Grade 11 Physics Workbook

St John Baptist De La Salle Catholic School, Addis Ababa

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1. Physics & Human Society

Chapter Summary

Physics, a Beautiful Science

- Physics is a natural science that involves the study of matter and its motion through space and time, along with related concepts such as energy and force. It is the study of the universe itself; how it began, how it operates, and how it will be done.
- Many scientific disciplines, such as biophysics, physical chemistry and engineering, are hybrids of physics and other sciences.
- The application of physics is fundamental towards significant contributions in new technologies that arise from theoretical breakthroughs that we use daily. All electronics, cryptographic encryptions, medical instruments, the internet itself, and more have been the direct result of physics.

Models, Theories & Laws

- Concepts in physics cannot be proven, they can only be supported or disproven through observation and experimentation.
- A model is an evidence-based representation of something that is either too difficult or impossible to display directly.
- A theory is an explanation for patterns in nature that is supported by scientific evidence and verified multiple times by various groups of researchers.
- A law uses concise language, often expressed as a mathematical equation, to describe a generalized pattern in nature that is supported by scientific evidence and repeated experiments.
- A background in physics is probably one of the most versatile career paths. You can use your skills to work in multiple disciplines including but not limited to astronomy, healthcare, engineering, energy, technology, meteorology, finance, and the like..
- Recent developments in physics include discovery and imaging of black holes, quantum cryptography, quantum computing, AI & ML, Gravitational Waves, Understanding of the Universe through many missions like the recent JWST, Neutrino Astronomy, and many more exciting stuff.

The Scientific Method

The scientific method provides scientists with a well structured scientific platform to help find the answers to their questions. It can be summarized as follows

1. Ask a question about the world around you.
2. Do background research on your questions.
3. Make a hypothesis about the event that gives a sensible result. You must be able to test your hypothesis through experiment.
4. Design an experiment to test the hypothesis. These methods must be repeatable and follow a logical approach.
5. Collect data accurately and interpret the data. You must be able to take measurements, collect information, and present your data in a useful format (drawings, explanations, tables and graphs).
6. Draw conclusions from the results of the experiment. Your observations must be made objectively, never force the data to fit your hypothesis.
7. Decide whether your hypothesis explains the data collected accurately.
8. If the data fits your hypothesis, verify your results by repeating the experiment or getting someone else to repeat the experiment.
9. If your data does not fit your hypothesis perform more background research a make a new hypothesis.

Questions

1. How is a model different from a theory?(For instance, you have learned phrases like "the Dalton Atomic Model" and "Kinetic Theory of Gases".. why is one a model and the other a theory?)

2. What is the difference between algorithms that are *computationally secure* and those that are *information theoretically secure*?

3. What are common ways people's passwords and personal information get compromised? How can one protect themselves from such attacks?

4. We have discussed in class the discrepancy between the same observation but different analyses of a data set. We took the news regarding observations by JWST data being interpreted differently by different groups of scientists. A prominent bloc suggest that the electromagnetically undetectable, but seemingly gravitationally present "matter" is dark matter while dissidents suggest that Newton's Universal Gravitation Law applies differently for distant large galaxies. Which idea do you seem to agree more with? Why?

5. Research is extremely important for many different reasons; we recently saw its significance during the COVID-19 pandemic when many otherwise expensive journals were pressured into making the pandemic related researches published and accessible for free. The free movement of research led to many people believing in the methodology of the vaccine production and even more others chipping in ideas to better the research being done. Now that the pandemic is over, many of those articles are back on paywall and one has to pay large sums to access the research articles. Explain whether you agree on the current model of article publications or whether you think research articles should be open access always. Give examples of open access journals and/or research repositories.

6. In collaborations like the CERN (European Organization for Nuclear Research), there are multiple people from different backgrounds, institutions, and even countries collaborating to do research. CERN is the home of many experiments such as ALICE(A Large Ion Collider Experiment), LHC(the Large Hadron Collider), CMS(Compact Muon Solenoid) which have been significant in many high energy physics experiments such as the one done to discover the famous Higgs Boson.

    - What (simply)is the significance of the Higgs Boson?

    - Why is such a big collaboration important in your opinion? Why wasn't, say the Higgs Boson discovered in a small lab of 4 people in a rural town?

- CMS(Compact Muon Solenoid) is a general purpose particle accelerator. Say, for example, a theorist proposed existence of a particle that you would like to detect. Based on electromagnetism concepts we discussed last semester, how would you design an experiment to detect said particle?

7. Physics communities are important to nourish underrepresented members of the community and also generally to advocate for physics within the general community. Out of the communities we have seen in class, which ones do you feel most interested by? Why?

8. Your hobbies are probably directly or indirectly related to physics. List some of your hobbies and explain how physics plays a role.

9. What is the difference between experiential and non-experiential knowledge?

10. It is true that in science(as in any other field), rivalries do exist. It wouldn't be an exaggeration to, perhaps, suggest that scientific rivalries may even be on the fiercer side of the rivalry spectrum, so to speak. Some of these rivalries include ones between *Nikola Tesla* and *Thomas Edison*, *Isaac Newton* and *Gottfried Leibniz*, *Isaac Newton* and *Robert Hooke* and ones between countries. It would be wrong to suggest that rivalries serve no purpose, however, in the pursuit of scientific truth, working with adversaries can pay off. A research dubbed *Adversarial Collaboration Project* which ran at UPenn hypothesized that for advancement of scientific facts, rivals would have to work together. What is your take on this? How different do you think the world could have been if adversarial collaborations were a common practice since the early days of science?

2. Vectors

Chapter Summary

Scalars and Vectors

- A vector quantity is any quantity that has magnitude and direction, such as displacement or velocity.
- Geometrically, vectors are represented by arrows, with the end marked by an arrowhead. The length of the vector is its magnitude, which is a positive scalar. On a plane, the direction of a vector is given by the angle the vector makes with a reference direction, often an angle with the horizontal(usually +X-axis). The direction angle of a vector is a scalar.
- Two vectors are equal if and only if they have the same magnitudes and directions. Parallel vectors have the same direction angles but may have different magnitudes. Antiparallel vectors have direction angles that differ by 180°. Orthogonal vectors have direction angles that differ by 90°.
- When a vector is multiplied by a scalar, the result is another vector of a different length than the length of the original vector. Multiplication by a positive scalar does not change the original direction; only the magnitude is affected. Multiplication by a negative scalar reverses the original direction. The resulting vector is antiparallel to the original vector. Multiplication by a scalar is distributive. Vectors can be divided by nonzero scalars but cannot be divided by vectors.
- Two or more vectors can be added to form another vector. The vector sum is called the resultant vector. We can add vectors to vectors or scalars to scalars, but we cannot add scalars to vectors. Vector addition is commutative and associative.
- To construct a resultant vector of two vectors in a plane geometrically, we use the parallelogram rule. To construct a resultant vector of many vectors in a plane geometrically, we use the tail-to-head method.

Coordinate Systems and Components of a Vector

- Vectors are described in terms of their components in a coordinate system. In two dimensions (in a plane), vectors have two components. In three dimensions (in space), vectors have three components.
- A vector component of a vector is its part in an axis direction. The vector component is the product of the unit vector of an axis with its scalar component along this axis. A vector is the resultant of its vector components.
- Scalar components of a vector are differences of coordinates, where coordinates of the origin are subtracted from end point coordinates of a vector.
- In a rectangular(Cartesian) system, the magnitude of a vector is the square root of the sum of the squares of its components.
- In a plane, the direction of a vector is given by an angle the vector has with the positive x-axis. This direction angle is measured counterclockwise. The scalar x-component of a vector can be expressed as the product of its magnitude with the cosine of its direction angle, and the scalar y-component can be expressed as the product of its magnitude with the sine of its direction angle.
- In a plane, there are two equivalent coordinate systems. The Cartesian coordinate system is defined by unit vectors $\hat{i}$ and $\hat{j}$ along the x-axis and the y-axis, respectively. The polar coordinate system is defined by the radial unit vector $\hat{r}$, which gives the direction from the origin, and a unit vector $\hat{t}$, which is perpendicular (orthogonal) to the radial direction.

Vector Operations : Addition/Subtraction

- We can graphically add/subtract vectors using triangle and parallelogram methods. To do that, however, we have to draw the vectors scaled.
- When using parallelogram method, we can sort of make it hybrid by introducing mathematical tools such as the law of cosines $b^2 = a^2 + c^2 - 2ca\,\cos\theta$ such that θ is the angle between a and c.
- Analytical methods of vector algebra allow us to find resultants of sums or differences of vectors without having to draw them. Analytical methods of vector addition are exact, contrary to graphical methods, which are approximate.
- Analytical methods of vector algebra are used routinely in mechanics, electricity, and magnetism. They are important mathematical tools of physics.

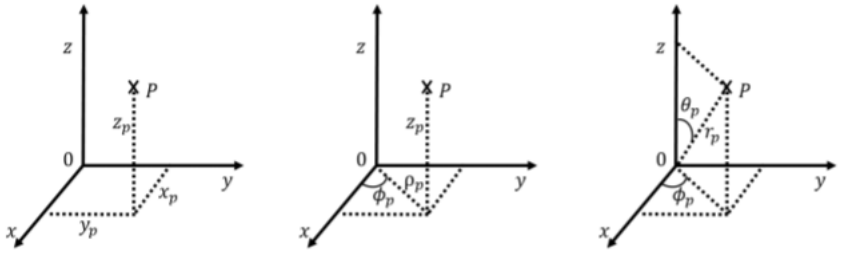
Vector Operations : Product

- There are two kinds of multiplication for vectors. One kind of multiplication is the scalar product, also known as the dot product. The other kind of multiplication is the vector product, also known as the cross product. The scalar product of vectors is a number (scalar). The vector product of vectors is a vector.
- Both kinds of multiplication have the distributive property, but only the scalar product has the commutative property. The vector product has the anticommutative property, which means that when we change the order in which two vectors are multiplied, the result acquires a minus sign.
- The scalar product of two vectors is obtained by multiplying their magnitudes with the cosine of the angle between them. The scalar product of orthogonal vectors vanishes; the scalar product of antiparallel vectors is negative.
- The vector product of two vectors is a vector perpendicular to both of them. Its magnitude is obtained by multiplying their magnitudes by the sine of the angle between them. The direction of the vector product can be determined by the corkscrew right-hand rule. The vector product of two either parallel or antiparallel vectors vanishes. The magnitude of the vector product is largest for orthogonal vectors.

- The scalar product of vectors is used to find angles between vectors and in the definitions of derived scalar physical quantities such as work or energy.
- The cross product of vectors is used in definitions of derived vector physical quantities such as torque or magnetic force, and in describing rotations.

Useful Mathematical Facts

- Polar coordinates in a two dimensions $\begin{cases} x = r\cos\varphi \\ y = r\sin\varphi \end{cases}$



- Cylindrical coordinate system $\begin{cases} \rho & = \sqrt{x^2+y^2} \\ \tan(\phi) & = \frac{y}{x} \\ z & = z \end{cases}$
- Spherical coordinate system $\begin{cases} r & = \sqrt{x^2+y^2+z^2} \\ \cos(\theta) & = \frac{z}{r} = \frac{z}{\sqrt{x^2+y^2+z^2}} \\ \tan(\phi) & = \frac{y}{x} \end{cases}$
- Equal vectors & condition for equivalence $\vec{A} = \vec{B} \Leftrightarrow \begin{cases} A_x = B_x \\ A_y = B_y \\ A_z = B_z \end{cases}$
- A unit vector $\hat{V} = \dfrac{\vec{V}}{V}$
- Dot product of unit vectors $\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0$
- Cross product of unit vectors $\begin{cases} \hat{i}\times\hat{j} = +\hat{k}, \\ \hat{j}\times\hat{l} = +\hat{i}, \\ \hat{l}\times\hat{i} = +\hat{j}. \end{cases}$

Questions

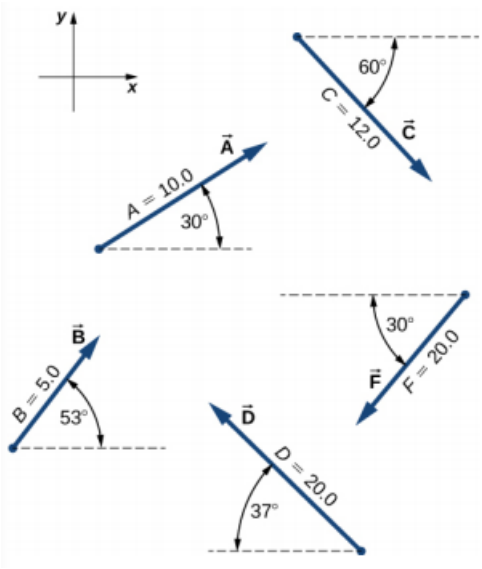
11. Basics of vector understanding.

- A vector has zero magnitude. Is it necessary to specify its direction? Explain.

- Can a magnitude of a vector be negative?

- If three vectors sum up to zero, what geometric condition do they satisfy? Show all the steps.

12. For the figure given below, use triangle or parallelogram methods of vector addition to find the resultant. Use law of cosines to find the length of the resultant.



- $3\vec{A} - 2\vec{F}$

- $\vec{A} - \vec{C} + \vec{B}$

- $\vec{A} - \vec{D} + \vec{F} - 4\vec{F}$

13. The magnitudes of two displacement vectors are $|\vec{A}| = 12$ cm and $|\vec{B}| = 5$ cm. What are the largest and the smallest values of the magnitude of the resultant $\vec{R} = \vec{A} + \vec{B}$?

14. The polar coordinates of a point are $(-\frac{4}{3}\pi, 4)$. What are its Cartesian coordinates?

15. • What is the displacement vector from point (1,2,3) to point (7,8,9)?

• What angle does that displacement vector make with the x axis?

16. A force vector points at an angle of 53^0 above the +x axis. It has a y component of 340 newtons. Find

• the magnitude

• the x component

17. Vector **A** has a magnitude of 9.00 units and points due West. Vector **B** points due north.

• What is the magnitude of B, if the vector A+B points 45.0^0 north of east?

• Find the magnitude of A + B.

18. For an object moving in uniform circular motion, the direction of the instantaneous acceleration vector is
A. equal to zero B. directed radially outward
C. directed radially inward D. tangent to the path of motion

19. Which of the following sets of 3 forces CANNOT have a vector sum of zero? **Why?**
    A. 10, 10 and 10 Newtons B. 10, 10 and 20 Newtons
    C. 10, 20 and 20 Newtons D. 10, 20 and 40 Newtons

20. What is the magnitude (length) of the vector $2\hat{i} + 9\hat{j} - 4\hat{k}$?

21. What is the unit vector in the direction of the above vector? After you find the unit vector, show that it is a unit vector by calculating its magnitude.

22. Convert the following equation using Cartesian coordinates to cylindrical ones.

    - $x^4 + \frac{2}{7}x^3 - 6z = 4 - 2y^2$

23. The standard equation of an ellipse in the Cartesian plane is $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$. Show that its equation in the polar coordinate system is given by $r = \frac{1}{1 + e\cos\theta}$.

24. Let's assume we have three vectors such that $\vec{A} = 3\hat{i} - 7\hat{j}$, $\vec{B} = \hat{i} + \hat{j} + 4\hat{k}$, and$\vec{C} = 5\hat{j} - 8\hat{k}$. Find the following

    - $|\vec{A}|$ and $\hat{A}$

- the component of $\vec{C}$ along $\vec{A}$

- $\vec{A} \times \vec{C}$

- $\vec{A} \times (\vec{C} \cdot \vec{B})$

- $\vec{A} \times (\vec{C} \times \vec{B})$

- $\hat{i} \cdot (\vec{C} \times \vec{B})$

25. Convert the following equation in Cartesian coordinates to spherical ones.
    - $3x^2 + y^2 = 8x + 2z - 4$

26. Find a unit vector parallel to either direction of the line described by 4x+y = 8.

27. • Vector $\vec{B}$ is 7.0 cm long and vector $\vec{A}$ is 4.0 cm long. Find the angle between these two vectors when $|\vec{A}+\vec{B}|=|\vec{A}-\vec{B}|$

• Draw the vectors and join their tails after you have found the angle between them. What special kind of parallelogram have you constructed using the two vectors and their extensions?

28. Calculate the vector product of $\vec{a}$ and $\vec{b}$ given that $\vec{a}= 2\hat{i} + \hat{j} + \hat{k}$ and $\vec{b} = \hat{i} - \hat{j} - \hat{k}$.

29. Show that the area of a parallelogram formed by two vectors is equal to their cross product.

30. What is the angle between vectors $\vec{A} = \langle 1, 2, 3, 4\rangle$ and $\vec{B} = \langle 0, -1, 4, -2\rangle$?

31. For the two vectors above, find $\text{proj}_{\vec{A}}\vec{B}$.