This document was written primarily for:

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<th>Category</th>
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<tr>
<td>Students</td>
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<td>Teachers</td>
<td>✅ of Physics 30</td>
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<td>Administrators</td>
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<td>Parents</td>
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<td>General Audience</td>
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<td>Others</td>
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**Contents**

Teacher Involvement in the Diploma Examination Process ........................................... 1
Diploma Examination Weighting .................................................................................. 1
Time Limits on Diploma Examinations ....................................................................... 1
Course Objectives ....................................................................................................... 2
Program of Studies ..................................................................................................... 2

*NEW* Program of Studies Clarifications ................................................................. 3
Performance Expectations ......................................................................................... 12
Performance Standards ............................................................................................ 14
Examination Specifications and Design ..................................................................... 15

*NEW* Feedback from Field Testing, Diploma Examinations, and Teachers .......... 18
Diploma Examinations: Multiple Forms ................................................................... 21
Examination Security .................................................................................................. 22

Maintaining Consistent Standards Over Time on Diploma Examinations ............... 22
Field Testing ............................................................................................................... 23
Benefits of Field Tests ............................................................................................... 24
Special-format Practice Tests ..................................................................................... 25
Publications and Supporting Documents ................................................................... 26

Physics Data Pages .................................................................................................... 26
Using Calculators ......................................................................................................... 26

Illustrative Numerical-response Items Assessing Mandated Skills ......................... 27

*NEW* Illustrative Items from Field Testing or Diploma Examinations Showing Word Usage and Exploring Misconceptions ................................................................. 36

*NEW* Questions Showing Assessment at Various Cognitive Levels .................... 43
Illustrative Graphing Skills ........................................................................................ 45
Numeracy on Physics Examinations ......................................................................... 47
Instructions Pages for Physics 30 Diploma Examinations ........................................ 52

*NEW* Data Pages for Physics 30 Diploma Examinations ........................................... 55

Contacts 2018–2019 .................................................................................................... 58

Please note that if you cannot access one of the direct website links referred to in this document, you can find diploma examination-related materials on the [Alberta Education website](https://www.education.gov.ab.ca/).
Teacher Involvement in the Diploma Examination Process

High-quality diploma examinations are the product of close collaboration between classroom teachers and Alberta Education. Classroom teachers from across Alberta are involved in many aspects of diploma-examination development, including the development of raw items; the building, reviewing, and administering of field tests; and the reviewing of diploma examinations.

Alberta Education values the involvement of the teachers and often asks school jurisdictions for the names of teachers who are interested in being involved in all of the development processes for diploma exams. Teachers who are interested in developing raw items, building and/or reviewing field tests, or building and/or reviewing diploma examinations are encouraged to talk to their principals about how they can submit their names for approval to be involved in these processes. Although the call for submission occurs early in the fall, teachers are welcome to have their names submitted at any time.

Periodically we send out information to those Physics 30 teachers who are on our contact list.

For more information, contact

Marc Kozak  
Physics 30, Examiner  
780-427-6196 or Marc.Kozak@gov.ab.ca

Diploma Examination Weighting

On September 1, 2015, the diploma examination weighting shifted from a 50/50 weighting to a 70/30 weighting, where the school-awarded grades are worth 70 percent. For further information, please refer to Marks, Results, and Appeals.

Time Limits on Diploma Examinations

All students may now use extra time to write diploma exams. This means that all students now have up to 6 hours to complete the Physics 30 Diploma Examination, if they need it. The examination is still designed so that the majority of students can comfortably complete it within 3 hours. The examination instructions state both the original time and the total time now available.

Extra time is available for diploma examinations in all subjects, but the total time allowed is not the same in all subjects. For more information about accommodations and provisions for students, please refer to the General Information Bulletin.
Course Objectives

Physics 30 is intended to further students’ understanding and application of fundamental physics concepts and skills. The focus of the course is on understanding the physics principles behind the natural events that students experience and the technology that they use in their daily lives. The course encourages enthusiasm for the scientific enterprise and develops positive attitudes about physics as an interesting human activity with personal meaning. It develops knowledge, skills, and attitudes to help students become capable of and committed to setting goals, making informed choices, and acting in ways that will improve their own lives as well as life in their communities.

To develop the required knowledge, skills, and attitudes in Physics 30, students must have successfully completed Science 10 and Physics 20.

Although there is no mathematics prerequisite for Physics 20, students who have successfully completed Mathematics 20–1 or Mathematics 20–2 will have better algebra skills to use in the course.

Program of Studies

The Physics 20–30 Program of Studies was implemented in September 2007, and the first diploma examination on the program was administered in November 2008. The program was updated in 2014 to include links to mathematics.

The program of studies is available online at education.alberta.ca. Comments and questions are both appreciated and encouraged. In response to the questions and feedback received, the points on the following page clarify some aspects of the relationship between the Physics 20–30 Program of Studies and the Physics 30 Diploma Examination.


**Program of Studies Clarifications**

This section of the Physics 30 Information Bulletin describes the expectations mandated in the *Physics 20–30 Program of Studies, 2007* (Updated 2014) as assessed on the Physics 30 Diploma Examination. Only selected portions of the program of studies are addressed here. The selection is based on comments from teachers or student performance on field tests and diploma examinations.

For a description of what is expected at the classroom-based or student-based level, please refer to the Student-based Performance Standards found on the Alberta Education site. Details of the location are provided on page 5 and page 25 of this document.

**Expectations That Span ALL the General Outcomes**

**Specific Outcomes for Skills (s)**

.1s: *Students will* formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

• design an experiment and identify and control major variables

A controlled variable is one that, if not controlled, would reduce the confidence of the conclusions based on the observations. The manipulated variable is the one that, in a fair test, is changed by the researcher. The responding variable is the only one that responds directly to the changes in the manipulated variable. The Physics 30 Diploma Examination will not use the terms *dependent* and *independent variables*.

.3s *Students will* analyze data and apply mathematical and conceptual models to develop and assess possible solutions

• analyze graphs
• infer mathematical relationships from empirical evidence
• use free-body diagrams

The analyzing of graphs, their shape as well as slope or area, is a foundational skill to scientific literacy. This includes, but is not limited to, relating graph shape to possible mathematical relationships and curve straightening as well as using the slope, area, or intercept to bring physics meaning to the data. The variable that was manipulated in the experiment/investigation will be plotted on the *x*-axis, but for curve straightening, either the variable on the *x-* or the *y*-axis or both may be manipulated.

Free-body diagrams consist of labelled arrows that point from, or toward, a point that represents the centre of mass of the object on which the forces act. Free-body diagrams should NEVER contain rectilinear components of the vectors.
For numerical-response items, the diploma examination will use this piece of art to show directions.

\[ \begin{align*}
2 & \leftrightarrow \quad 3 \\
1 & \leftrightarrow \quad 4 \\
5 & \quad 6 \\
7 & \times 9 \\
8 & \cdot 0
\end{align*} \]

Students should be selecting the direction that is closest to the direction of the vector they are matching. It is not the intent of the examination to have directions limited to these ten.

**.4s Students will** work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results
- use appropriate International System of Units (SI) notation, fundamental and derived units and significant digits
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
- use the delta notation correctly when describing changes in quantities

Although the examination cannot address working collaboratively directly, the clarity and consistency of communication can be assessed. This includes, but is not limited to, the algebra of unit analysis, using scientific notation and SI prefixes, as well as evaluating the quality of results of an investigation. The significance of limiting the number of digits in a measured (or calculated) value is based on the quality of the measurements made. **Note:** When recording answers for a numerical-response item, a calculated value of 0.25 has two significant digits but is considered a three-digit answer.

**Sign Conventions**

In the .2s part of the program, students are using vectors to show direction. In the .3s, students are using vector addition (graphically or algebraically) to determine a net vector. The .4s includes sign conventions as a quick and meaningful way of communicating information. The challenge inherent in quick methods is that they are used unwisely. Students should be able to explain the significance of the sign, positive (+) or negative (−), and why they are using it.

Examples of wise use of signs:

- Defining “down” as positive for a P20 trajectory caused by an unbalanced gravitational force allows the use of +9.81 m/s\(^2\) for the acceleration caused by gravity, which makes the keystrokes easier.
- Introducing a Cartesian plane into the solution of a two-dimensional interaction such that the signs on the x- and y-components make sense for an algebraic analysis.
- Assigning + and – relative to a thin lens. It is immaterial which side is + and which is −.
- Correctly using delta notation for electric potential difference or for mass defect such that the change in the final energy state of the system is consistent.
Examples of weak use of signs:

- Failing to recognize what the negative sign in the magnification equation signifies.
- Substituting the nature of charge into the electrostatics equations. It is much better to calculate the magnitude separately from the direction and then apply Newton’s third law to determine the directions.

Specific Outcomes for Science, Technology, and Society (STS)

Each STS question will be assessed and reported on in one of two ways: “assesses an STS outcome” or “in an STS context.”

The diploma examination will present situations in which students are to apply the understandings mandated in the Specific Outcomes for Knowledge and Specific Outcomes for Skills. When the situation is an exact match to the description in the program of studies that is in regular font, then the reporting is “assesses an STS outcome.” When the situation does not exactly match the description in the program, it will be reported as “in an STS context.” The italics examples in the program of study are a suggestion for when a teacher doesn’t have a better or a locally developed approach for making the physics fit the real-world experience of the students.

The relationship between the Specific Outcomes for Science, Technology, and Society and the philosophy of science education is addressed on page 5 and following of the program of studies under Foundation 3. There are three main areas: Nature of Science (NS), Science and Technology (ST), and Social and Environmental Contexts (SEC). These are also used in the item description of the examination report.

Specific Outcomes for Knowledge

The actual cognitive load required of the students is much greater than “knowledge – recall/reproduce.” On page 13 of this document, a coloured chart matches the verbs to the associated cognition. The Physics 30 Diploma Examination will assess the outcomes at any level up to but not exceeding the mandated cognition. The mark that a student receives on the diploma examination will reflect the cognition that the student, in general, is able to apply. The relationship between the student score and the cognition is described in the section titled “Performance Expectations,” found on page 12 of this document.

For a description of the relationship between the classroom mark and the cognition that the student is using, in general, please see the Student-based Performance Standards.
General Outcome A: Momentum and Impulse

1. *Students will* explain how momentum is conserved when objects interact in an isolated system.

A1.1k, the definition and calculation of momentum, links to C2.6k, the momentum of a photon, and to D4.1k, the analysis of paths of unknown charged particles in external magnetic fields.

A1.3k expects students to apply the idea of systems. An isolated system is one for which no outside force does work on objects inside the system. As a result, only forces inside the system are significant. The analysis of this is based on Newton’s third law. Newton’s third law leads into conservation of momentum only when no external forces are able to do work. Students should understand this logical progression.

A1.4k links to C2.6k and the analysis of Compton scattering. In the real world, momentum is usually not conserved. Students should analyze the situations presented to them. They should not be assuming either that momentum is always conserved or that it is never conserved.

A1.3s mandates 2-dimensional analysis. For diploma questions, a well-drawn, scaled vector addition diagram will yield results good enough to answer questions. Students can calculate rectilinear components, but this is often a more time-intensive method. Students do not need to use sine or cosine laws, but if they have these tools, their use may save time. **Note:** These expectations also apply to B1.3s, B2.3s, and B3.3s.
General Outcomes B: Forces and Fields

1. *Students will* explain the behaviour of electric charges, using the laws that govern electrical interactions.
2. *Students will* describe electrical phenomena, using the electric field theory.
3. *Students will* explain how the properties of electric and magnetic fields are applied in numerous devices.

B1.3k, methods of charging, will usually use an electron-transfer model. This model is very good for describing the charging of metal objects. It is a weak model for describing what happens in charging by friction, where ion transfer is a much more likely mechanism. Students will NOT be tested on this subtlety.

B1.2sts links to B1.5k, in which students should be able to compare and contrast Coulomb’s torsion balance apparatus and experiment with those of Cavendish, as well as with B1.1s, experimental design, and with B1.3s, data analysis.

B1.8k allows the diploma examination to link electric forces to gravitational forces. This links to B2.3k, which relates electric potential difference to gravitational potential difference, as well as to B3.2k, which asks students to compare all three types of fields in terms of sources and directions. Direction includes shape and the relationship between field line density and field strength.

B2.2k, comparing forces and fields, is becoming a very interesting outcome: The classical understanding of a field was to explain “action-at-a-distance” forces, which caused acceleration; one current understanding of a field is as a mathematical model used to explain the observed world. These two approaches start in very different places and use different methods. Students should be familiar with the foundational philosophy that physics is about testing models against the real world, and where the models fail, the appropriate response is to either modify the model or devise a different test.

B2.8k and B2.3s link the linear and parabolic paths of charged particles in uniform electric fields to the identical analyses of objects moving in gravitational fields from Physics 20. The path of a charged object following a circular trajectory in a radial electric field is also an appropriate analysis to ask the students. This links to D2.1k, the application of Maxwell’s theory to the evolution of the model of the atom.

B2.9k and B2.3s mandate the application of the physics principle of conservation of energy. This conservation principle shows up again in B3, C2, D2, and D4. Conservation of energy requires students to define the system that they are analyzing. This should be done explicitly and at the start of the analysis. The mathematics follows from the definition.

*BNEW* B2.10k involves both a simplified analysis of cases where the oil drop is suspended, because then the frictional/buoyant forces are negligible, and a more complex analysis of cases where the motion is either uniform or accelerated. The quantum nature of charge is addressed in the program here but there are also links to D1 and the evolution of the model of the atom.
B3.6k, B3.2s, and B3.3s mandate that students analyze situations in which forces are balanced and those in which forces are unbalanced.

B3.7k and B3.9k mandate that students be familiar with the phenomena of the “motor effect” and the “generator effect.” The principle of conservation of energy is a strong mechanism to explain the phenomena.

B3.2s mandates that students should be able to apply hand rules to determine the nature of the charge (sign), the direction of charge motion, the direction of conductor motion, the direction of the force acting on the charge, the direction of the force acting on the conductor, the direction of the external magnetic field, and the direction of the induced magnetic field. The diploma examination will use the word current when the nature of the moving charge doesn’t matter and will specify the nature of the charge when it does.

General Outcomes C: Electromagnetic Radiation

1. Students will explain the nature and behaviour of EMR, using the wave model.
2. Students will explain the photoelectric effect, using the quantum model.

C1.4k and C1.1s mandate that students should devise or analyze an experimental design to determine the speed of light. This relates as well to C1.4s and evaluating the quality of the results. This outcome is not limited to historical experiments.

C1.6k and C1.11k are significant in helping students understand the process of having a model that can be used to describe or explain observations that, when the observations don’t match the description, result in a necessary change to the model or in new experiments. C1.6k deals with the change in direction without specifying a mechanism. C1.11k deals with using wave-related observations to explain observations associated with refraction.

To reinforce this difference, the two equations are separate on the equation sheet.

C1.7k requires mindful use of words by students and teachers: Lenses are described by the effect that they have on light rays, and mirrors are described in terms of the shape of the reflective surface. This helps students who might pursue a career in optics to avoid learning incorrect descriptions of lenses and mirrors. The outcome builds on the ray diagram skills from Science 8, so questions on the diploma examination will require the interpretation of a ray diagram rather than just the creation of a ray diagram.

C1.10k is another example of model testing and revising. This outcome relates to the small angle theorem, which links to C1.6k and Physics 20 pendulum analysis. When this outcome is done well, students become more confident in understanding that models have strengths while also necessarily having limitations.

C1.2s is the section of the program with the longest list of mandated measurement situations. This part of the program is an excellent place to ensure that students have explored their full experimental skills because the equipment can be inexpensive and the risk of student harm is low. The diploma examination will require students to make measurements of angles or distances on observations. Students should bring a protractor and a ruler to the examination writing. If they
A ruler is printed on the tear-out pages for them to use. This ruler is sufficient for the requirements of the examination.

C2.3k should build on Physics 20 mechanical waves and C1. This is another example of models failing to provide descriptions that match observations. Students should be able to build a prediction based on a classical-mechanical or an electromagnetic wave model. They should be able to articulate why the observations associated with the photoelectric effect are NOT consistent with either model and then describe how the model of light being composed of photons provides a description that matches observations.

**NEW** C2.4k requires an early-1900s understanding of the photoelectric effect consistent with Einstein’s explanation that 1 photon = 1 electron and intensity is a measure of the number of photons. Recent advancements in technology show that this model is insufficient, but current models are beyond the *Physics 20–30 Program of Studies, 2007* (Updated 2014).

C2.6k links to A1.4k, A1.5k, and A1.1k. Students should be able to analyze a simple Compton event in terms of conservation of momentum or conservation of energy. The diploma examination will **not** require a full mathematical analysis using both conservation principles.

Also, the program mandates that students calculate the momentum of a photon. The converse, the wavelength of a moving particle, can be tested on the diploma examination by telling the students how to apply the de Broglie relationship.

C2.1sts relates the historical work of scientists to changing experiments (Hertz) and changing models (Planck).

**General Outcomes D: Atomic Physics**

1. *Students will* describe the electrical nature of the atom.
2. *Students will* describe the quantization of energy in atoms and nuclei.
3. *Students will* describe nuclear fission and fusion as powerful energy sources in nature.
4. *Students will* describe the ongoing development of models of the structure of matter.

D1 is a wonderful place to really explore the reciprocity between theoretical advances and technological advances. When this unit is done well, students have a deep understanding of the relationship between observations and the characteristics of models that developed in response to the observations; they also understand that every model has its limitations. This links directly to D2.1k, which relates the theory from the mid-1800s to the model proposed in the late 1800s.
D3.1k requires students to understand that biological damage is caused when radiation (alpha, beta, or gamma) deposits its energy in living tissue.

- Students should be able to link B1.2k, electrical interactions, to the nature and size of charge on the three types of radiation: alpha particles will interact more strongly, and then beta particles, while gamma interactions are NOT described by a Coulomb model. Electrically charged radiation deposits energy continuously, but not uniformly, as it travels through biological tissue.
  - Beta particles are much less massive than alpha particles and are more easily scattered during interactions with atomic nuclei; so their paths through materials are much less direct than those of alpha particles.
  - Alpha particles ionize virtually every molecule they pass, creating between 4000 and 9000 ion pairs per micrometre of tissue. Beta particles ionize only about 1 in 1000 molecules encountered and create only 6 to 8 ion pairs per micrometre of tissue.
  - The rate of ionization for an alpha particle increases as the particle slows and peaks just before the alpha particle stops. Most of the energy released is within a very small volume of space compared to that for a beta particle.

- Students should be able to apply ideas from C2.1k, photon energy; C2.3k, work function, or D2.4k, electron energy levels; C2.6k, the Compton effect; and D3.1sts, pair production, to describe/predict how gamma radiation interacts with biological tissues:
  - Energy below a threshold (the energy required to free an electron, the energy required to break a molecular bond) will not produce any effect on the photon, so it will penetrate the tissue and cause no damage.
  - Energy high enough to free an electron (photoelectric effect) will result in the photon disappearing but the production of a free low-energy electron and an ion, which affects the chemistry in the living tissue. This is the most probable interaction.
  - Energy high enough to break molecular bonds will result in the photon disappearing but also the production of ions, which affect the chemistry in the living tissues.
  - Energy high enough to cause Compton scattering results in lower but still high-energy photons, high-energy electrons, and ions whose associated damage is described above.
  - Energy high enough to cause pair production results in the photon disappearing and the production of new charged particles where a positron-electron annihilation occurs fairly quickly, producing high-energy photons.

- The effects of the various types of damage are different, too.
  - Referring specifically to the ionization effect on living matter, there are several main concerns: production of free radicals from water, which may recombine to form peroxide (H₂O₂) that initiates harmful chemical reactions in cells and tissues; breaking bonds within macromolecules, destroying their functioning; and genetic damage to DNA molecules (self-repairing but now with transcription errors (mutations) built in).

Highly interactive means not highly penetrating. In other words, a gamma photon is highly penetrating and is not likely to interact; a beta particle has less penetrating ability in living tissue, so it is more likely to interact. The gamma photon will likely be absorbed and cause changes to the chemistry near the absorption site, whereas the beta particle will lose energy as it is scattered, and its rate of energy loss increases, with most of its energy lost at the end. Its interactions also
change the chemistry near each scattering.

A widely held misconception is that radiation is dangerous and that the higher the energy is, the more dangerous the radiation is. A more solid analysis includes the energy, charge, mass, and number of radiation particles to evaluate the likelihood and nature of damage.

D3.2s requires the analysis of a graph to determine half-life. Students should be using more than one value from the curve in determining the half-life. The diploma examination will not use semi-log paper.

D3.6k links to D3.1k, properties of beta particles, to D3.2k, beta-positive and beta-negative particles and their neutrino partners, and to D3.1sts, permitting the assessment of annihilation reactions. The information on the data sheets can make these calculations more like recall. Students should also know the terms electron and positron as matter-antimatter partners.

D3.2sts, assessing risk, D3.1k, biological effects and D3.4s, communication and units, combine to allow for a rich discussion with students about the multitude of units for measuring and reporting the rate and significance of radiation. For example, number of counts, becquerell, currie, rad, rem, grey, and severt.

D4.1k is related to but goes beyond B3.2s. If students already know what the particles are, then the task is reported as B3.2s. If the students need to determine characteristics of unknown particles, then the task is reported as D4.1s or D4.3s.

D4.2k requires the students to know that the net strong nuclear interaction is a repelling force at distances smaller than $10^{-16}$ m, very strong at a range of $10^{-15}$ m, and insignificant at distances longer than $10^{-15}$ m. This links to D1.4k and the description of the atom based on the alpha-particle scattering experiments. This also links to B1.6k or B1.7k, which involve the analysis of one or more charged objects near each other.

D4.3k specifies which standard model is being used to describe protons and neutrons. This is another area where the general concept of a model being only as good as what it can be used to explain is significant. There are observations with which the standard model is consistent, and there are others with which it does not agree. Students should not be memorizing truths.
Performance Expectations

Curriculum Standards

Provincial curriculum standards help to communicate how well students need to perform in order to be judged as having achieved the objectives specified in the *Physics 20–30 Program of Studies, 2007* (Updated 2014). The specific statements of standards are written primarily to advise Physics 30 teachers of the extent to which students must know the Physics 30 content and be able to demonstrate the required skills in order to pass the diploma examination.

Linking Program Verbs to Cognitive Expectations

Some of the verbs used in the *Physics 20–30 Program of Studies* carry cognitive expectations, and others describe skills and attitudes that students should develop. It is very important to separate the ideas of cognitive task and student success: students can be very successful at a cognitively demanding task and experience very little success at a cognitively undemanding task. For example, students should memorize the EMR spectrum. If they have not, then classifying a type of EMR by photon energy is cognitively easy but the students will have low success.

In general terms, there are low cognitive tasks, medium cognitive tasks, and higher cognitive tasks. Historically, these were first described by Bloom. More recently, Bloom’s taxonomy was revised by Anderson and Krathwohl. The following coloured chart blends curricular expectations with these taxonomies in a way that is fairly consistent for the four diploma examinations that assess science: Biology 30, Chemistry 30, Physics 30, and Science 30.

The pink section contains verbs that relate to skill development. The Physics 30 Diploma Examination continues to evolve in how it asks the students to show their skills. As the examination platform changes from paper to digital, the contexts in which the students will use their skills also evolve.

The yellow sections contain cognitively undemanding tasks.

The green section covers most of the calculations that are required in Physics 20 and 30. In general, using an equation to determine an answer is an application. In order to pass both Physics 20 and 30, students need to be able to function in the green area.

The final section is shaded blue. In these areas, students are transferring from one area to another, or building new connections, or creating new methods of solution. Students who are not able to analyze, evaluate, or create should not be receiving grades above 80 percent. This distinction may be difficult for classroom teachers, because the first few times a student tries a particular method of solution, the student likely will be doing “blue” cognition. Once a method has been reduced to an algorithm, the cognition the student is using falls to “green.”
It is important to remember that the graphic should serve only as a guideline and that the verbs are not permanently fixed in the categories shown above. A verb can indicate a variety of cognitive levels depending on the context in which it is used, and the two taken together are what determines the cognitive expectation.
Performance Standards

Acceptable Standard

Students who achieve the acceptable standard in Physics 30 will receive a final course mark of 50 percent or higher. Students achieving the acceptable standard have gained new skills and knowledge in physics but may encounter difficulties if they choose to enroll in post-secondary physics courses. These students are able to define basic physics terms and are able to state and use formulas as they appear on the equation sheet. They can do this in situations where they need to sort through a limited amount of information. Their laboratory skills are limited to following explicit directions and to using laboratory data to verify known physics information. They are able to identify manipulated and responding variables, but not relevant controlled variables. These students are able to relate graph shape to memorized relationships, but their analysis of graphs is limited to linear data. These students tend to use item-specific methods in their problem solving and rarely apply the major principles of physics in their solutions. When explaining the connections between science, technology, and society, these students tend to use examples provided from textbooks. These students have difficulty connecting physics to real-life scenarios beyond the classroom.

Standard of Excellence

Students who achieve the standard of excellence in Physics 30 receive a final course mark of 80 percent or higher. They have demonstrated their ability and interest in both mathematics and physics and feel confident about their scientific abilities. These students should encounter little difficulty in post-secondary physics programs and should be encouraged to pursue careers in which they will utilize their talents in physics. Students who achieve the standard of excellence show flexibility and creativity when solving problems, and changes in problem format do not cause them major difficulties. They seek general methods to solve problems and are not afraid to use physics principles as a framework for their solutions. In the laboratory, students who achieve the standard of excellence can deal with data that are less than perfect or with instructions that are incomplete. These students are able to explicitly relate graph shape to mathematical models and to physics equations. They transfer knowledge from one area of physics to another and can express their answers in clear and concise terms. These students are able to apply cause-and-effect logic in a variety of situations: algebraically, experimentally, etc. In addition, these students can connect their understanding of physics to real-world situations that include technological applications and implications beyond the classroom setting.
Examination Specifications and Design

Each Physics 30 Diploma Examination is constructed as closely as possible to the following specifications.

Program of Studies Outcomes

The design supports the integration of all Physics 30 general outcomes (GOs) as mandated in the *Physics 20–30 Program of Studies, 2007 (Updated 2014)*.

Adjustments in the emphasis may be necessary because the examination includes machine-scored scenarios or contexts that cover more than one general outcome. As a result, the examination is not necessarily arranged sequentially by units but is instead built around scenarios or contexts that support STS connections; a set of questions may assess students’ ability to integrate several GOs.

<table>
<thead>
<tr>
<th>GO</th>
<th>Emphasis (Curricular Fit)</th>
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<tbody>
<tr>
<td>A</td>
<td>10–20%</td>
</tr>
<tr>
<td>B</td>
<td>25–35%</td>
</tr>
<tr>
<td>C</td>
<td>25–35%</td>
</tr>
<tr>
<td>D</td>
<td>20–30%</td>
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**GO A  Momentum and Impulse**

Students will explain how momentum is conserved when objects interact in an isolated system.

**GO B  Forces and Fields**

Students will explain the behaviour of electric charges, using the laws that govern electrical interactions. They will describe electrical phenomena, using the electric field theory. They will explain how the properties of electric and magnetic fields are applied in numerous devices.

**GO C  Electromagnetic Radiation**

Students will explain the nature and behaviour of electromagnetic radiation, using the wave model. They will explain the photoelectric effect, using the quantum model.

**GO D  Atomic Physics**

Students will describe the electrical nature of the atom. They will describe the quantization of energy in atoms and nuclei. They will describe nuclear fission and fusion as powerful energy sources in nature. They will describe the ongoing development of models of the structure of matter.
Questions on the diploma examination will require students to demonstrate knowledge of physics concepts and to apply skills in a context that supports making science, technology, and society (STS) connections.

<table>
<thead>
<tr>
<th>Scientific Process and Communication Skills</th>
<th>Science, Technology, and Society Connections (STS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will</td>
<td>Students will</td>
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<tr>
<td>• formulate questions about observed</td>
<td>• explain that technological problems often require</td>
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<tr>
<td>relationships and plan investigations of</td>
<td>multiple solutions that involve different designs,</td>
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<tr>
<td>questions, ideas, problems, and issues</td>
<td>materials, and processes, and that have both</td>
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<tr>
<td>• use a broad range of tools and techniques to</td>
<td>intended and unintended consequences</td>
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<tr>
<td>record data and information</td>
<td>• explain that concepts, models, and theories are</td>
</tr>
<tr>
<td>• analyze data and apply mathematical and</td>
<td>often used in interpreting and explaining</td>
</tr>
<tr>
<td>conceptual models to develop and assess</td>
<td>observations, and in predicting future</td>
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<tr>
<td>possible solutions</td>
<td>observations</td>
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<tr>
<td>• apply the skills and conventions of science in</td>
<td>• explain that scientific knowledge may lead to</td>
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<tr>
<td>communicating information and ideas, and</td>
<td>the development of new technologies and that new</td>
</tr>
<tr>
<td>in assessing results</td>
<td>technologies may lead to or facilitate scientific</td>
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<td></td>
<td>discovery</td>
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<td></td>
<td>• explain that the goal of technology is to provide</td>
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<td></td>
<td>solutions to practical problems</td>
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<td></td>
<td>• explain that scientific knowledge is subject to change</td>
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<td>as new evidence becomes apparent, and as laws</td>
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<td></td>
<td>and theories are tested and subsequently revised,</td>
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<td></td>
<td>reinforced, or rejected</td>
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<td></td>
<td>• explain that scientific knowledge and theories</td>
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<td></td>
<td>develop through hypotheses, the collection of</td>
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<td>evidence, investigation, and the ability to provide</td>
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<td>explanations</td>
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<td>• explain that the goal of science is knowledge</td>
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<td>about the natural world</td>
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<td>• explain that the products of technology are</td>
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<td></td>
<td>devices, systems, and processes that meet given</td>
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<td>needs, and that the appropriateness, risks, and</td>
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<td>benefits of technologies need to be assessed for</td>
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<tr>
<td></td>
<td>each potential application from a variety of</td>
</tr>
<tr>
<td></td>
<td>perspectives, including sustainability</td>
</tr>
</tbody>
</table>
The Physics 30 Diploma Examination consists of 36 multiple-choice and 14 numerical-response items of equal weight. Fewer than half the items require a calculation.

**Machine-scored Items**

Answers for multiple-choice items are recorded in the first section of the machine-scored answer sheet. Answers for numerical-response items are recorded in the second section on the same side of the same machine-scored answer sheet.

**Multiple-choice items** are of two types: discrete and context-dependent. A discrete item stands on its own without any additional directions or information. It may take the form of a question or an incomplete statement. A context-dependent item provides information that is separate from the item stem. Many of the multiple-choice items are context dependent. A particular context may be used for more than one multiple-choice item as well as for more than one numerical-response item.

**Numerical-response items** are of three types: calculation of numerical values; selection of numbered events, structures, or functions from a diagram or list; and determination of a sequence of events.

Students should be familiar with the different formats of numerical-response items and the procedure for completely filling in the bubbles on the answer sheet.

Numerical-response items with multiple valid answers allow for student-generated responses that allow students to demonstrate cause-and-effect reasoning. The potential for multiple valid answers can be challenging to students who have been reinforced in thinking there is “only one right answer.”

**Assessment of Skills and STS Connections**

Physics 30 examination items are designed to measure students’ understanding of physics concepts mandated by the *Physics 20–30 Program of Studies, 2007* (Updated 2014). Some items also measure students’ understanding and use of skills associated with scientific inquiry, and some items have been designed to measure students’ understanding of the connections among science, technology, and society. As a result, many items measure how well students can apply the skills and knowledge they have acquired in science to everyday life.

**Constants**

Students should use constants provided on the data sheet and recorded to three significant digits rather than constants stored in calculators. This is important in order to obtain correct numerical-response answers.
Feedback from Field Testing, Diploma Examinations, and Teachers

The following points are in response to comments from students and teachers on field tests, comments from teachers on the perusal copies of the diploma examinations, and comments made by teachers at professional development opportunities. These points also reflect areas of student strengths (items many students get correct) and areas of weakness (items many students do not get correct). Each point is linked to program outcome(s).

Comments Relating to General Skills Outcomes

(.1s) When students are asked about experimental design, they do not know which variable(s) to control. However, students are very successful at identifying what was manipulated and what responded.

(.2s) When students are required to make observations, they often do not know to what precision to record their values. This applies to reading scales on graphs as well. In general, they demonstrate a profound lack of understanding of the difference between a calculated value and a measured value.

*NEW

Students also have difficulty in deciding on what a valid measurement is, and what affects the quality of the data that are based on measurements. This includes measuring inside to inside distances on a dot-timer track or between antinodes in an interference pattern. Students also measure angles to the nearest 5° rather than making the best estimate based on the scale on the protractor. They will choose to make an observation that produces a smaller value rather than a larger value, which indicates that they are not attempting to minimize the inherent error in the measurement.

Students may be asked to make measurements on diagrams using a ruler or protractor. Students may be prompted in the context box or stem of the item that measurements are required. As a rule, the diagrams on the Physics 30 Diploma Examination are drawn to scale and when this is not the case, a note will be provided stating that the diagram is not drawn to scale.

(.3s) Students are very good at calculating the slope of a line, but experience significant difficulty in relating the slope, \( m \), from \( y = mx + b \), to the physics that describes the situation. This ability to map one model onto another is a measure of non-algorithmic thinking that is necessary to achieve the standard of excellence in Physics 30. This analysis should be modelled for Grade 11 students, but they will likely not be able to complete such an analysis independently.

Students are very successful at identifying the directions of forces acting on masses. Students are good at identifying the directions of forces acting on stationary charges as long as Newton's third law does not need to be applied. Students have limited success in applying hand rules to describe the relationship between direction of motion, type of charge, and direction of magnetic field. This weakness has increased each year that a machine-scored-only examination has been in place.

(.4s) Students experience significant challenges in evaluating the quality of results.
Comments Relating to Specific Knowledge Outcomes

On items that assess C1.8k, students have difficulty in using diffraction and interference correctly. The dispersion of the energy as a wave moves past a barrier is diffraction. When waves overlap and their energy temporarily superimposes, the observation of the net energy is interference.

Students are able to analyze balanced forces in the context of B2.10k, a Millikan situation, or B3.6k, a velocity selector. They tend to struggle when the magnetic force on a current-carrying conductor is balanced by the gravitational force.

Students are able to analyze a single unbalanced force causing linear acceleration (B1.6k, B1.3s, and B2.8k, B2.3s) or circular motion (B3.5k, B3.3s). Students have significant difficulty in analyzing a situation in which the forces are unbalanced, but still parallel/anti-parallel (B2.10k, B2.3s, and B3.6k, B3.3s).

Students should know the relationships among the direction of a net unbalanced force, the initial direction of particle motion, and the resulting path shape. The description of a path shape as linear, parabolic, or circular should immediately convey the relevant physics applications. The converse is also true: from a description of the physics, students should be able to identify the expected path shape.

Students experience more-significant difficulty with B3.2s, use of hand rules, than they did in the previous program of studies. The misconception of describing magnetic interactions using electrostatic principles or vice versa is often a more popular choice than the correct answer on multiple-choice items.

The term EMR will be used in place of electromagnetic radiation when appropriate. This relates to C1.

Outcomes D3.2k and D3.4k require students to bring different skills and cognition to the process of writing and balancing nuclear reactions. Students are very successful at D3.2k and are able to correctly match the particle/antiparticle pairs. Students are very successful at balancing nuclear decay reactions. They experience significant difficulty in meeting the expectation of D3.4k, apply conservation of charge and conservation of mass number. This suggests that students may be doing arithmetic on the top and bottom numbers rather than understanding the importance of what the numbers represent. D3.4k can also be assessed by asking the students to convert a verbal description of a reaction into a balanced decay equation.

Comments Relating to Conservation of Energy

A1.5k – Students are very successful at classifying collision interactions as elastic or inelastic.

B2.9k – Students are successful at applying conservation of energy in a uniform electric field if the starting or ending speed is zero. Students are less successful if the charged particle has some kinetic energy before or after experiencing a force or moving through a potential difference. Students are much less successful if the force or potential difference acts to reduce the kinetic energy of the charged particle.
C2 – Students are very successful at using energy principles in calculations dealing with the photoelectric effect. Students are less successful at using conservation of energy principles in analyzing a Compton scattering event. This is an interesting observation, as students are very successful at classifying collisions based on changes to the energy of a system. This suggests students may be using algorithmic-based methods in units rather than physics principles in response to a particular context.

D2.5k – Students are successful at calculations relating to energy-level transitions when an energy level diagram is provided. They are much more successful at calculations in which photon energy is released. Students are less successful when they need to combine the idea of an elastic collision (an incoming electron causing the excitation) and determining the possible excited state of the target atom. Students are also less successful at relating energy levels to ionization energy and to the work function of a surface. Again, this suggests that students may be applying particular algorithms rather than general physics principles when analyzing situations.

The emission of gamma photons by an excited nucleus as part of radioactive decay can be modelled as a change in energy states analogous to the emission of a photon by an excited atom or molecule. Students who have a superficial understanding of conservation of energy struggle with this application, while students who have a big-picture foundation experience success.

D3.6k – Students are very successful at using the equation $\Delta E = \Delta mc^2$ when they are given the energy in units of either J or eV or mass in units of kg. They are less successful when they need to apply the equation to a table of masses associated with a particular nuclear reaction or when describing an annihilation reaction.

**Physics Principles**

The linking of two of the 10 physics principles given on the data sheet to the solution to a problem continues to be a challenge for many students. This is most directly assessed on the two-item scenario that appears at the end of the diploma examination: numerical-response item 13 asks the students to calculate something, and numerical-response item 14 asks the students to identify the physics principles they used. Historically, this trend is more significant for students writing the examination in French. In general, for this type of item, there are some situations in which one principle is subsumed by another (e.g., circular motion and accelerated motion). There are some situations in which two principles are equivalent (e.g., work-energy theorem and conservation of energy), but this is not always true. This type of item is not likely to reward a memorized approach. For more examples of the assessment of physics principles using items like numerical-response item 13 and numerical-response item 14, see the Physics 30 Archive or the practice questions on Quest A+. Links to these resources are given on page 25.
**Diploma Examinations: Multiple Forms**

As part of Alberta Education’s commitment to fairness to students and flexibility in the writing of diploma examinations, there are two distinct forms (versions) of diploma examinations in some subjects during major administrations (January and June). The two forms are equated to baseline examinations to ensure that the same standard applies to both forms. Both forms adhere to the established blueprint specifications and are thoroughly reviewed by a technical review committee.

To facilitate the analysis of school-level results, each school receives only one examination form per subject. In subjects offering a translated French-language examination, both forms are administered in English and in French.

For more information, contact

Deanna Shostak  
Director, Diploma Programs  
780-422-5160 or Deanna.Shostak@gov.ab.ca

or

*NEW* Pascal Couture  
Director, Exam Administration  
780-492-1462 or Pascal.Couture@gov.ab.ca
**Examination Security**

All Physics 30 diploma examinations will be held secure until they are released to the public by the minister. No secure diploma examination is to be previewed, copied, or discussed. All examination materials must remain secured after their administration.

For the January and June examinations, teachers whose students are writing the examination will be allowed access to a digital teacher perusal copy for review purposes one hour after the examination has started. For more information about teacher perusal copies and examination security, please refer to the General Information Bulletin.

**Maintaining Consistent Standards Over Time on Diploma Examinations**

A goal of Alberta Education is to make scores achieved on examinations within the same subject directly comparable from session to session, thereby enhancing fairness to students across administrations.

In order to achieve this goal, the examination has a number of questions in common with a previous examination. Common items are used to find out if the student population writing in one administration differs in achievement from the student population writing in another administration. Common items are also used to find out if the unique items (questions that have never appeared in a previous examination) differ in difficulty from the unique items on the baseline examination, setting the standard to which all students are held.

A statistical process called equating adjusts for differences in difficulty between examinations. Examination marks may be adjusted depending upon the difficulty of the examination written relative to the baseline examination. Therefore, the resulting equated examination scores have the same meaning regardless of when and to whom the examination was administered. Equated diploma examination marks are reported to students. More information about equating is available here.

Because of the security required to enable fair and appropriate assessment of student achievement over time, Physics 30 diploma examinations will be fully secured and will not be released at the time of writing.
Field Testing

Physics 30 Field Tests for 2018–2019

Physics 30 will be offering the following unit and year-end field test lengths:

- 50-minute Unit A field test available as digital only
- 50-minute Unit B field test available as digital only
- 50-minute Unit C field test available as digital only
- 50-minute Unit D field test available as digital only
- 50-minute year-end field test available as hybrid (paper items, answered online) or digital
- 70-minute year-end field test available as hybrid (paper items, answered online) or digital
- 150-minute year-end full-length field test available as hybrid (paper items, answered online) or digital

Online Field Testing

All Grade 12 science and mathematics field tests are offered exclusively through the Quest A+ online delivery system. In addition to digital field tests, hybrid field tests are also available this school year. With a hybrid field test, students receive a paper copy of the test but must respond to the questions online.

Students should use paper data booklets, data pages, or formula sheets for all science and mathematics field tests. These resources will also appear in the online delivery system. Students should also have scrap paper, which may be accessed and downloaded from the “Teacher Resources” section on the home page of the Field Test Request System. All paper data sheets or scrap paper with markings must be securely shredded at the end of the field test administration.

Teachers have a 24-hour window to peruse the digital or hybrid field test and are provided with data on how their students performed. These data include the proportion of students who chose each alternative on multiple-choice items and the proportion who left a numerical-response item blank. Test items are blueprinted to program of studies outcomes. This allows teachers to use field test results to learn more about their students’ strengths and weaknesses.

Once logged into the digital or hybrid field test, teachers have the same length of time to peruse the test as their students did to write it. Teachers might choose to log into the field test, submit the confidentiality form, and then log out of the test so that they can finish perusing the test after receiving their students’ data.

In addition, teachers have greater flexibility in selecting the time and date when students write, rather than being bound to a pre-determined date.

Finally, online administration enables every school, large or small, to participate. Historically, it was impractical to send field-test administrators to schools in remote locations or schools with small classes. Now, all Alberta schools can participate in field tests.

It is important to note that the security of field test items remains vital to the administration of diploma examinations. Participating teachers must commit to maintaining the security of field-test
items. In the case of hybrid field tests, paper copies are mailed to schools and the questions are accessed in the same format as digital-format field tests. Prior to the hybrid field test, the paper copies must be kept secure by the school principal. After the administration of a hybrid-format field test, teachers must mail all paper copies back to Alberta Education.

Benefits of Field Tests

How do field tests help teachers and students?

Teachers receive each student’s score promptly, gaining useful, immediate information about their students’ levels of expertise and knowledge. Students also benefit from writing a test that duplicates some of the experience of writing a diploma examination. Field tests provide students and teachers with good examples of the style and content of questions that may appear on diploma examinations. Finally, because of field testing, students, teachers, and parents can be reassured that the questions on diploma examinations have undergone a rigorous process of development, improvement, and validation.

Why are field tests necessary?

Field testing is an absolutely essential stage in the development of fair, valid, and reliable provincial examinations. Field testing is basically a process of “testing a test” and “testing questions” before they become part of a diploma examination. Potential diploma examination questions are administered to students in diploma courses throughout the province to determine their difficulty level and appropriateness. Ideally, each field test requires a large student sample to provide the examination developers with reliable information (statistical data and written validation comments from teachers and students).

How are field test data used?

The data received from field tests show the reliability of each question. Sometimes, after one field test round, it is clear that certain questions work very well in terms of fairness, validity, and appropriateness to course content. These questions then move into the diploma examination bank to be used at a future date.

Other questions or sets of questions may not perform as well as we require. These questions are subject to revision and review, and retested in a second or third field test with the aim of generating questions that meet our standards. These changes are influenced by the written comments of students and teachers, who provide valuable advice about the appropriateness of the questions, adequacy of writing-time limits, test length, text readability, artwork/graphics clarity and suitability, and question difficulty.
Further Information

Teachers requesting field tests must have a Public Authentication System (PAS) account. All requests are made through the Field Test Request System. Further information, including the closing dates to request a field test, may be obtained by contacting Field.Test@gov.ab.ca, or from the General Information Bulletin. Practice items are available at QuestA+.

For more information, contact

Deanna Shostak
Director, Diploma Programs
780-422-5160 or Deanna.Shostak@gov.ab.ca

or

*NEW* Pascal Couture
Director, Exam Administration
780-492-1462 or Pascal.Couture@gov.ab.ca

Special-format Practice Tests

To provide students an opportunity to practise diploma examination-style questions and content in Braille, audio, large print, or coloured print versions, Alberta Education is making special-format practice tests available. Tests are offered in all subjects with a corresponding diploma examination. Alberta schools with registered Alberta K–12 students may place orders for these tests. Braille tests are available in English and, by request, in French. All tests are provided free of charge, but limits may be placed on order volumes to ensure access for everyone.

For more information or to place an order, contact

Laura LaFramboise
Distribution Coordinator, Exam Administration
780-492-1644 or Laura.LaFramboise@gov.ab.ca
Publications and Supporting Documents

In addition to this bulletin, the following documents are published by Alberta Education.

- Physics 20–30 Program of Studies, 2007 (Updated 2014) available on education.alberta.ca
- Physics 20 and 30 Student-Based Performance Standards available on education.alberta.ca
- Mathematics and Science Guide for Students available on education.alberta.ca
- Physics 30 Archived Information Bulletin available on education.alberta.ca
- Diploma Examination Detailed Reports available on the Alberta Education Extranet

The Provincial Assessment Sector supports online assessment with the testing platform Quest A+ at http://questaplus.alberta.ca.

Physics Data Pages

Physics tear-out data pages are included at the back of the diploma examination booklet. These data pages are available on the Alberta Education website.

- Physics 30 Data Booklet available on education.alberta.ca

They are also included on pages 54 to 56 in this document.

Students should be familiar with the data pages before writing the diploma examination.

Using Calculators

The Physics 30 Diploma Examination requires the use of an approved calculator. The calculator policy, calculator criteria, expectations, and keystrokes required for clearing approved calculators can be found in the General Information Bulletin on the Alberta Education website.

- Using Calculators available on education.alberta.ca
Illustrative Numerical-response Items Assessing Mandated Skills

This item illustrates how student-made measurements can be incorporated into machine-scored items on the Physics 30 Diploma Examination. This item assesses B2.5k, B2.2s, and B2.3s.

30-B2.5k, Students will calculate the electric potential difference between two points in a uniform electric field; 30-B2.2k, Students will compare forces and fields; 30-B2.3k, Students will compare, qualitatively, gravitational potential energy and electric potential energy

Use the following information to answer numerical-response question 1.

A beam of electrons is incident on a region containing a uniform electric field as shown below. The electrons in the beam each have a speed of $4.5 \times 10^5$ m/s. While in the electric field the electrons accelerate toward the top plate.

Note: You will want to make your measurements on this diagram.
**Numerical Response**

1. Based on your measurements, the strength of the uniform electric field in the region is _________ N/C.
   
   (Record the two digits of your answer in the numerical-response section on the answer sheet.)
   
   Answer: 14 or 15 or 13

2. Two physics principles must be used to determine the strength of the uniform electric field. Using the numbers on the tear-out data sheet, match the physics principles with the order in which they are used. (There is more than one correct answer.)

   **Number:** _________ and _________
   
   **Physics principle:** Used first Used second
   
   (Record both digits of your answer in the numerical-response section on the answer sheet.)
   
   Answer: 0 and 1, in any order

   **Note:** Although conservation of energy (5) or the work energy theorem (3) could be used, they are not the most direct method as the algebra eventually requires the use of a force in the vertical direction.
This item illustrates the design-an-experiment skill mandated in the program of studies outcome B3.1s.

**B3.1s, Students will formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues • design an experiment to demonstrate the effect of a uniform magnetic field on a current-carrying conductor**

*Use the following information to answer numerical-response question 3.*

A group of students sets up the apparatus shown below.

**Apparatus**

![Diagram of apparatus](image.png)
Research Questions

1. Does the length of the wire in the magnetic field affect the magnetic force?
2. Does the magnitude of the current in the wire affect the magnetic force?
3. Does the strength of the magnetic field produced by the C-shaped magnet affect the magnetic force?
4. Does the direction of the electron flow affect the magnetic force?
5. Does the orientation of the wire relative to the external magnetic field affect the magnetic force?

Variables

6. Force on wire
7. Length of wire
8. Strength of the C-shaped magnet
9. Current in wire

Numerical Response

3. Using the numbers above, choose one research question that could be investigated using the apparatus and match three of the variables to their respective roles in the investigation of that research question as given below. (There is more than one correct answer.)

Number:  

<table>
<thead>
<tr>
<th>Research question</th>
<th>Manipulated variable</th>
<th>Responding variable</th>
<th>One of the variables that must be controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Force on wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Length of wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Strength of the C-shaped magnet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Current in wire</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Record all four digits of your answer in the numerical-response section on the answer sheet.)

Answer: 1768, 1769, 2967, 2968, 4967, or 4968
Use the following information to answer numerical-response question 4.

Students use three of the optical apparatus illustrated below to produce a focused, real image in a darkened room. One of the apparatus has a focal length of 10.0 cm.

**Optical Apparatus**

<table>
<thead>
<tr>
<th>Sources</th>
<th>Lenses</th>
<th>Mirrors</th>
<th>Diffraction grating</th>
<th>Double-slit apparatus</th>
<th>Screen</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Laser" /></td>
<td><img src="image2.png" alt="Lens" /></td>
<td><img src="image3.png" alt="Mirror" /></td>
<td><img src="image4.png" alt="Grating" /></td>
<td><img src="image5.png" alt="Apparatus" /></td>
<td><img src="image6.png" alt="Screen" /></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

The students place one apparatus at each labelled location on an optics bench, as shown below. The optics bench is scaled in millimetres and labelled in centimetres.

**Note:** The diagrams are not drawn to scale.

C1.1s, *Students will* formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues; C1.2s, *Students will* conduct an investigation to determine the focal length of a … curved mirror; and C1.3s, *Students will* use ray diagrams to describe an image formed by … curved mirrors.
**Numerical Response**

4. The apparatus placed at location

- **X** is numbered ________ (Record in the *first* column)
- **Y** is numbered ________ (Record in the *second* column)
- **Z** is numbered ________ (Record in the *third* column)

(Record your answer in the numerical-response section on the answer sheet.)

Answer: 194, 094, 491, or 490

**Commentary**

This section of the program of studies, C1, is intended to be very hands-on. In a standardized assessment context, we need to illustrate the optics experiences that students should have had. To that end, we chose the simple device of a metre stick on its side. Apparatus can be positioned on the metre stick, beside the metre stick, and at one edge of the metre stick. Based on where the apparatus are positioned, students can make predictions or actual measurements. The list of apparatus matches some of the mandated optics experiences.

This question is not at recall level because, since the object is more than a focal length away from the mirror, the screen (where the image is observed) is between the mirror and the object. When the students are faced with this conundrum in the lab, they have to explore how putting the object and the image just a bit off the axis allows the geometry to work and a real image to form.

This type of question has many possible applications for assessing experimental design and measurement skills.
This item illustrates how students can demonstrate the performing and recording skills mandated by program of studies outcome C1.2s.

C1.2s, Students will conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information • perform an experiment to determine the index of refraction of several different substances

Use the following information to answer numerical-response question 5.

A ray of light travelling from water into an unknown medium is shown below.

Note: You will need to make measurements using a ruler or a protractor.

Numerical Response

5. If the index of refraction of the water is 1.33, then the index of refraction of the second medium is __________.

(Record your three-digit answer in the numerical-response section on the answer sheet.)

Answer: Any value between 1.54 and 1.69
This item allows students to explore the technology of a velocity selector tuned so that the path of positively charged ions is undeflected. In order to be able to do the quantitative analysis correctly, the ability to build a free-body diagram is a prerequisite.

**B3.6k, Students will** explain, quantitatively, how uniform magnetic and electric fields affect a moving electric charge, using the relationships among charge, motion, field direction and strength, when motion and field directions are mutually perpendicular;

**B2.6k, Students will** explain, quantitatively, electric fields in terms of intensity (strength) and direction, relative to the source of the field and to the effect on an electric charge;

**B3.3s, Students will** analyze data and apply mathematical and conceptual models to develop and assess possible solutions • analyze, quantitatively, the motion of an electric charge following a straight path in uniform and mutually perpendicular electric and magnetic fields, using Newton’s second law and vector addition;

**B2.3s, Students will** analyze data and apply mathematical and conceptual models to develop and assess possible solutions • use free-body diagrams to describe the forces acting on a charge in an electric field.

*Use the following information to answer numerical-response question 6.*

A positively charged ion travels through a region that contains perpendicular electric and magnetic fields. The ion passes through the region undeflected at a constant speed.

![Diagram](image-url)

**Directions**

1. 2 3
2. 4 5
3. 6 7
4. 8
5. 9

To go back after using an internal link, simultaneously press and hold Alt + (in some browsers).
Numerical Response

6. Match the numbers on the directions given above with the descriptions given below.

<table>
<thead>
<tr>
<th>Direction:</th>
<th>Description:</th>
<th>Direction of the electric force on the ion</th>
<th>Direction of the electric field in the region</th>
<th>Direction of the magnetic force on the ion</th>
<th>Direction of the magnetic field in the region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answer: 5560</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Record all **four digits** of your answer in the response boxes at the bottom of the screen.)

Commentary

In order for students to determine the correct answer, they need to be able to follow process.

The direction of the electric force is toward the negatively charged plate (opposites attract). The arrow that is in that direction is numbered 5.

The direction of the electric field is defined as the direction of the force on a positive test charge, so in this situation the students should choose the same direction, numbered 5.

The next blank requires the students to apply several ideas: undeflected motion means net force is zero, and there are exactly two significant forces acting on the positively charged particle. So the magnetic force must be in the opposite direction to that of the electric force, and this direction is number 6.

Finally, the students use a hand rule to determine the relative orientation of the velocity, force, and magnetic field. As a result, students should see that the magnetic field is perpendicular to the velocity and force and directed out of the plane of the diagram. The direction that shows this is the point of the arrow, numbered 0.

Analysis of Field-test Data

Just over 37% of the students who answered this question were able to get the directions of the electric force and electric field correct. Another 1% got the direction wrong and indicated that both directions were the same. Just over 37% of the students who answered this question provided directions for the first and third blanks that were opposite to each other. Finally, just over 58% of the students who answered this question provided a direction of the magnetic field that was perpendicular to the plane of the diagram.
Illustrative Items from Field Testing or Diploma Examinations Showing Word Usage and Exploring Misconceptions

These items have been chosen to illustrate students’ strongly held misconceptions and word usage on the diploma examination.

This first item explores the misconceptions that students hold regarding Newton’s third law.

Use the following information to answer question 1.

Two carts, travelling at the same initial speed, move toward each other on a table, as shown below. Cart I has a total mass of 500 g and Cart II has a total mass of 250 g.

The carts collide. After contact, the carts remain separate from each other and move independently.

1. Which of the following vector diagrams, drawn to scale, shows the magnitude and direction of the impulse experienced by each cart during contact?

*A.*

B.

C.

D.

Commentary

This question explores the application of Newton’s third law in the student-familiar context of a collision. The majority of the students who answered this question were divided between choices B and C. This reflects a strongly held misconception of the relationship between force and acceleration.
In general, students were unsuccessful in answering this question. The diagram illustrates that the nature of the excess charge is the same as that of the charging rod, which should allow the students to recognize that the method of charging is conduction. Since the excess charge remains localized on the surface of the sphere, students should recognize this as a characteristic of an electrical insulator.

This item is included because student performance on the field-test item suggests they struggle with this program outcome.

B1.3k *Students will* compare the methods of transferring charge (conduction and induction); and B1.4k, explain, qualitatively, the distribution of charge on the surfaces of conductors and insulators

*Use the following information to answer question 2.*

A negatively charged rod is brought into contact with an initially neutral sphere supported by an insulated stand. The rod is removed and the resulting net charge distribution on the sphere is illustrated below.

2. *The sphere has been charged by the process of _____i_____, and the material that the sphere is made of is classified as _____ii_____.*

The statement above is completed by the information in row

<table>
<thead>
<tr>
<th>Row</th>
<th>i</th>
<th>ii</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>induction</td>
<td>a conductor</td>
</tr>
<tr>
<td>B.</td>
<td>induction</td>
<td>an insulator</td>
</tr>
<tr>
<td>C.</td>
<td>conduction</td>
<td>a conductor</td>
</tr>
<tr>
<td><em>D.</em></td>
<td>conduction</td>
<td>an insulator</td>
</tr>
</tbody>
</table>

*Commentary*

In general, students were unsuccessful in answering this question. The diagram illustrates that the nature of the excess charge is the same as that of the charging rod, which should allow the students to recognize that the method of charging is conduction. Since the excess charge remains localized on the surface of the sphere, students should recognize this as a characteristic of an electrical insulator.
This group of two items illustrates how the outcome B3.9k can be assessed.

Use the following information to answer question 3.

A very strong bar magnet is dropped onto a foam block through a copper ring that has a slit cut into it, as shown below.

3. When the south pole of the magnet moves into the ring from above, the direction the electrons inside the copper ring will move is from ____i____. Compared to X, the nature of the charge on Y will be relatively ____ii____.

The statements above are completed by the information in row

<table>
<thead>
<tr>
<th>Row</th>
<th>i</th>
<th>ii</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>X to Y</td>
<td>negative</td>
</tr>
<tr>
<td>B.</td>
<td>X to Y</td>
<td>positive</td>
</tr>
<tr>
<td>C.</td>
<td>Y to X</td>
<td>negative</td>
</tr>
<tr>
<td>*D.</td>
<td>Y to X</td>
<td>positive</td>
</tr>
</tbody>
</table>
Use the following information to answer question 4.

A positively charged sphere is suspended on the end of an insulated string in the region between two vertical, metal, parallel plates that are connected to a coil of wire. A magnet is suddenly thrust into the coil of wire, as illustrated below.

4. When the magnet is moved as illustrated above, then the direction of the motion of the positively charged sphere is

   A. into the page
   B. toward Plate I
   *C. toward Plate II
   D. out of the page
This group of two items illustrates the use of convex and/or concave for a mirror and diverging and/or converging for a lens.

These words are chosen to make the items completely unambiguous. A convex mirror can only reflect the light off one face and the ray diagram is clear. However, a convex-convex lens can be either diverging or converging depending on the relative positions of the surfaces. So that students know exactly what is happening, we describe the effect of the lens on the light.

Use the following information to answer question 5.

When a girl who is 122 cm tall stands 40 cm in front of a particular mirror, her virtual image in the mirror is upright and 54 cm tall.

5. The mirror is ____i____, and the girl’s image is located ____ii____ away from the mirror.

The statement above is completed by the information in row

<table>
<thead>
<tr>
<th>Row</th>
<th>( i )</th>
<th>( ii )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>convex</td>
<td>18 cm</td>
</tr>
<tr>
<td>B.</td>
<td>convex</td>
<td>90 cm</td>
</tr>
<tr>
<td>C.</td>
<td>concave</td>
<td>18 cm</td>
</tr>
<tr>
<td>D.</td>
<td>concave</td>
<td>90 cm</td>
</tr>
</tbody>
</table>

*NEW

Use the following information to answer question 6.

In an investigation, a group of students measures an object to be 10.0 cm tall. They place the object 3.2 cm in front of a thin lens. The students are unable to locate a real, focused image. They draw a ray diagram and notice that the focused virtual image forms on the same side of the lens as the object and is 1.3 times larger than the object.

6. The type of lens and its calculated focal length are, respectively,

A. diverging, and 1.8 cm  
B. diverging, and 14 cm  
C. converging, and 1.8 cm  
*D. converging, and 14 cm
This two-item set illustrates the assessment of Unit D outcomes D3.5k, D3.3s, and D3.6k.

D3.5k, Students will compare and contrast the characteristics of fission and fusion reactions; D3.3s, Students will compare the energy released in a nuclear reaction to the energy released in a chemical reaction, on the basis of energy per unit mass of reactants; and D3.6k, Students will relate, qualitatively and quantitatively, the mass defect of the nucleus to the energy released in nuclear reactions, using Einstein’s concept of mass-energy equivalence.

Use the following information to answer question 7 and numerical-response question 7.

**Nuclear Reactions**

Reaction I: \( ^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n \)

Reaction II: \( ^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^1_0n \)

Reaction II is currently used in nuclear reactors in Canada. When 1.00 kg of uranium fuel is burned, \( 6.11 \times 10^{13} \) J of energy is released.

7. Which of the following rows identifies the fission reaction and compares the energy released in the two reactions per kilogram of fuel?

<table>
<thead>
<tr>
<th>Row</th>
<th>Fission</th>
<th>Energy per Kilogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Reaction I</td>
<td>Reaction I releases more than Reaction II</td>
</tr>
<tr>
<td>B.</td>
<td>Reaction I</td>
<td>Reaction I releases less than Reaction II</td>
</tr>
<tr>
<td>*C.</td>
<td>Reaction II</td>
<td>Reaction I releases more than Reaction II</td>
</tr>
<tr>
<td>D.</td>
<td>Reaction II</td>
<td>Reaction I releases less than Reaction II</td>
</tr>
</tbody>
</table>

**Numerical Response**

7. The mass equivalent of the energy released by the burning of uranium fuel in a Canadian nuclear reactor, expressed in scientific notation, is \( a.bc \times 10^{-d} \) kg.

The values of \( a, b, c, \) and \( d \) are _____, _____, _____, and _____.

(Record all four digits of your answer in the numerical-response section on the answer sheet.)

Answer: 6794
This item illustrates the difference between *use* and *derive* in the context of the de Broglie equation. By providing the equation and naming the variables, students use \( p = mv \) from A1.1k to solve the problem. Without the equation in the context box, this question is beyond the expectations of the program of studies.

*Use the following information to answer question 8.*

Solar wind is hot plasma ejected from the surface of the Sun. The plasma consists, in part, of electrons. de Broglie hypothesized that a moving particle has a wavelength that relates to its momentum, given by the formula below.

\[
\lambda = \frac{h}{p}
\]

8. The wavelength of one solar-wind electron that has a measured speed of \( 4.0 \times 10^5 \text{ m/s} \) is

A. \( 9.9 \times 10^{-13} \text{ m} \)
B. \( 1.8 \times 10^{-9} \text{ m} \)
C. \( 6.2 \times 10^6 \text{ m} \)
D. \( 1.1 \times 10^{10} \text{ m} \)
**Questions Showing Assessment at Various Cognitive Levels**

This group of three items shows how outcome C2.6k can be tested at a knowledge-recall level (K), a comprehension and application level (C/A), and a higher mental activity level (HMA), respectively.

Students achieving the standard of excellence need to be given the opportunity to show their true ability on HMA-level tasks.

*NEW* Use the following information to answer questions 9 and 10 and numerical-response question 8.

In a Compton scattering event, an incident photon that has an energy of $2.0 \times 10^{-14}$ J is directed toward a carbon target. The scattered photon is detected, having been deflected through an angle of 133°, as shown below.

The scattering event can be analyzed to compare the incident and scattered photons, and to determine the predicted path of the scattered electron.

9. Which of the following rows correctly compares the characteristics of the scattered photon to those of the incident photon?

<table>
<thead>
<tr>
<th>Row</th>
<th>Wavelength or Frequency</th>
<th>Speed or Momentum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>The scattered wavelength is longer.</td>
<td>The scattered speed is slower.</td>
</tr>
<tr>
<td>B.</td>
<td>The scattered wavelength is longer.</td>
<td>The scattered momentum is less.</td>
</tr>
<tr>
<td>C.</td>
<td>The scattered frequency is higher.</td>
<td>The scattered speed is slower.</td>
</tr>
<tr>
<td>D.</td>
<td>The scattered frequency is higher.</td>
<td>The scattered momentum is less.</td>
</tr>
</tbody>
</table>
**NEW**  **Numerical Response**

8. The wavelength of the scattered photon, expressed in scientific notation, is \( a.b \times 10^{-cd} \) m. The values of \( a, b, c, \) and \( d \) are _____, _____, _____, and _____.

(Record all **four digits** of your answer in the response boxes at the bottom of the screen.)

Answer: 1411

**NEW** 10. Which of the following diagrams **best** represents the predicted path of the scattered electron?

A. ![Diagram A](image1)

B. ![Diagram B](image2)

C. ![Diagram C](image3)

D. ![Diagram D](image4)
**Illustrative Graphing Skills**

The following set of items illustrates how graphical analysis can be assessed on the Physics 30 Diploma Examination.

*Use the following information to answer question 11 and numerical-response question 9.*

Students perform an experiment using two low-friction laboratory carts. A piece of timer tape is attached to Cart I and fed through a spark timer apparatus. The timer makes a mark on the tape each 0.10 s. Cart I is pushed toward Cart II, which is initially at rest. The carts collide, the piece of clay is deformed and holds the carts together as they continue to move. The mass of Cart I is 1.54 kg.

![Diagram of experiment with two carts colliding](image)

The students repeat the above procedure, manipulating the initial speed of Cart I.

The graph of their observations is given below.

**Speed of Carts I and II (After the Collision) as a Function of the Speed of Cart I (Before the Collision)**

![Graph of speed data](image)
11. **The collision of the two carts is classified as ___ i ___ because ___ ii ___.**

The statement above is completed by the information in row

<table>
<thead>
<tr>
<th>Row</th>
<th>i</th>
<th>ii</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>elastic</td>
<td>momentum is conserved</td>
</tr>
<tr>
<td>B.</td>
<td>elastic</td>
<td>kinetic energy is conserved</td>
</tr>
<tr>
<td>C.</td>
<td>inelastic</td>
<td>momentum is not conserved</td>
</tr>
<tr>
<td>*D.</td>
<td>inelastic</td>
<td>kinetic energy is not conserved</td>
</tr>
</tbody>
</table>

**Numerical Response**

9. Based on a point on the line of best fit, if Cart I had a speed of 6.0 cm/s before the collision, then the combined speed of the two carts after the collision would be \(a. b\) cm/s. You will need to record the values of \(a\) and \(b\).

Based on the slope of the line of best fit, the **combined** mass of the two carts is \(e. f\) kg. You will need to record the values of \(e\) and \(f\).

The values of \(a, b, e,\) and \(f\) are _____, _____, _____, and _____.

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Answer: Any answer in which the point and calculated value were consistent with a line of best fit for these data was scored as correct. For example, 2633 is acceptable, while 2832 is not.
**Numeracy on Physics Examinations**

Venn diagrams are a set-theory method that is useful in comparing characteristics or classifying ideas.

Based on student comments from field tests, students understand that Venn diagrams are used to sort, classify, or compare, but this is a new way of looking at ideas in physics.

The two items on the following pages illustrate how mandated program outcomes can be assessed using numeracy and a numerical-response format.

D3.5k, *Students will* compare and contrast the characteristics of fission and fusion reactions.
Use the following information to answer numerical-response question 10.

The Venn diagram below can be used to compare fission and fusion.

<table>
<thead>
<tr>
<th>Fission</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

**Numerical Response**

10. Match the numbers of the regions in the Venn diagram above with the descriptions given below. (The numbers may be used more than once. There is more than one correct answer.)

The measurable mass of the products is less than the measurable mass of the reactants in a spontaneous reaction. ________ (Record in the first box)

The kinetic energy of the system increases in a spontaneous reaction. ________ (Record in the second box)

\[ _{92}^{236}U \rightarrow _{56}^{141}Ba + _{36}^{92}Kr + 3_0^1n \] ________ (Record in the third box)

\[ _{92}^{236}U \rightarrow _{90}^{232}Th + 4_2^4\alpha \] ________ (Record in the fourth box)

(Record your answer in the numerical-response section on the answer sheet.)

Answer: 3114 and 3314

**Commentary**

This Venn diagram allows students to compare both concepts and reaction types. The process for answering this question is as follows.

A decrease in measurable mass in a spontaneous reaction occurs in both nuclear fission and nuclear fusion, making the first blank a 3. We allowed two answers for the second blank, 3 and 1, because at a Grade 12 level we expect a 3, but from an advanced-physics perspective there are examples of nuclear fusion that do not increase the kinetic energy of the system. This is one of the great strengths of a numerical-response-style question: all valid answers can be accepted. For the last two blanks, the uranium fission reaction equation would be classified as fission only (1) and alpha decay of uranium is neither fission nor fusion (therefore 4).
The top three incorrect answers provided by students and the frequency of those answers:

<table>
<thead>
<tr>
<th>Answer</th>
<th>Frequency</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1314</td>
<td>5%</td>
<td>These students can distinguish between types of nuclear reactions but are missing the conceptual foundation.</td>
</tr>
<tr>
<td>2314</td>
<td>5%</td>
<td>These students can distinguish between types of nuclear reactions but are missing the conceptual foundation.</td>
</tr>
<tr>
<td>3412</td>
<td>5%</td>
<td>These students have the memorized knowledge foundation but not the understanding to distinguish between types of nuclear reactions.</td>
</tr>
</tbody>
</table>
B3.2k, Students will compare gravitational, electric and magnetic fields (caused by permanent magnets and moving charges) in terms of their sources and directions.

Use the following information to answer numerical-response question 11.

The Venn diagram below can be used to compare gravitational fields, electric fields, and magnetic fields.

Venn Diagram* of Fields

* In this Venn diagram, the numbered regions represent aspects of fields that are unique to one field (regions 1, 2, and 3), shared by two of the fields (regions 4, 5, and 6), shared by all three of the fields (region 7), or are not an aspect of any of the fields (region 8).

Numerical Response

11. Match the numbers of the regions in the Venn diagram above with the descriptions given below.

<table>
<thead>
<tr>
<th>Number:</th>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Can be directed toward the source</td>
</tr>
</tbody>
</table>

(Record all four digits of your answer in the response boxes at the bottom of the screen.)

Answer: 7658
Commentary

This Venn diagram is a really powerful way of meeting outcome B3.2k in terms of comparing fields. To be successful, students need to have a solid foundation in the characteristics of each of the fields. For example, gravity is always radially inward, electric fields are perpendicular to the surface so that point sources give radial fields and flat plates produce parallel field lines, and magnetic fields are closed loops.

In the specifics of this question, directed toward the source is true for ALL of them (7). The word *can* is much weaker than is *always*, which would have produced a first-blank answer of 1. The second blank is true for electric and magnetic fields but not gravitational fields, so the region is 6. Fields that fall as $\frac{1}{r^2}$ are gravitational and electric but not magnetic, which makes the region 5. The final blank is not an attribute of any of these fields and would be classified into region 8.

This type of question has many possible applications for assessing outcomes in Physics 30.
Instructions Pages for Physics 30 Diploma Examinations

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Physics 30
Grade 12 Diploma Examination

Description

Time: 3 hours. This closed-book examination was developed to be completed in 3 hours; however, you may take up to 6 hours to complete the examination, should you need it.

This examination consists of 36 multiple-choice and 14 numerical-response questions, of equal value.

This examination contains sets of related questions. A set of questions may contain multiple-choice and/or numerical-response questions.

Tear-out data pages are included near the back of this booklet. A Periodic Table of the Elements is also provided.

Instructions

- Turn to the last page of the examination booklet. Carefully fold and tear out the machine-scored answer sheet along the perforation.

Note: The perforated pages at the back of this booklet may be torn out and used for your rough work. No marks will be given for work done on the tear-out pages.

- Use only an HB pencil for the answer sheet.
- Fill in the information on the back cover of the examination booklet and the answer sheet as directed by the presiding examiner.
- You are expected to provide your own calculator. You may use any scientific calculator or a graphing calculator approved by Alberta Education.
- You must have cleared your calculator of all information that is stored in the programmable or parametric memory.
- You may use a ruler and a protractor.
- Read each question carefully.
- Consider all numbers used in the examination to be the result of a measurement or an observation.
- When performing calculations, use the values of the constants provided on the tear-out data pages.
- If you wish to change an answer, erase all traces of your first answer.
- Do not fold the answer sheet.
- The presiding examiner will collect your answer sheet and examination booklet and send them to Alberta Education.
- Now read the detailed instructions for answering machine-scored questions.
**Multiple Choice**

- Decide which of the choices best completes the statement or answers the question.
- Locate that question number on the separate answer sheet provided and fill in the circle that corresponds to your choice.

**Example**

This examination is for the subject of

A. chemistry  
B. biology  
C. physics  
D. science

Answer Sheet

Example

**Calculation Question and Solution**

If a 121 N force is applied to a 77.7 kg mass at rest on a frictionless surface, the acceleration of the mass will be __________ m/s².

(Record your three-digit answer in the numerical-response section on the answer sheet.)

\[ a = \frac{F}{m} = \frac{121 \text{ N}}{77.7 \text{ kg}} = 1.557 \text{ m/s}^2 \]

Record 1.56 on the answer sheet

Example

**Scientific-notation Question and Solution**

The charge on an electron is \(-a.b \times 10^{cd}\) C. The values of \(a, b, c,\) and \(d\) are ___, ___, ___, and ___.

(Record all four digits of your answer in the numerical-response section on the answer sheet.)

Answer: \(q = -1.6 \times 10^{-19}\) C

Record 1619 on the answer sheet
**Correct-order Question and Solution**

<table>
<thead>
<tr>
<th>Four Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Physics</td>
</tr>
<tr>
<td>2 Biology</td>
</tr>
<tr>
<td>3 Science</td>
</tr>
<tr>
<td>4 Chemistry</td>
</tr>
</tbody>
</table>

When the subjects above are arranged in alphabetical order, their order is ____, ____, ____., and ____.

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Answer: 2413

**Any-order Question and Solution**

Selected Terms Used to Describe Waves

<table>
<thead>
<tr>
<th>1 Crest</th>
<th>2 Transverse</th>
<th>3 Longitudinal</th>
<th>4 Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Pressure</td>
<td>6 Vector</td>
<td>7 Scalar</td>
<td>8 Differential</td>
</tr>
</tbody>
</table>

The terms in the above list that apply to a sound wave travelling in air are numbered ____., ____., and ____.

(Record all **three digits** of your answer in any order in the numerical-response section on the answer sheet.)

Answer: 345

**Matching Question and Solution**

<table>
<thead>
<tr>
<th>Physics Quantities</th>
<th>Classifications</th>
<th>Base SI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Distance</td>
<td>4 Vector</td>
<td>6 m</td>
</tr>
<tr>
<td>2 Acceleration</td>
<td>5 Scalar</td>
<td>7 m/s</td>
</tr>
<tr>
<td>3 Kinetic energy</td>
<td></td>
<td>8 m/s²</td>
</tr>
<tr>
<td>4 Pressure</td>
<td></td>
<td>9 kg·m²/s²</td>
</tr>
</tbody>
</table>

Using the numbers above, choose **one of the physics quantities**, classify it and identify its base SI units as described below.

(There is more than one correct answer.)

**Number:**

**Description:** Physics quantity

**Classification:**

**Base SI units**

(Record all **three digits** of your answer in the numerical-response section on the answer sheet.)

Answer: 156 or 248 or 359

**Record 156 on the answer sheet**

Record 248 or 359 in the same manner.

Note: All answers containing only the three digits 3, 4, and 5, in any order, will be scored as correct.
### Periodic Table of the Elements

<table>
<thead>
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PHYSICS DATA SHEET

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<td>Speed of Light in Vacuum</td>
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Physics Principles

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<tr>
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<td>2 Uniform circular motion ($\vec{F}_{\text{net}}$ is radially inward)</td>
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<td>3 Work-energy theorem</td>
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<td>4 Conservation of momentum</td>
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<td>7 Conservation of charge</td>
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Prefixes Used with SI Units

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### Kinematics

\[
\vec{v}_{\text{ave}} = \frac{\Delta \vec{d}}{\Delta t} \\
\vec{a}_{\text{ave}} = \frac{\Delta \vec{v}}{\Delta t} \\
\vec{a} = \frac{\vec{v}_i + \vec{v}_f}{2} t \\
|\vec{v}| = \frac{2 \pi r}{T} \\
|\vec{a}| = \frac{v^2}{r} = \frac{4 \pi^2 r}{T^2}
\]

### Dynamics

\[
\vec{a} = \frac{\vec{F}_{\text{net}}}{m} \\
|\vec{F}| = \mu |\vec{F}_N| \\
|\vec{g}| = \frac{Gm_1 m_2}{r^2} \\
\vec{F}_s = -k\vec{x} \\
\vec{g} = \frac{\vec{F}_g}{m}
\]

### Momentum and Energy

\[
\vec{p} = m\vec{v} \\
E_k = \frac{1}{2} mv^2 \\
F \Delta t = m \Delta \vec{v} \\
W = |\vec{F}| |\Delta \vec{d}| \cos \theta \\
E_p = \frac{1}{2} k \vec{x}^2 \\
W = \Delta E \\
P = \frac{W}{t}
\]

### Waves

\[
T = 2\pi \frac{m}{k} \\
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \\
\frac{n_2}{n_1} = \frac{\sin \theta_1}{\sin \theta_2} \\
f = \left(\frac{v}{v_1 + v_2}\right) f_s \\
\lambda = \frac{d \sin \theta}{n} \\
\lambda = \frac{xd}{nl}
\]

### Electricity and Magnetism

\[
|\vec{F}_e| = \frac{k q_1 q_2}{r^2} \quad \Delta V = \frac{\Delta E}{q} \\
|\vec{E}| = \frac{k q}{r^2} \quad I = \frac{q}{t} \\
\vec{E} = \frac{\vec{F}_e}{q} \\
|\vec{F}_m| = \mu I |\vec{B}| \\
|\vec{E}| = \frac{\Delta V}{\Delta d} \quad |\vec{F}_m| = q \nu |\vec{B}|
\]

### Atomic Physics

\[
W = hf_0 \\
E = hf = \frac{hc}{\lambda} \\
E_{k\text{max}} = q_e V_{\text{stop}} \\
N = N_0 \left(1 \frac{1}{2}\right)
\]

### Quantum Mechanics and Nuclear Physics

\[
\Delta E = \Delta m c^2 \\
E = pc \\
p = \frac{h}{\lambda} \\
\Delta \lambda = \frac{h}{m c(1 - \cos \theta)}
\]

### Trigonometry and Geometry

\[
\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}} \\
\cos \theta = \frac{\text{adjacent}}{\text{hypotenuse}} \\
\tan \theta = \frac{\text{opposite}}{\text{adjacent}} \\
\frac{\Delta y}{\Delta x} = m = \frac{\Delta y}{\Delta x} \\
y = mx + b \\
\text{Line}
\]

\[
|\vec{F}| = \mu |\vec{F}_N| \\
|\vec{g}| = \frac{Gm_1 m_2}{r^2} \\
\vec{F}_s = -k\vec{x} \\
\vec{g} = \frac{\vec{F}_g}{m}
\]

### Area

\[
\text{Rectangle} = lw \\
\text{Triangle} = \frac{1}{2} ab \\
\text{Circle} = \pi r^2
\]

### Circumference

\[
\text{Circle} = 2\pi r
\]
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