a while and decreases thereafter.

11. Along the frictionless path you have chosen in question 8, the main force(s) acting on the puck after receiving the kick is (are):

- (A) a downward force of gravity.
- (B) a downward force of gravity, and a horizontal force in the direction of motion.
- (C) a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion.
- (D) a downward force of gravity and an upward force exerted by the surface.
- (E) none. (No forces act on the puck.)

3

12. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow?

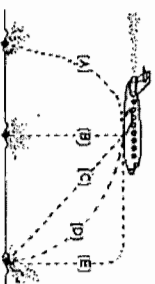


13. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):

- (A) a downward force of gravity along with a steadily decreasing upward force.
- (B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth.
- (C) an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity.
- (D) an almost constant downward force of gravity only.
- (E) none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth.

14. A bowling ball accidentally falls out of the cargo bay of an airplane as it flies along in a horizontal direction.

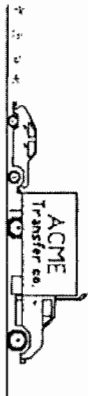
As observed by a person standing on the ground and viewing the plane as in the figure at right, which path would the bowling ball most closely follow after leaving the airplane?



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USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).

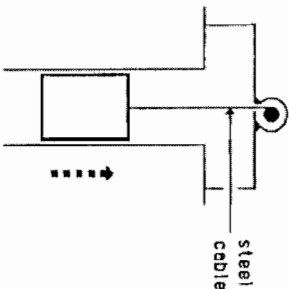
A large truck breaks down on the road and receives a push back into town by a small compact car as shown in the figure below.



15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
- (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
  - (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
  - (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
  - (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
  - (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.
16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
- (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
  - (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
  - (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
  - (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
  - (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

17. An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:

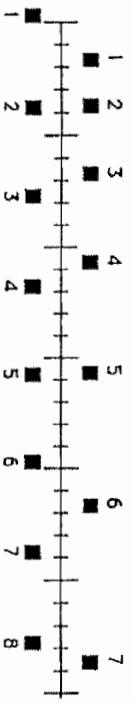
- (A) the upward force by the cable is greater than the downward force of gravity.
- (B) the upward force by the cable is equal to the downward force of gravity.
- (C) the upward force by the cable is smaller than the downward force of gravity.
- (D) the upward force by the cable is smaller than the sum of the downward force of gravity and a downward force due to the air.
- (E) none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).



18. The figure below shows a boy swinging on a rope, starting at a point higher than A.
- Consider the following distinct forces:
1. A downward force of gravity.
  2. A force exerted by the rope pointing from A to O.
  3. A force in the direction of the boy's motion.
  4. A force pointing from O to A.
- Which of the above forces is (are) acting on the boy when he is at position A?
- (A) 1 only.
  - (B) 1 and 2.
  - (C) 1 and 3.
  - (D) 1, 2, and 3.
  - (E) 1, 3, and 4.



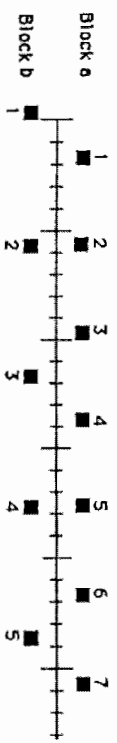
19. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



Do the blocks ever have the same speed?

- (A) No.
- (B) Yes, at instant 2.
- (C) Yes, at instant 5.
- (D) Yes, at instants 2 and 5.
- (E) Yes, at some time during the interval 3 to 4.

20. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.

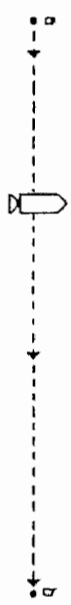


The accelerations of the blocks are related as follows:

- (A) The acceleration of "a" is greater than the acceleration of "b".
- (B) The acceleration of "a" equals the acceleration of "b". Both accelerations are greater than zero.
- (C) The acceleration of "b" is greater than the acceleration of "a".
- (D) The acceleration of "a" equals the acceleration of "b". Both accelerations are zero.
- (E) Not enough information is given to answer the question.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (21 through 24).

A rocket drifts sideways in outer space from point "a" to point "b" as shown below. The rocket is subject to no outside forces. Starting at position "b", the rocket's engine is turned on and produces a constant thrust (force on the rocket) at right angles to the line "ab". The constant thrust is maintained until the rocket reaches a point "c" in space.



21. Which of the paths below best represents the path of the rocket between points "b" and "c"?

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

22. As the rocket moves from position "b" to position "c", its speed is:

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

23. At point "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond point "c"?

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

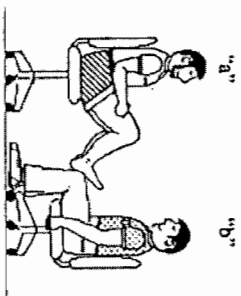
24. Beyond position "c" the speed of the rocket is:

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed " $v_0$ ".  
The constant horizontal force applied by the woman:
- (A) has the same magnitude as the weight of the box.
  - (B) is greater than the weight of the box.
  - (C) has the same magnitude as the total force which resists the motion of the box.
  - (D) is greater than the total force which resists the motion of the box.
  - (E) is greater than either the weight of the box or the total force which resists its motion.

26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:
- (A) with a constant speed that is double the speed " $v_0$ " in the previous question.
  - (B) with a constant speed that is greater than the speed " $v_0$ " in the previous question, but not necessarily twice as great.
  - (C) for a while with a speed that is constant and greater than the speed " $v_0$ " in the previous question, then with a speed that increases thereafter.
  - (D) for a while with an increasing speed, then with a constant speed thereafter.
  - (E) with a continuously increasing speed.
27. If the woman in question 25 suddenly stops applying a horizontal force to the block, then the block will:
- (A) immediately come to a stop.
  - (B) continue moving at a constant speed for a while and then slow to a stop.
  - (C) immediately start slowing to a stop.
  - (D) continue at a constant speed.
  - (E) increase its speed for a while and then start slowing to a stop.

28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b" as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move.



- During the push and while the students are still touching one another:
- (A) neither student exerts a force on the other.
  - (B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
  - (C) each student exerts a force on the other, but "b" exerts the larger force.
  - (D) each student exerts a force on the other, but "a" exerts the larger force.
  - (E) each student exerts the same amount of force on the other.
29. An empty office chair is at rest on a floor. Consider the following forces:
1. A downward force of gravity.
  2. An upward force exerted by the floor.
  3. A net downward force exerted by the air.
- Which of the forces is (are) acting on the office chair?
- (A) 1 only.
  - (B) 1 and 2.
  - (C) 2 and 3.
  - (D) 1, 2, and 3.
  - (E) none of the forces. (Since the chair is at rest there are no forces acting upon it.)
30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racket so that the ball passes over the net and lands in her opponent's court. Consider the following forces:
1. A downward force of gravity.
  2. A force by the "hit".
  3. A force exerted by the air.
- Which of the above forces is (are) acting on the tennis ball after it has left contact with the racket and before it touches the ground?
- (A) 1 only.
  - (B) 1 and 2.
  - (C) 1 and 3.
  - (D) 2 and 3.
  - (E) 1, 2, and 3.