Nova Scotia Examinations
Physics 12
2002 Results

Introduction

This report provides teachers, administrators, and others with an overview of the results from the January 2002 and June 2002 administrations of the Physics 12 examination. The Physics 12 examination was administered in January to first-semester students and a parallel examination was administered in June to second-semester and full-year students. The students were given three hours to complete each examination, which consisted of forty selected response questions and nineteen constructed response questions. Based on the weight of the content areas in the *Atlantic Canada Science Curriculum, Physics 12*, each examination assigned a value of 50 percent to force, motion, work, and energy; 30 percent to fields; and 20 percent to modern physics/radioactivity, half of which was a case study. Thirty-five percent of the examination questions were at cognitive level one, 45 percent at cognitive level two, and 20 percent at cognitive level three. (See page 3 for an explanation of cognitive levels.) More information about the examination is published in the *Nova Scotia Examinations Physics 12 Teacher Information Guide, 2001*.

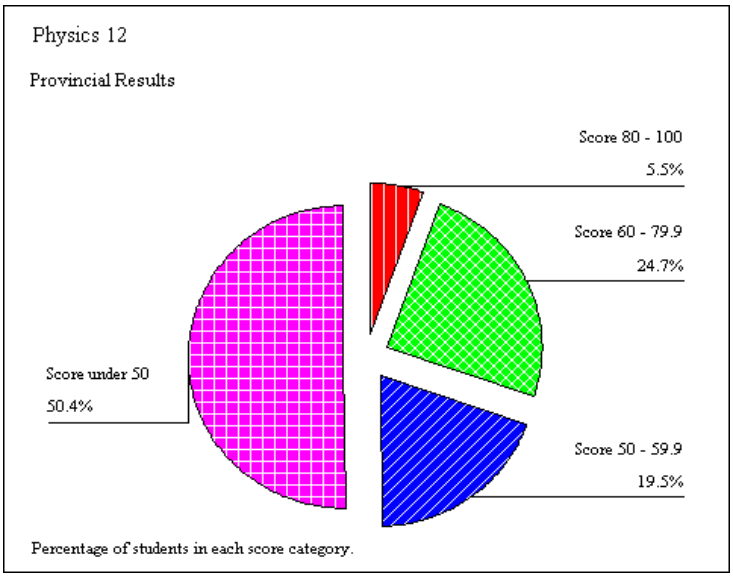
Fifty percent of students in Physics 12 were successful in passing the examination. The pass mark for the examination is 50 percent.

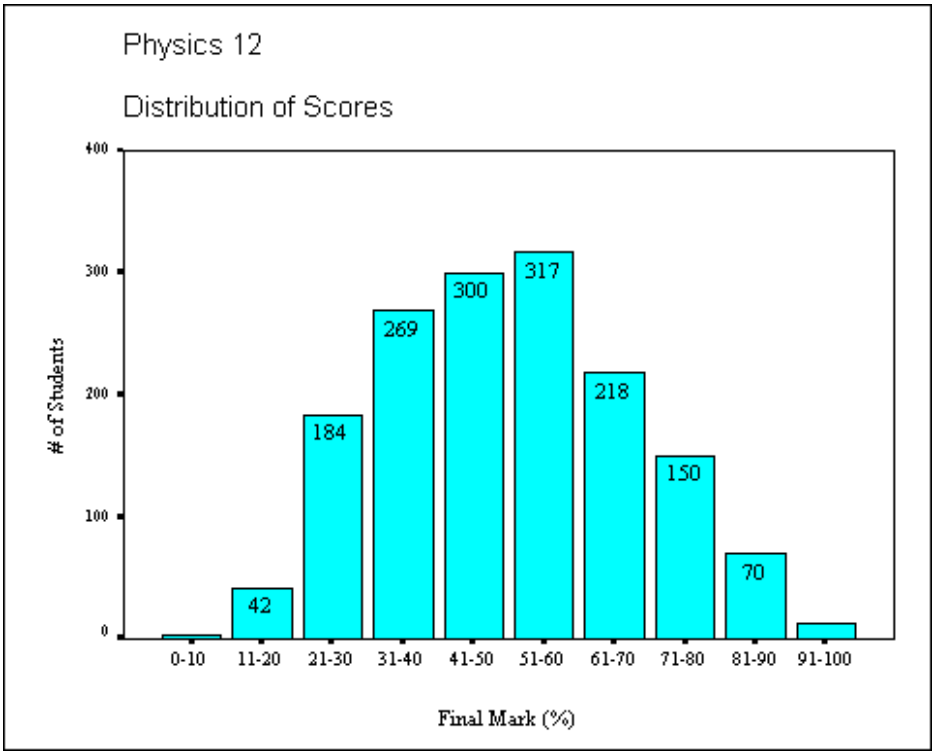
Participation and Sample Size

The examination was administered to a total of 2288 students. Teachers marked their own students' papers with marking guides provided by the Department of Education, and a mark out of 30 percent was added to the students' class marks to determine their final course marks. A sample of these examinations, 1565, was then also marked centrally to yield results at the board and provincial levels. This sample provided results at the 95 percent confidence level, with a confidence interval of ±1.39 percent. (See page 4 for an explanation of "confidence interval.")

Provincial Results

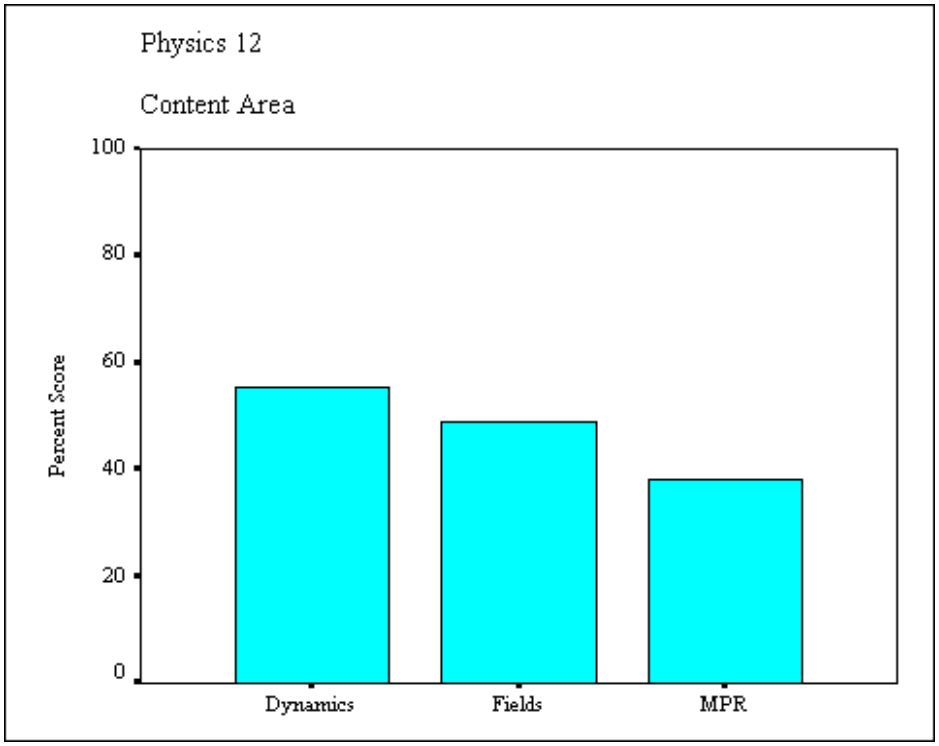
The provincial average score was 50 out of a possible 100 marks. The following graphs provide a breakdown and distribution of the scores.





Provincial Results by Content Area

The major content areas examined were force, motion, work, and energy (dynamics); fields; and waves/modern physics/radioactivity (MPR). The following graph presents the results at the provincial level for each content area (dynamics 55 percent, fields 49 percent, and MPR 38 percent).



Explanation of Cognitive Levels
Cognitive levels indicate the type of intellectual process required to respond to a test item; they are NOT degrees of difficulty. A recall item is extremely difficult if the student cannot remember the answer. A level 2 problem that requires the student to equate expressions for F_c and F_g can be quite easy for the student who recognizes the pattern.

Knowledge (Level 1)
Knowledge refers to test situations that emphasize the remembrance, either by recognition or recall, of ideas, material, or phenomena. This level comprises knowledge of terminology, specific facts (definitions, laws, principles, etc.), conventions, classifications and categories, methods of inquiry, principles and generalizations, and theories and structures. Stem words within these questions might include: *what, list, define, name, describe*.

Comprehension and Application (Level 2)
Comprehension refers to responses that demonstrate an understanding of the literal message contained in a communication, meaning that the student is able to translate, interpret, or extrapolate. Translation refers to the ability to put a communication into another language. Interpretation involves re-ordering ideas (inferences, generalizations, or summaries). Extrapolation is the ability to estimate or predict based on an understanding of trends and tendencies. Stem words include: *explain, interpret, summarize, give examples, predict, translate*.

Application requires the student to select and apply an appropriate abstraction (theory, principle, idea, method) to a new situation. Stem words include: *compute, solve, apply, construct*.

Analysis+ (includes Synthesis and Evaluation) (Level 3)
Analysis comprises the ability to recognize unstated assumptions, to distinguish a conclusion from statements that support it, to recognize facts or assumptions that are essential to a main thesis, to distinguish cause-effect relationships from other sequential relationships, and to recognize a writer's viewpoint. Stem words include: *why does ...work?, distinguish, how are the parts of...related?*

Synthesis is the production of something original from the component parts identified in analysis. Stems include: *propose ways to test a hypotheses, design an experiment to investigate..., formulate and modify a hypotheses related to..., make generalizations based on the analysis of data.*

Evaluation is defined as making judgements about the value of ideas, solutions, and methods. It involves the use of criteria to appraise the extent to which details are accurate, effective, economical, or satisfying. Evaluation includes developing and applying given criteria to judgements of work done, indicating logical fallacies in arguments, and comparing major theories and generalizations. Stems include: *What prediction can you make based on your data?, How could you refine the experiment to improve the data?, What are the positive and negative implications of...?, What course of action do you recommend based on the data/information?*

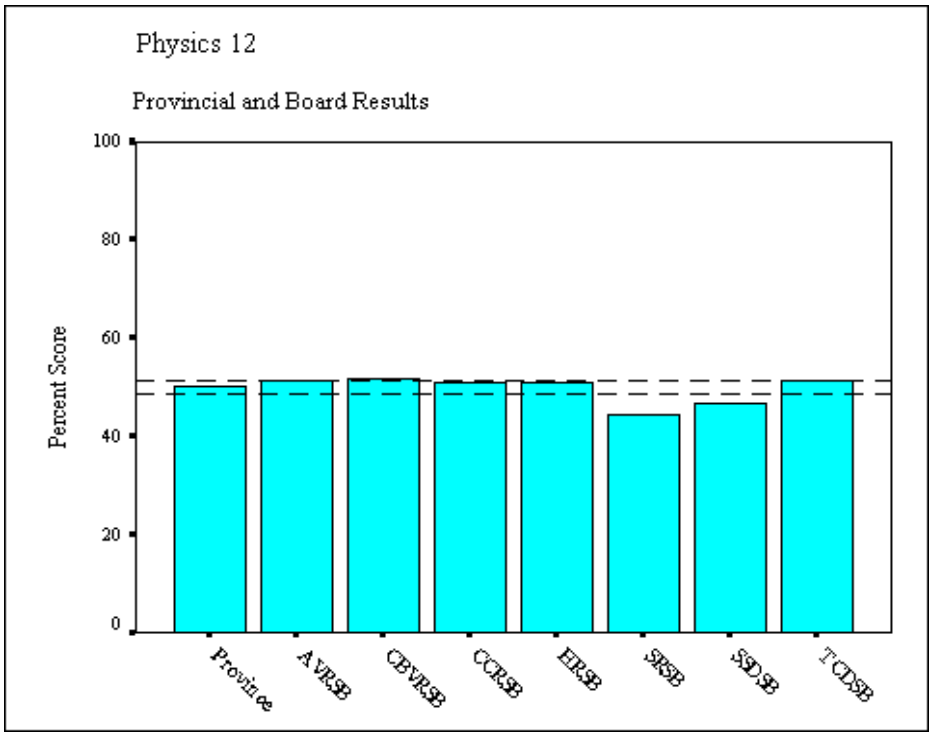
Examination items that require primarily algebraic problem solving are categorized by level according to the following guidelines: If the solution requires the student to make direct replacement of data in a single expression, the item will be considered a level 1 item. If the solution requires several equations or substantial rearrangement, the item will be considered a level 2 item. A level 3 problem will require the interpretation of supplied data and/or a degree of analysis beyond the typical application of formulae.

Provincial and Board Results

The graph below shows the average percent score for each school board except the Conseil scolaire acadien provincial, whose students did not take part in the examination.

It should be noted that a significant number of students did not attempt to answer all examination questions. A zero was assigned to the questions that were not attempted. The results, as presented by the graph, include these data. Marks ranged from a low of 10 percent to a high of 98 percent.

The parallel broken lines on the graph provide the **confidence interval** for provincial results only. The confidence interval represents the high- and low-end points between which the actual results would fall 95 percent of the time. In other words, one can be confident that the actual results for the province would fall in the range of ±1.39 percent, 19 times out of 20, if the physics examination was repeated with different samples from the same student population.



Board	Average	Confidence Interval
Annapolis Valley Regional School Board–AVRSB	51.3%	±2.97%
Cape Breton-Victoria Regional School Board–CBVRSB	51.7%	±3.41%
Chignecto-Central Regional School Board–CCRSB	50.9%	±3.22%
Halifax Regional School Board–HRSB	50.9%	±3.02%
Strait Regional School Board–SRSB	44.2%	±1.74%
South Shore District School Board–SSDSB	46.7%	±4.49%
Tri-County District School Board–TCDSB	51.3%	±2.17%

Note: Confidence intervals at school board level vary with sample size for each board.

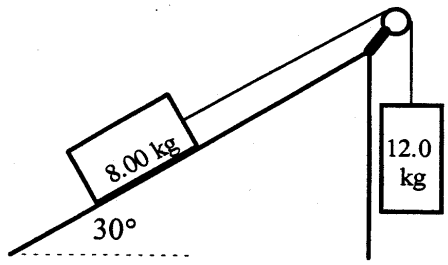
Examiners' Observations
Overall, the performance of students on both the January and June administrations of the Physics 12 examination was significantly improved over the preceding year. Once again, however, many students did not attempt to answer all the examination questions. The majority of students did not clearly present their solutions and explanations. Frequently, there was little evidence of an organized approach or definite methodology for solving the problems presented by the examination questions. Few students produced a table of data from the text of the questions. As well, many students did not write an algebraic statement at the beginning of their solutions, nor did they reorganize algebraic statements before values were replaced. Many students did not express dimensions (units) through their solutions. Vector analysis of dynamics cases, collisions, and fields were particularly weak. Students do not seem to recognize the usefulness of a large, proportional diagram.

The Nova Scotia physics teachers who participated in the central scoring sessions expressed concerns about the distribution of scores. On the January and June exams combined, an average of 13 percent of students received full marks for each of the constructed response questions. This is considerably higher than one would expect in a normal distribution. Since the examination is based on the entire curriculum, and has questions of varying difficulty, this result is impressive. A larger than anticipated group of students has excellent command of the full breadth of the curriculum. Unfortunately, an even larger group of students, (28.5 percent), either did not answer, or obtained a score of zero on these items. One is left to wonder how such a large group of students could get zero on an examination that generated a higher than normal distribution of perfect scores. Measures of central tendency, such as the mean, do not adequately demonstrate this clustering of scores. On the selected response (multiple choice) portions of the exams, the mean and median were both 24 out of a maximum of 39 (61.5 percent).

There is serious concern about literacy skills demonstrated on this examination. A large number of students did not demonstrate the ability to successfully decode a question and to phrase a coherent reply. Also, an all-too-typical example of poor student writing is included at the end of the exemplars (page 11).

Samples Questions, Student Responses, and Observations
Following on pages 6–10, several student responses to constructed response questions on the June examination are included as exemplars. While the presentations may not be perfect, they are clear enough to justify full marks in the judgement of the examiners.

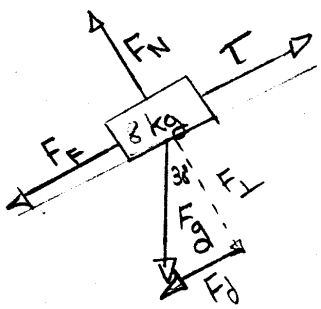
41.



coefficient of friction is 0.200

The system shown above is held at rest. If it is released, what will be the magnitude of the acceleration of the system? Draw a clear free-body diagram as part of your solution.

value: 6



$F_g = mg$
$= (12.0\,kg)(9.8\,N/kg)$
$= 118\,N$

$F_g = mg$
$= (8.00\,kg)(9.8\,N/kg)$
$= 78.4\,N$

$F_N = F_g \cos\theta$
$= (78.4\,N)(\cos 30°)$
$= 67.9\,N$

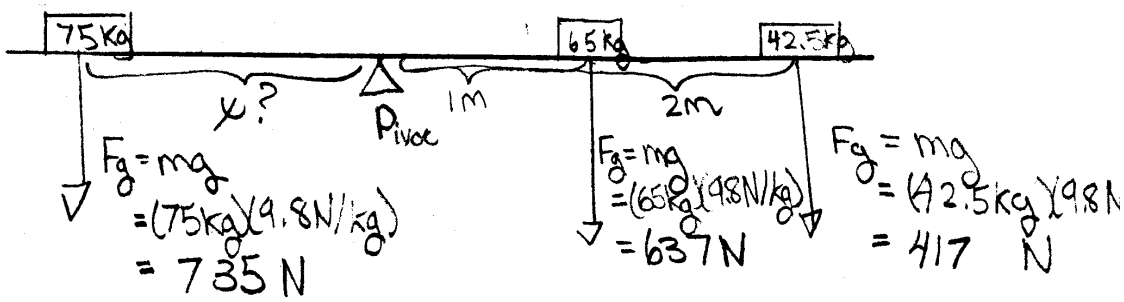
$F_d = F_g \sin\theta$
$= (78.4\,N)\sin 30°$
$= 39.2\,N$

$F_F = \mu F_N$
$= (0.200)(67.9)$
$= 13.6\,N$

$F_{Net} = F_{app} - F_{resist}$
$F_{Net} = F_g - F_F - F_d$
$F_{Net} = 118\,N - 39.2\,N - 13.6\,N$
$F_{Net} = 65\,N$

$F_{Net} = ma$
$a = \frac{F_{Net}}{m}$
$a = \frac{65\,N}{(8.00\,kg + 12.0\,kg)}$
$\boxed{a = 3.3\,m/s^2}$

42. Three friends experiment with a large see-saw. A 65.0 kg person sits 1.00 m from the pivot. A 42.5 kg person sits on the same side at the 2.00 m position. What is the minimum length of the other side of the see-saw if a 75.0 kg person wants to just balance the other two? **value: 3**



$$CWt = CCWt$$

$$Fd_{\perp} + Fd_{\perp} = Fd_{\perp}$$

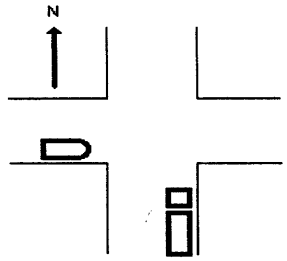
$$(637N)(1m) + (417N)(2m) = (735N)x$$

$$637Nm + 834Nm = (735N)x$$

$$\frac{1471Nm}{735N} = \frac{(735N)x}{735N}$$

$$\boxed{x = 2.00m \text{ minimum}}$$

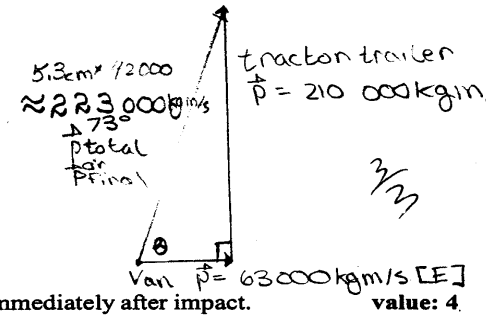
43. A 2100 kg minivan, travelling East at 30.0 m/s, collides with a 21 000 kg tractor trailer, travelling North at 10.0 m/s. The two vehicles remain stuck together after impact.



A) Calculate the momentum of each vehicle prior to the collision. Construct a momentum diagram in approximate scale showing the two original momenta and the final momentum.
value: 3

Van
$\vec{p} = m\vec{v}$
$p = (2100\,kg)(30.0\,m/s\,[E])$
$p = 63\,000\,kgm/s\,[E]$

Trailer
$\vec{p} = m\vec{v}$
$p = (21\,000\,kg)(10\,m/s\,[N])$
$p = 210\,000\,kgm/s\,[N]$



3/3

B) Determine the velocity of the combined mass immediately after impact. **value: 4**

$c^2 = a^2 + b^2$
$c^2 = (63\,000\,kgm/s)^2 + (210\,000\,kgm/s)^2$
$c^2 = 3969000\,000\,kg^2m^2/s^4 + 4.41 \times 10^{10}\,kg^2m^2/s^4$
$c^2 = 4{,}807 \times 10^{10}\,kg^2m^2/s^4$
$c = 220\,000\,kgm/s$

000
2100
3100

4/4

$\vec{p}_{tot} = \vec{p}_{tot}'$
$\vec{p} = m\vec{v}$
$\vec{v} = \frac{\vec{p}}{m}$
$\vec{v} = \frac{220\,000\,kgm/s}{(2100\,kg + 21\,000\,kg)}$
$\vec{v} = 9.5\,m/s$

$\theta = \tan^{-1}\left(\frac{opp}{adj}\right)$
$\theta = \tan^{-1}\left(\frac{210\,000\,kgm/s}{63\,000\,kgm/s}\right)$
$\theta = 73°$

$\boxed{\vec{v} = 9.5\,m/s\ [E\ 73°\ N]}$

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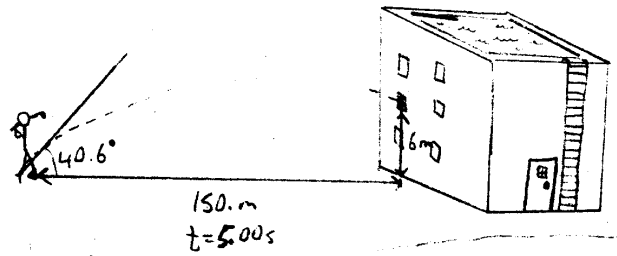
44. A golfer is practising his/her swing at a distance of 150. m from a house. On the way back to the ground, 5.00 seconds after being hit, the ball goes through a second storey window that is 6.00 m from the ground. With what initial velocity did the ball leave the face of the golf club? Ignore the effects of air resistance in your calculations. Draw a diagram that shows the horizontal and vertical components of the initial velocity. **value: 6**



The initial velocity was 39.5m/s at an angle of 40.6° above the ground

Horizontal

$d_x = 150.\ m$

$V_x = 30.0\ m/s$

$t = 5.00\ s$

Vertical

$V_i = 25.7\ m/s$

$V_f = 23.3\ m/s$

$\Delta d_y = 6\ m$

$a = -9.80\ m/s$

$t = 5.00\ s$

$V_x = d_x / t$

$V_x = \frac{150\ m}{5.00\ s}$

$V_x = 30.0\ m/s$

$\Delta \vec{d} = \vec{V}_i t + \frac{1}{2} a t^2$ so $V_i = \frac{-(\frac{1}{2} a t^2) + \Delta d}{t}$

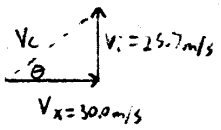
$6\ m = V_i (5.00\ s) + \frac{1}{2}(-9.80\ m/s^2)(5.00\ s)^2$

$V_i = \frac{6\ m - (\frac{1}{2}(-9.80\ m/s^2)(5.00\ s)^2)}{5.00\ s}$

$V_i = \frac{6\ m - 122.5\ m}{5.00\ s}$

$V_i = \frac{128.5\ m}{5.00\ s}$

$V_i = 25.7\ m/s$



$V_c^2 = V_x^2 + V_i^2$

$V_c^2 = (30.0\ m/s)^2 + (25.7\ m/s)^2$

$V_c^2 = 1560.49\ m^2/s^2$

$V_c = 39.5\ m/s$

$\tan\theta = \frac{opp}{adj}$

$\tan\theta = \frac{25.7\ m/s}{30.0\ m/s}$

$\tan\theta = .85666$

$\theta = 40.586°$

$V_f^2 = V_i^2 + 2ad$

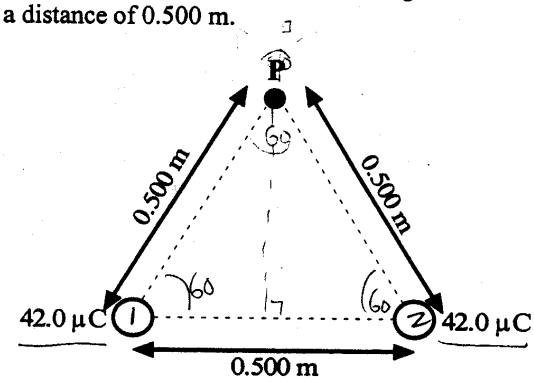
$V_f^2 = (25.7\ m/s)^2 + 2(-9.80\ m/s^2)$

$V_f^2 = 542.89\ m^2/s^2$

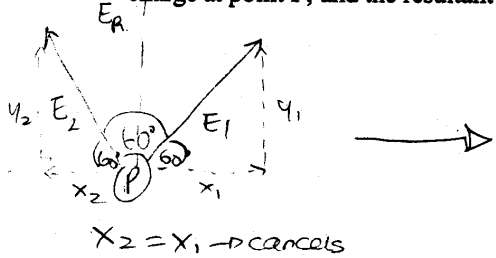
$V_f = 23.3\ m/s$

Examiners' Comments: *Note the algebraic rearrangement of the displacement equation.*

45. The diagram below shows two equal positive 42.0 μ C charges at the base of an equilateral triangle separated by a distance of 0.500 m.



A) Draw a vector diagram, to approximate scale, showing the electric field strength due to each charge at point P, and the resultant electric field strength at point P. **value: 2**



$E_{resultant} = \sin 60°(E_1) + \sin 60°(E_2)$

B) Determine the electric field strength at point P. **value: 4**

$E_{resultant} = \sin 60°(E_1) + \sin 60°(E_2)$

$E_1 = \frac{kq}{d^2} = \frac{9\times10^9(42\times10^{-6})}{(0.5)^2} = 1.51\times10^6$ N/C

$E_2 = \frac{kq}{d^2} = \frac{9\times10^9(42\times10^{-6})}{(0.5)^2} = 1.51\times10^6$ N/C

$E_{resultant} = \sin 60\,(2\cdot 1.51\times10^6)$

$E_R = \boxed{2.62\times10^6 \text{ N/C}}$

in an upward direction!

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51. What are two serious concerns relating to nuclear power stations? In two or three sentences for each, elaborate on the nature of the concern and the degree of risk. **value: 4**

Two serious concerns relating to nuclear power stations are the voltage required on their power supplies. They have to use step up and down resistances in order to achieve safety for the public when dealing with power lines. If they don't the lines might have to much current in them and as the consu would always be "in the dark" due to there being too n power in the wire.

$E = mc^2$ $\lambda = \frac{h}{mv}$

Another concern is high power wires or lines. These are causing serious concerns to nuclear power stations. The wavelength the power must travell is too great of a distance and more nuclear power is needed for the energy to travell any distance.

Examiners' Comments

From the beginning of the response, it is clear that the student has misinterpreted the question, which is concerned with the ***production*** *of electricity by nuclear plants,* ***NOT*** *the* ***transmission*** *of electrical energy through transformers and lines. The opening sentence gives only one concern, although two were requested. Two unrelated equations are inserted without comment or elaboration. Careful reading of the response reveals serious structural problems. What does the following excerpt mean*: "The wavelength the power must travell is too great of a distance..."? *Because this example is far from unique, it is evident that students need more guidance and experience with respect to the construction of adequate written responses* ***within*** *the physics program in both grades 11 and 12.*

Examiners' Suggestions

1. Students need more practice doing free-body vector analysis of mechanical systems. Perhaps exercises in which students do only the vector analysis for some typical situations and NOT the algebraic solutions would be helpful.
2. Vector solutions such as determining total force and total momentum should include a large, clear diagram. A scaled diagram solution is acceptable, and is very helpful when framing the problem or checking the result of an algebraic solution.
3. Organization and presentation of algebraic solutions need improvement. The practice of solving equations for the unknown before known values are inserted should be required.

The Physics Program

The Physics 12 curriculum was implemented September 2000. It was planned and developed collaboratively by a regional committee under the auspices of the Atlantic Provinces Education Foundation (APEF). Physics 12 uses scientific processes throughout four units : Force, Motion, Work, and Energy; Fields; Waves and Modern Physics; and Radioactivity.

The first unit relates the study of mechanics to everyday occurrences based on the principles of classical physics. The topic of Forces, which cause motion and the application of interactions among objects, is the conceptual framework of this unit. The study of Fields provides a context for everyday experiences and develops knowledge of the principles of magnetism and electromagnetism. Waves and Modern Physics focusses on developing an integrated view of the achievements that form the essence of twentieth-century physics by extending understanding to the wider range of electromagnetic phenomena and making connections related to the structure of matter. The topic of Radioactivity explores the full range of types of radiation, including natural and artificial sources, and assesses the risks and benefits of exposure to each of them.

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Testing and Evaluation