

Grade 12 Physics

SPH4U

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September 13, 2025

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Chapter 1

Unit 1A

1.1 Review of Describing and Graphing Motion

1.1.1 Position: \vec{d}

Position is the **straight-line distance** from a fixed reference point to a location, with a direction to the location from the reference point.

1.1.2 displacement: $\Delta\vec{d}$

Displacement is the **change of position**

Formula:

$$\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$$

or

n = the amount of displacement you want to add

$$\Delta\vec{d}_{tot} = \sum_{i=1}^n \Delta\vec{d}_i$$

1.1.3 Velocity: \vec{v}

Velocity is the **rate of change of position**

$$\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$$

1.1.4 Acceleration: \vec{a}

Acceleration is the *rate of change* of velocity, always in the form of $\frac{m}{s^2}$

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$$

1.1.5 Graphing motion

For a **Position vs Time** graph:

- For a position/displacement vs time graph, the velocity = the *slope*
- A slope of zero = The object is not moving
- Instantaneous velocity (\vec{v}_{inst}) = the slope of **tangent** line to the graph at that point in time
- Average velocity (\vec{v}_{avg}) = the slope of **secant** line for that time interval

For a **Velocity vs Time** graph:

- Can get an object's instantaneous velocity directly from the graph
- slope = **acceleration**
- Displacement = The **area** between the graph and the time-axis for that time interval

1.2 Equations of Motion

To start off, there are five equations that are used in the calculation of motion

$$\vec{v}_f = \vec{v}_i + \vec{a} * \Delta t$$

$$\Delta \vec{d} = \frac{1}{2}(\vec{v}_i + \vec{v}_f) * \Delta t$$

$$\Delta \vec{d} = \vec{v}_i \Delta t + \frac{1}{2} \vec{a} * \Delta t^2$$

$$\Delta \vec{d} = \vec{v}_f \Delta t - \frac{1}{2} \vec{a} * \Delta t^2$$

$${\vec{v}_f}^2 = {\vec{v}_i}^2 + 2\vec{a}\Delta \vec{d}$$

1.2.1 Format requirements for answering Motion questions

1. You should always include a diagram that contains every known information from the question
2. \vec{v} should be presented for at least two decimal places
3. Always list steps in your answer
4. When using quadratic solving function on calculator, always write **Using Quadratic Eq* in your answer
5. When you form an equation system, you should label 1.2.3. on each equation in the system
6. Follow the Sig Digit rules
 - ! For **add** and **subtract**, keep the least **decimal places**
 - ! For **multiply** and **divide**, keep the least amount of **signficiant digit**

1.3 Adding and Subtracting 2-Dimensional Vectors

1.3.1 Vector addition and subtraction key words

- + Addition: Find "the **resultant**", "the total", or "the net".
- Subtraction: Find "the **difference**" or "the change in".

1.3.2 Steps for solving a vector problem

1. Read the question carefully
2. Show unit conventions
3. Write "givens" (It helps to roughly sketch each vector and their components)
4. Set direction conventions
5. Solve for each components (ex. Δd_{1y} , Δd_{2x})
6. Choose one component direction (ex. Just the 'x' direction) and solve the equations for that direction
7. Repeat with the other direction
8. Sketch your resulting x and y vectors, joining them head-to-tail.
9. Calculate the magnitude and direction of the resultant. (Trigonometry)
10. State the final answer, including the real-world direction

**Must show conversion factors*

8. State final answer, including the real-world direction

Example 4: A spy drone flies 735m [N27°W], then 590m [W15°S]. This turn takes 2.1 minutes. What was the drone's average velocity during this time?

Strategy: Find Δd_{tot} and Δt , then divide by Δt .

$\Delta t = 2.1 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} = 126 \text{ s}$

$\Delta d_1 = 735 \text{ m} [\text{N}27^\circ\text{W}]$

$\Delta d_2 = 590 \text{ m} [\text{W}15^\circ\text{S}]$

$\vec{V}_{avg} = \frac{\Delta d_{\text{tot}}}{\Delta t} = \frac{\Delta d_1 + \Delta d_2}{\Delta t} = \frac{735 \text{ m}[\text{N}27^\circ\text{W}] + 590 \text{ m}[\text{W}15^\circ\text{S}]}{126 \text{ s}}$

$\vec{V}_{avg-x} = \frac{-(735 \text{ m}) \sin 27^\circ + (-)(590 \text{ m}) \cos 15^\circ}{126 \text{ s}} = -7.1713 \dots \text{ m/s}$

$\vec{V}_{avg-y} = \frac{(-)(735 \text{ m}) \cos 27^\circ + (-)(590 \text{ m}) \sin 15^\circ}{126 \text{ s}} = 3.9856 \dots \text{ m/s}$

$\theta = \tan^{-1} \left(\frac{3.9856 \dots}{-7.1713 \dots} \right) = 29.064^\circ \approx 240^\circ$

$|\vec{V}_{avg}| = \sqrt{(3.9856 \dots)^2 + (-7.1713 \dots)^2} = 8.2044 \dots \text{ m/s} \approx 8.2 \text{ m/s}$

$\therefore \vec{V}_{avg} \approx 8.2 \text{ m/s} [\text{W}24^\circ\text{N}]$ OR $[\text{N}61^\circ\text{W}]$

Figure 1.1: A sample answer for vector question

1.3.3 Another question type

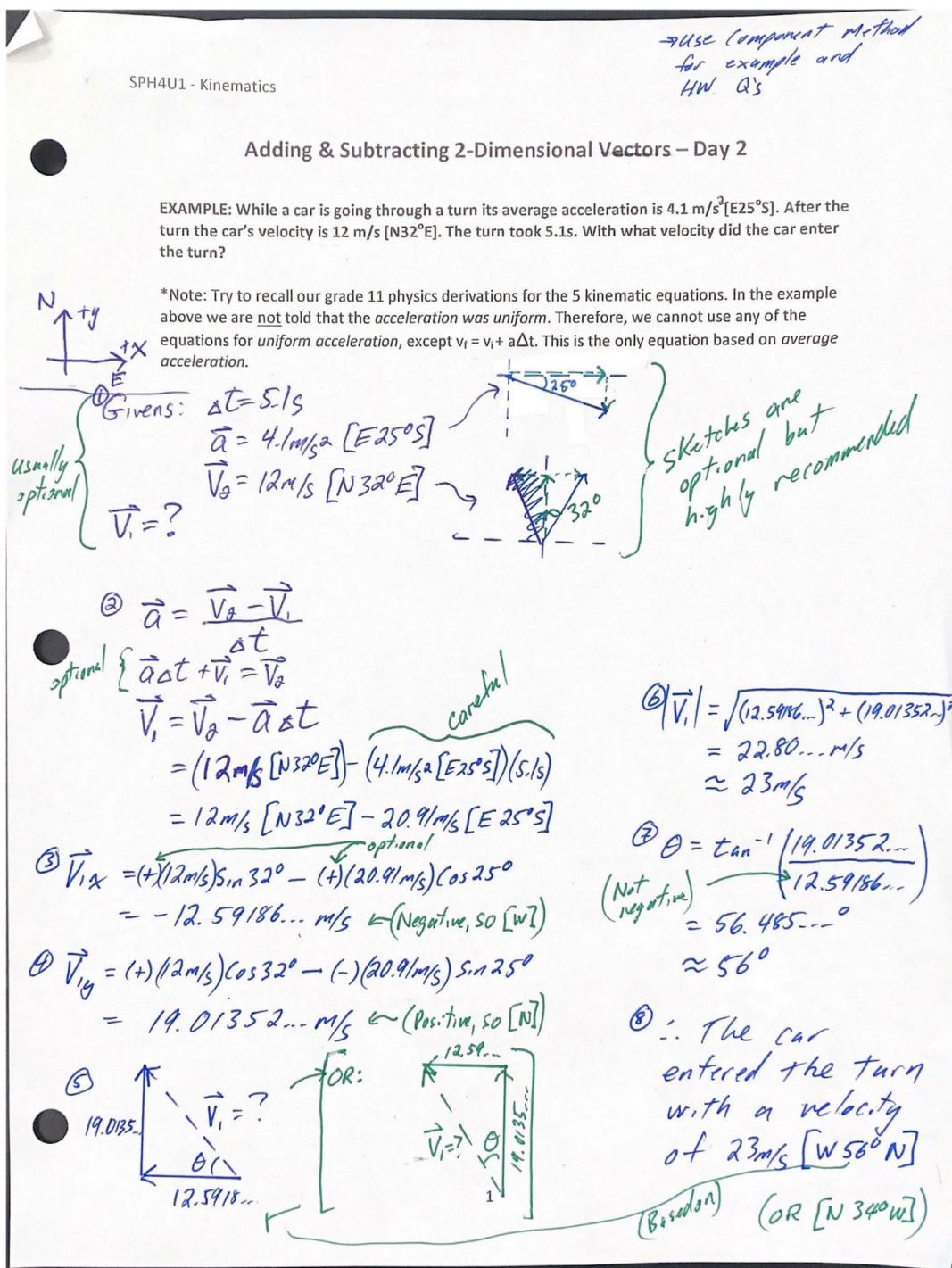


Figure 1.2: Remainder, multiply first

1.4 Frame of Reference

1.4.1 1 Dimension Frame of Reference

For certain **Chase and Collision** questions, you can use **frame of reference** to solve them

Example. How to write givens

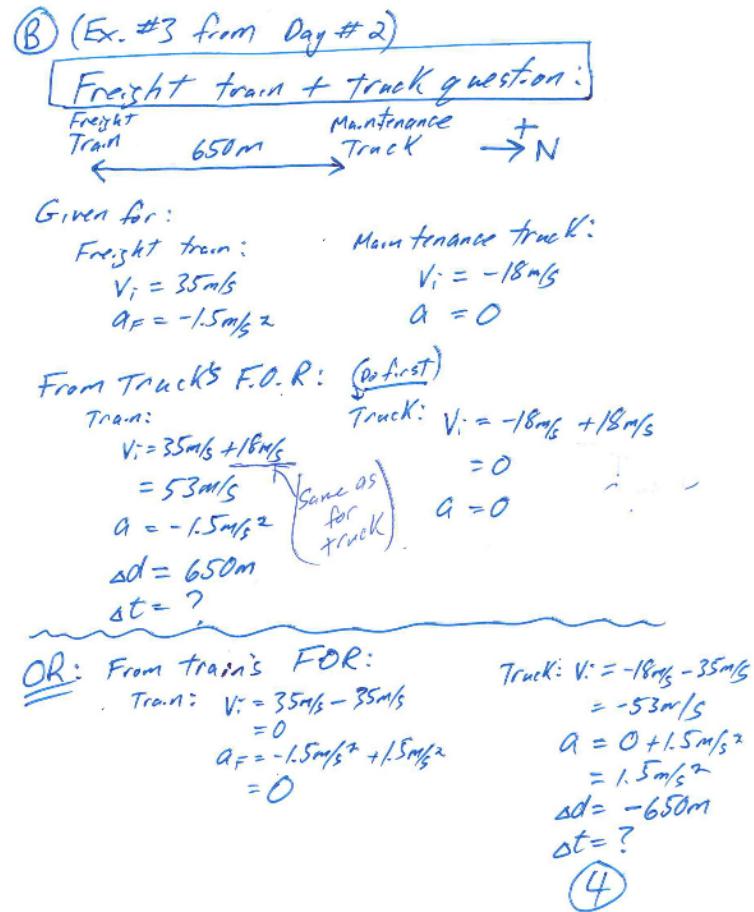


Figure 1.3: You should always write it

1.5 Relative Velocities in Two Dimensions

1.5.1 Recall

1. All velocities are related to an F.O.R that we consider to be motionless or stopped
2. A frame of reference is just a perspective from which we observe/or measure the motion of objects

1.5.2 Definition

We sometimes refer to something that another thing can travel through as *medium*. We also sometimes refer to the thing that is moving through the medium as *object(O)*, and the ground use the symbol (G)

Therefore the equation can be written as:

$$\vec{v}_{OG} = \vec{v}_{OM} + \vec{v}_{MG}$$

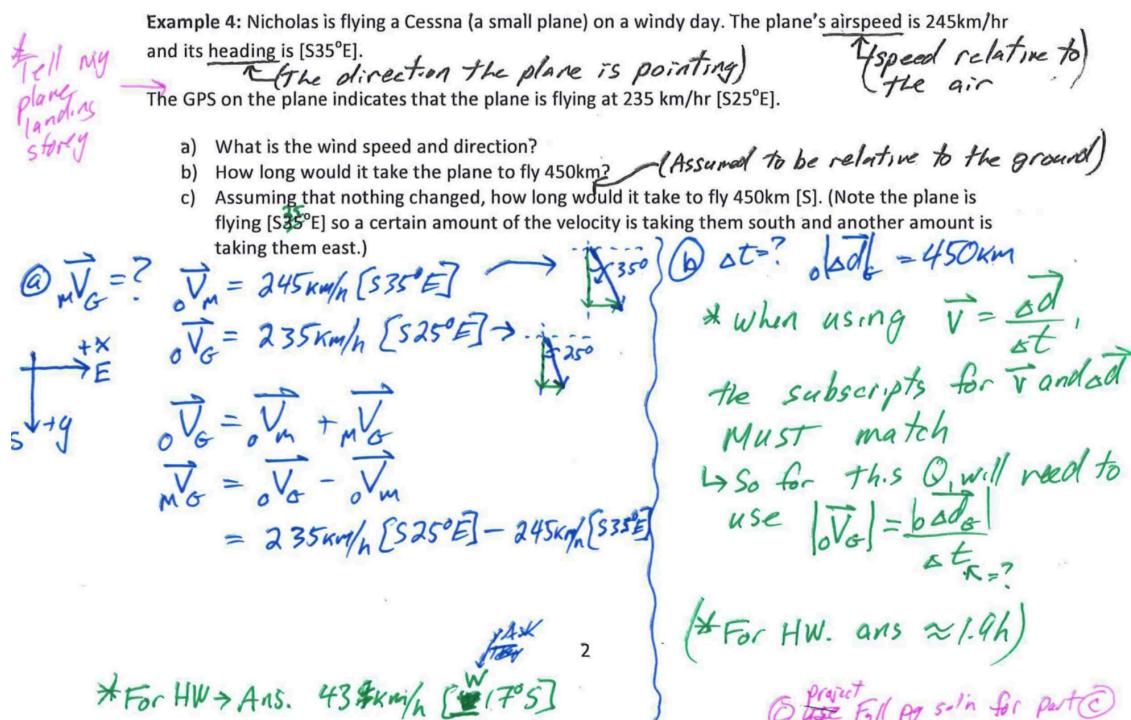


Figure 1.4: An example question

1.6 F.O.R in 2-D

2 = Why? When to use!

Resolving Vectors onto Rotated Direction Conventions

NOTE: Breaking a vector into components is called “resolving a vector”

Until now, we have chosen direction conventions that are in “nice directions” (such as north-south or east-west or up-down). However, it can be very useful to choose direction conventions that are at angles to these “nice directions”. This can make solving certain types of questions much easier!

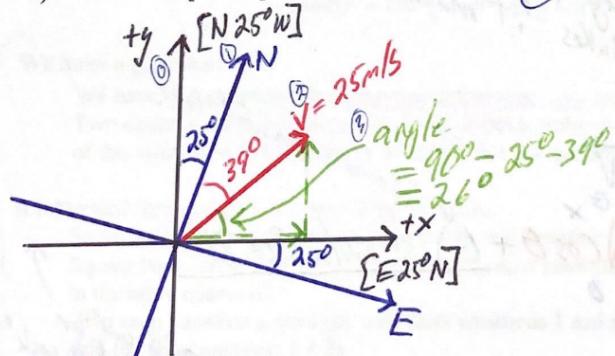
Steps in resolving vectors using rotated direction conventions:

1. Determine what will be your direction conventions (remember they MUST be perpendicular to each other).
2. Draw the rotated directions conventions, including labels. (Typically +y is drawn so that it points straight up.)
3. Add to the diagram two lines to indicate N-S and E-W.
4. Draw the vector, with its tail starting at the axis.
5. Draw the x and y components of the given vector.
6. Determine the angle between the given vector and one of the component lines (it will be between the tail of the given vector and the tail of the component that touches the tail of the given vector).
7. Use trigonometry to determine the two components.

(If you prefer, could instead always draw [N] as straight up)

Example 1: Given the following direction convention: [N25°W]: +y and [E25°N]: +x
Determine the x and y components of the following vectors:

a) 25 m/s [N39°E]



b) 275 km/h [W48°N]

(They try? for S.K.P.) *"Recommended for HW"*

$$\begin{aligned} x\text{-Component} &= +(25 \text{ m/s}) \cos 26^\circ \\ &= 22.4698 \dots \text{ m/s} \\ &\approx 22 \text{ m/s} \end{aligned}$$

$$\begin{cases} (\text{try do}) \\ y\text{-Component} = +(25 \text{ m/s}) \sin 26^\circ \\ = 10.959 \dots \text{ m/s} \\ \approx 11 \text{ m/s} \end{cases}$$

Figure 1.5: Teacher's note

1.7 Review of Netwon's Laws of Motion

1.7.1 Netwon's First Laws

Inertia is an object's **resistance** to a change in its state of uniform Motion.

Example. An object at rest will **remain at rest** And an object in motion will continue to **move in a straight line constant speed** UNLESS a non-zero net force acts on the object

1.7.2 Newton's second Law

Newton's *2nd* Law is the formula that explains the behaviour of object when the forces on the object are not zero.

We can orgnize to these formulas:

$$\vec{a} = \frac{\sum \vec{F}}{m} \quad (1.1)$$

and

$$\sum \vec{F} = m * \vec{a} \quad (1.2)$$

\vec{a} = acceleration of the object

m = mass of the object in kg

$\sum \vec{F}$ = The sum of the net force

1.7.3 Newton's Third Law

For every force, there is another force, which is *equal in magnitude* to the first force, but *opposite in direction*. These two forces will *act on separate objects*, unless they are "internal force"

This mean's that all forces Always **come in pairs**, but two forces may not be acting on the same object.

To fit the Newton's *3rd* Law pair forces, the two force must:

1. Be the same type of force

2. $\vec{F}_{A/B} = -\vec{F}_{B/A}$

1.7.4 Free Body Diagrams (FBD)

Example 2: Consider a calculator sitting on a textbook that is on a desk. Mr. McCumber pushes the textbook and it accelerates forward. The calculator stays at rest relative to the textbook. Draw the FBDs for each of the following.

For your subscripts let 'c' represent the calculator, 't' the textbook, 'E' the Earth, and 'f' the floor.

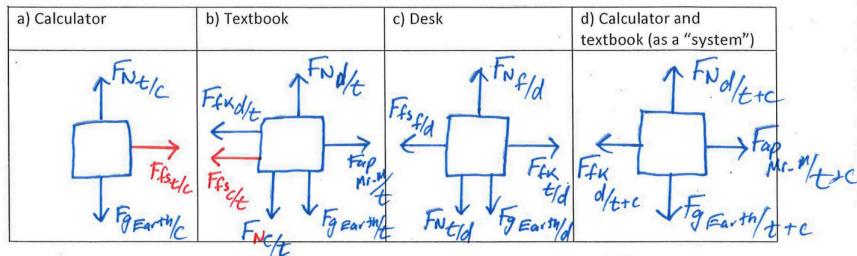


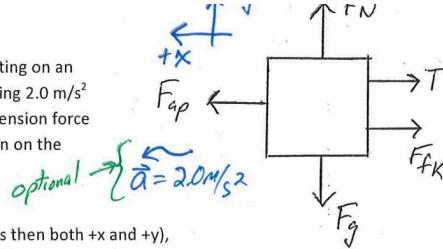
Figure 1.6: An example Free Body Diagram

1.7.5 Application of Newton's second Law

Here is an example:

Applying Newton's 2nd Law of Motion:

Example 3: The FBD on the right shows the forces acting on an object with a mass of 10.0 kg. The object is accelerating 2.0 m/s² [left]. The magnitudes of the applied force and the tension force are 25 N and 15 N. What is the force of kinetic friction on the object? (Don't forget a magnitude AND direction)



Typical steps (after the FBD):

1. Define direction conventions (if 2-dimensions then both +x and +y),
2. Write the equation for Newton's 2nd Law (with vector signs),
3. Replace "net force" with the appropriate forces shown in the FBD. During this step also consider the direction of the forces and remove any vector signs,
4. Solve for the unknown.

$$\begin{aligned} \sum \vec{F}_x &= m \vec{a}_x \\ \text{Drop the vector signs } \left\{ \begin{aligned} F_{ap} - T - F_{fk} &= m a_x \\ F_{fk} &= F_{ap} - T - m a_x \\ &= (25N) - (15N) - (10kg)(2m/s^2) \\ &= 5N \quad \text{or } [-] \\ F_{fk} &\approx 5.0N \text{ (Right)} \end{aligned} \right. \\ * \text{The fact that the ans. is positive does not mean that } \vec{F}_{fk} \text{ acts in the +ve direction, it indicates the direction of } \vec{F}_{fk} \text{ in the diagram is correct.} \end{aligned}$$

Figure 1.7: