

Grade 12 Physics

SPH4U

Qinghao Hu

September 22, 2025

Contents

| | |
|---|----------|
| 1 Unit 1A | 3 |
| 1.1 Review of Describing and Graphing Motion | 3 |
| 1.1.1 Position: \vec{d} | 3 |
| 1.1.2 displacement: $\Delta\vec{d}$ | 3 |
| 1.1.3 Velocity: \vec{v} | 3 |
| 1.1.4 Acceleration: \vec{a} | 3 |
| 1.1.5 Graphing motion | 4 |
| 1.2 Equations of Motion | 5 |
| 1.2.1 Format requirements for answering Motion questionss | 5 |
| 1.3 Adding and Subtracting 2-Dimensional Vectors | 6 |
| 1.3.1 Vector addition and subtraction key words | 6 |
| 1.3.2 Steps for solving a vector problem | 6 |
| 1.3.3 Another question type | 7 |
| 1.4 Frame of Reference | 8 |
| 1.4.1 1 Dimension Frame of Reference | 8 |
| 1.5 Relative Velocities in Two Dimensions | 9 |
| 1.5.1 Recall | 9 |
| 1.5.2 Definition | 9 |
| 1.6 F.O.R in 2-D | 10 |
| 1.7 Review of Netwon's Laws of Montion | 11 |
| 1.7.1 Netwon's First Laws | 11 |
| 1.7.2 Newton's second Law | 11 |
| 1.7.3 Newton's Third Law | 11 |
| 1.7.4 Free Body Diagrams (FBD) | 12 |
| 1.7.5 Application of Newton's second Law | 12 |
| 1.8 Review of Projectile Motion | 13 |
| 1.8.1 basic | 13 |
| 1.8.2 Special formula | 13 |
| 1.8.3 An example question | 14 |
| 1.9 Friction | 14 |
| 1.9.1 Kinetic Friction | 15 |
| 1.9.2 Static Friction | 15 |
| 1.9.3 Remainder | 15 |
| 1.10 Tension, compression and Pulleys | 16 |
| 1.10.1 Tention: T | 16 |
| 1.10.2 Compression: C | 16 |
| 1.11 Inclined plane with Friction | 17 |

| | |
|---|----|
| 1.11.1 How to determine the direction that the system will likely to accelerate . . . | 17 |
| 1.11.2 Example template | 17 |

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 \vec{d}_{tot} and divide by Δt .

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

$\vec{d}_1 = 735 \text{ m} [\text{N}27^\circ\text{W}]$

$\vec{d}_2 = 590 \text{ m} [\text{W}15^\circ\text{S}]$

$\vec{V}_{\text{avg}} = \frac{\vec{d}_{\text{tot}}}{\Delta t} = \frac{\vec{d}_1 + \vec{d}_2}{126 \text{ s}}$

$\vec{V}_{\text{avg}} = \frac{(735 \text{ m}) \cos 27^\circ \hat{i} + (-)(590 \text{ m}) \cos 15^\circ \hat{j}}{126 \text{ s}}$

$\vec{V}_{\text{avg}} = -7.1713 \text{ m/s}$

$V_{\text{avg}} = \sqrt{(3.9856 \text{ m/s})^2 + (7.1713 \text{ m/s})^2} = 8.2044 \text{ m/s} \approx 8.2 \text{ m/s}$

$\theta = \tan^{-1} \left(\frac{3.9856}{7.1713} \right) = 24.064^\circ \approx 24^\circ$

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

Figure 1.1: A sample answer for vector question

1.3.3 Another question type

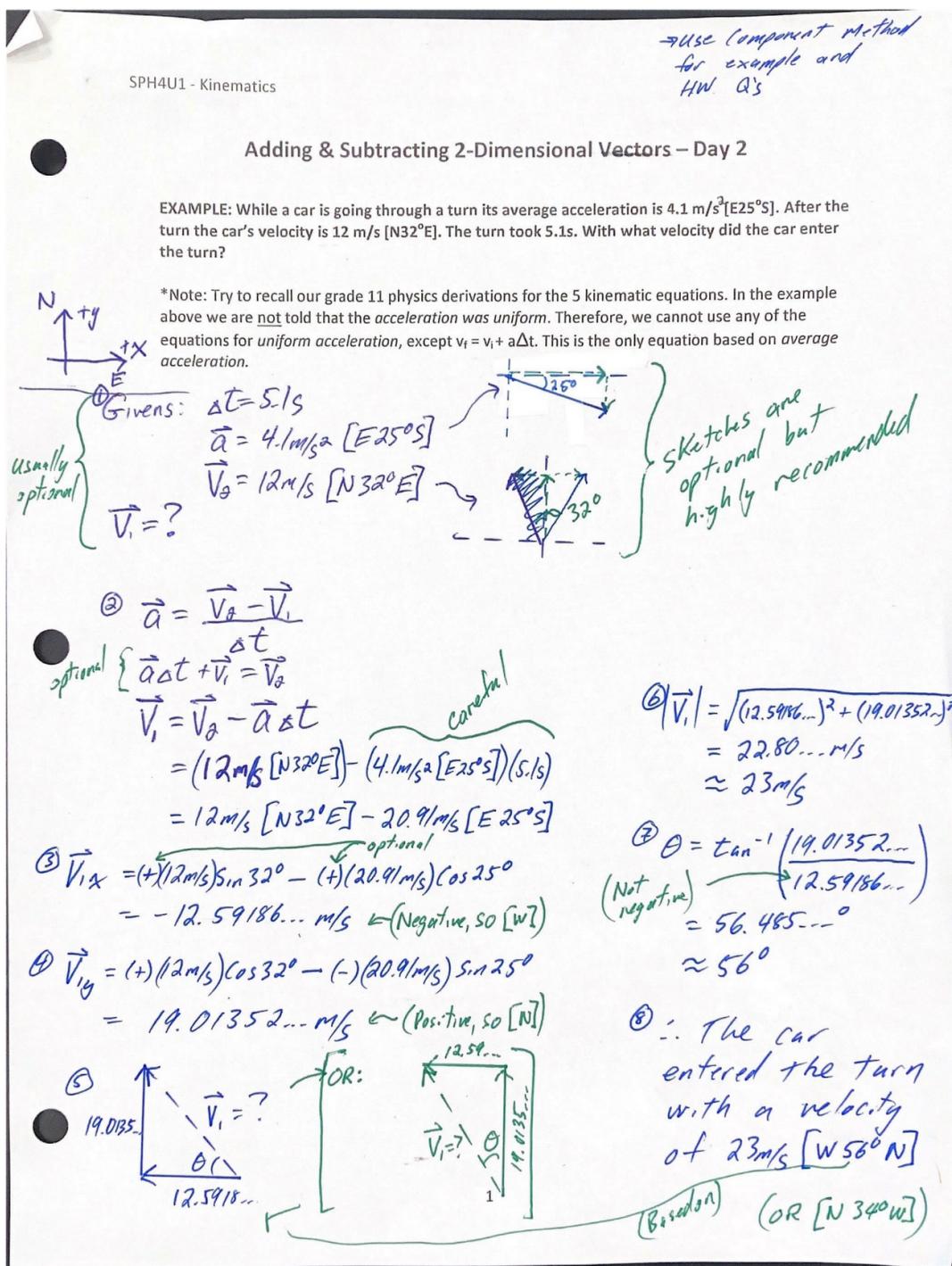


Figure 1.2: Remainder, multiply first

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

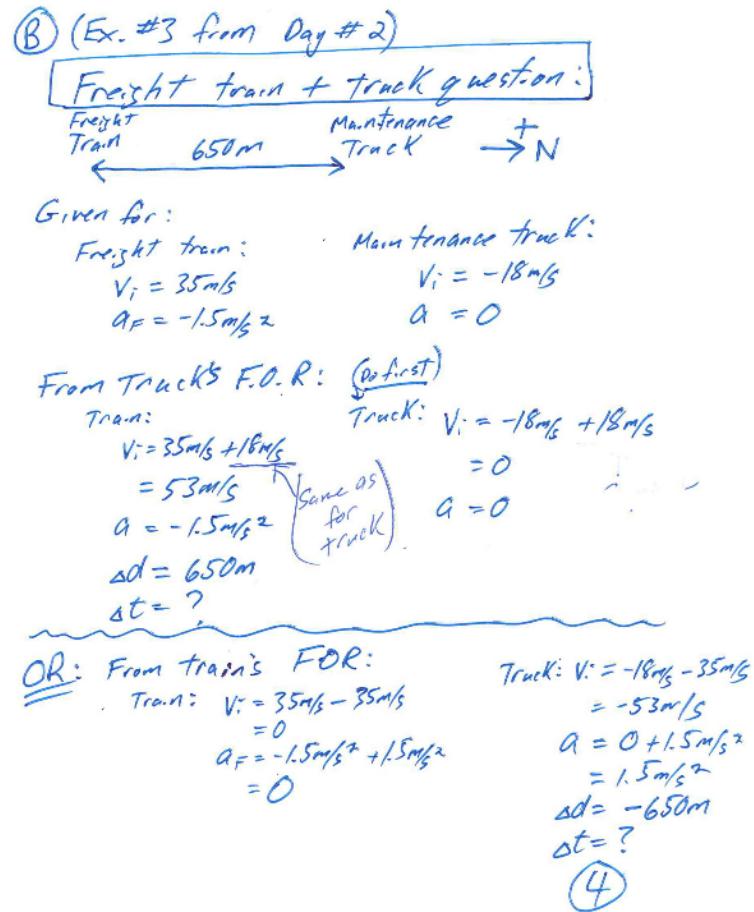


Figure 1.3: You should always write it

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:

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

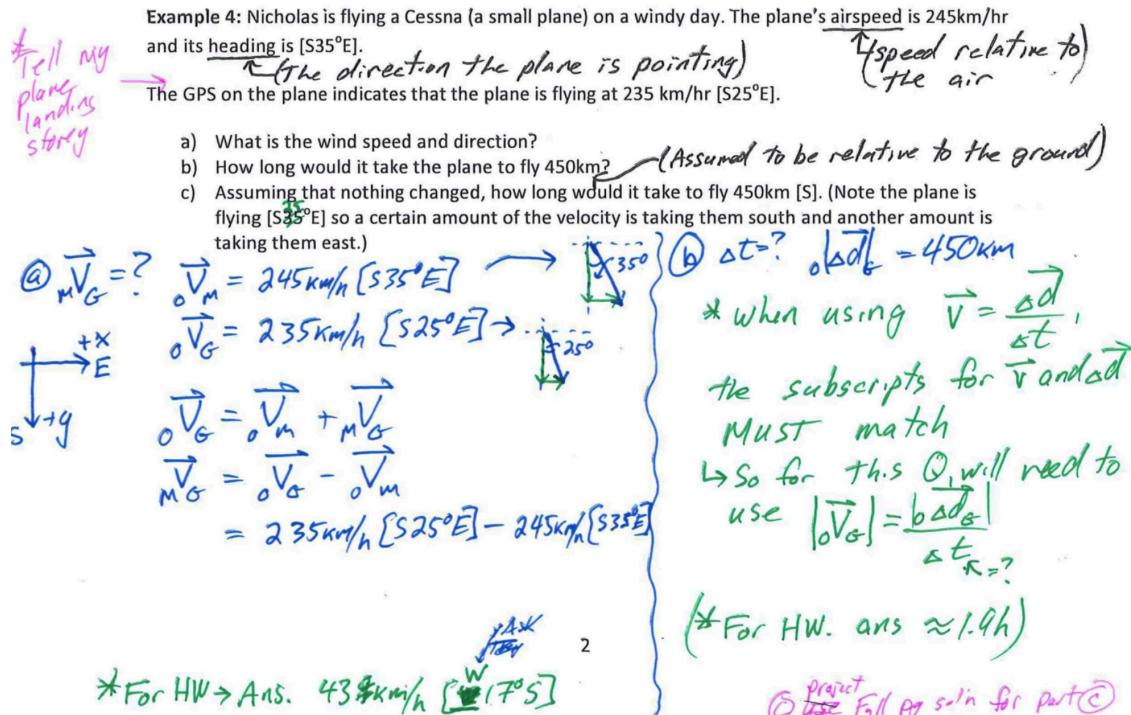


Figure 1.4: An example question

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!

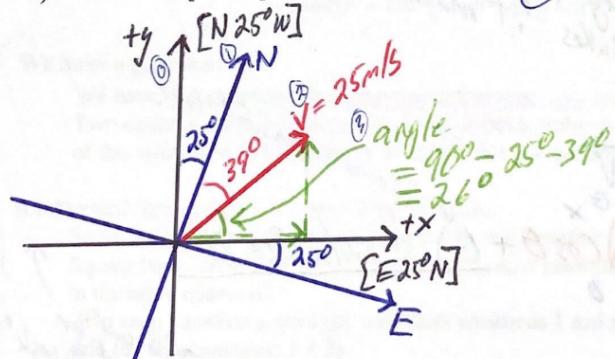
Steps in resolving vectors using rotated direction conventions:

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.

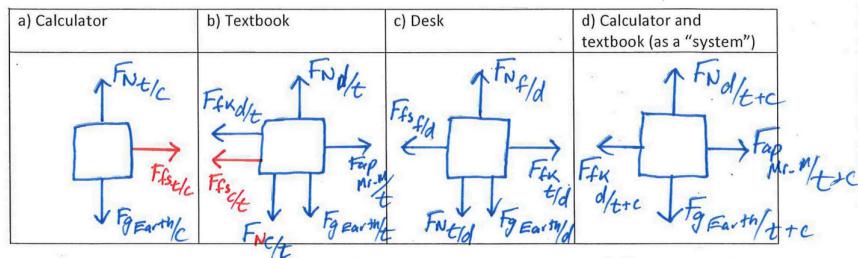


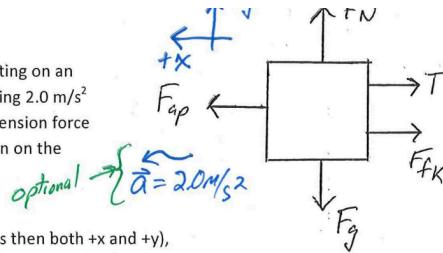
Figure 1.6: An example Free Body Diagram

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:

1.8 Review of Projectile Motion

1.8.1 basic

A simple projectile is an object that has a single, *non-uniform* acting on it. This single force must be a *non-contact* force between objects without the two objects being contact. Ex. Gravity forces, magnetic forces, electric forces

There are some kind of simple questions:

1. An object dropped
2. A soccer ball is kicked
3. A bullet is fired from a gun
4. An electron is moving through a uniform electrical field (Gravity is negligible)

Remainder: The object only accelerate in the direction of the net force. In any direction perpendicular to net force, the object main a constant velocity.

Some important points to remember:

- At maximum height all projectiles have a **vertical** velocity equal to **zero**
- When an object starts and ends at the same vertical location, the $\vec{\Delta d}_y = 0$
- When an object is dropped or launched horizontally, then $v_{y1} \vec{=} 0$

1.8.2 Special formula

$$R = \frac{v_i^2 * \sin 2\theta}{g} \quad (1.3)$$

R is the range of the projectile (Horizontal distance in m)

v_i is the launch speed of the projectile in (m/s)

θ is the launch angle of the projectile

g is acceleration due to gravity

The formula 1.3 can only be used if the project **starts and ends at the same vertical location**

1.8.3 An example question

Reminder, you should always label your direction conventions

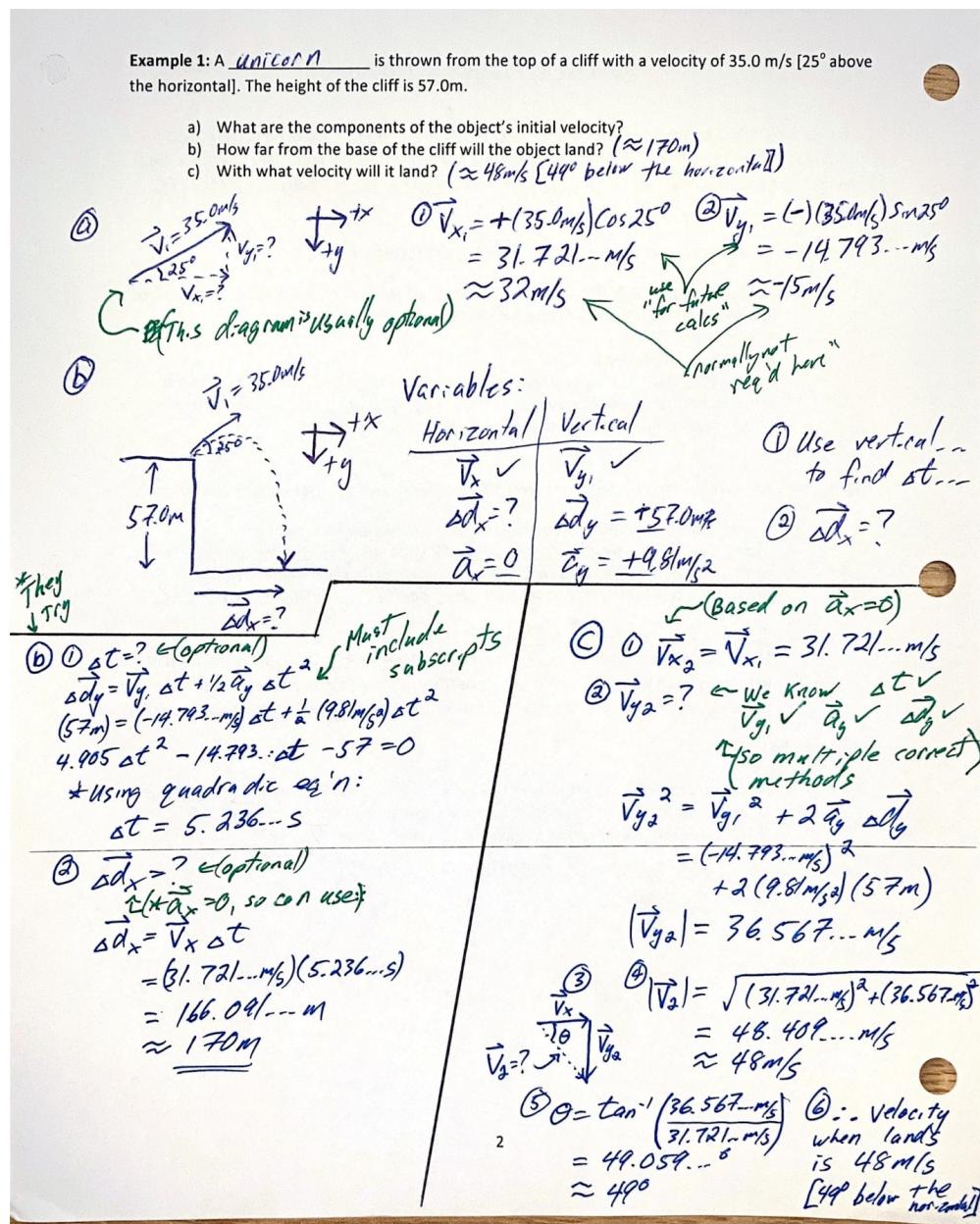


Figure 1.8:

1.9 Friction

In high school we deal with two types of friction: static and Kinetic

1.9.1 Kinetic Friction

Used when the two surfaces that are in contact are *slides relative to each other*.

$$F_{fk} = \mu_{fk} * F_n \quad (1.4)$$

Kinetic friction on an object can make an object slow down or speed up

1.9.2 Static Friction

Used when the two surfaces are Not Sliding relative to each other

$$F_{fs,max} = \mu_{fs} * F_n \quad (1.5)$$

1.9.3 Remainder

Don't forget to mention to prove $F_N = F_g$

Example: A 3.5 kg textbook is on a desk. The coefficient of static friction between the surface of the desk and the textbook is 0.41, and the coefficient of kinetic friction is 0.29.

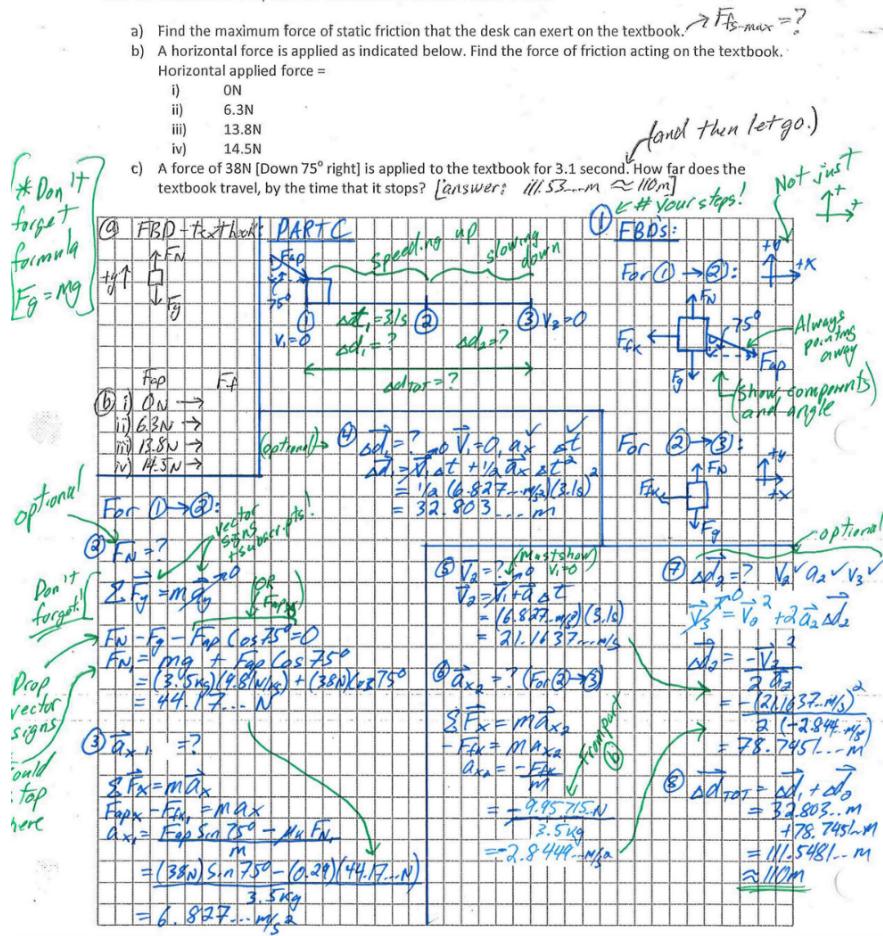


Figure 1.9:

1.10 Tension, compression and Pulleys

Internal Forces are Netwon's third Law pair of forces that act inside of an object or a system of objects that are in contact with each other.

According to the Netwon's third law, when we analyze the system, the sum of the forces equals 0. Thus, these forces will have no impact on the net force acting on the system and will have **no effect on the system's acceleration**

1.10.1 Tention: T

If one object is pulling the other object then you are dealing with **Tension**.

1.10.2 Compression: C

If one object is pushing the other object then you are dealing with **Compression**

Here is an example question

~~Do not solve pulley Q's as a "system"~~
SPH4U Physics - Dynamics

Example 4 ("Atwood Machine"): Mass 1 is 6.0 kg and mass 2 is 10.0 kg.

- Draw a FBD for each object MUST have separate direction conventions!
- Determine the acceleration of the system
- Determine the tension in the string.

④ FBD- m_1 : $FBD-m_2$

⑤ $\sum \vec{F}_1 = m_1 \vec{a}$ Don't need subscripts, keep signs
 $T - F_{g1} = m_1 a$ optional, leave vector sign on a
 $T - m_1 g = m_1 a$ Eq'n ①
optional: Sub in #3

⑥ $\sum \vec{F}_2 = m_2 \vec{a}$
 $F_{g2} - T = m_2 a$
 $m_2 g - T = m_2 a$ Eq'n ②
must include

⑦ $Eq'n ① + ②$:
 $m_2 g - m_1 g = (m_1 + m_2) a$
 $a = \frac{m_2 g - m_1 g}{m_1 + m_2}$ optional: factor out 'g'
 $= \frac{(10.0 \text{kg})(9.8 \text{m/s}^2) - (6.0 \text{kg})(9.8 \text{m/s}^2)}{10.0 \text{kg} + 6.0 \text{kg}}$
 $= 2.4525 \text{m/s}^2$ Don't forget directions!
(2nd)

To find 'T' sub
 \vec{a} value back into Eq'n ① OR Eq'n ②
 \rightarrow Sub \vec{a} into eq'n ①:
 $T - m_1 g = m_1 a$
 $T = m_1 (a + g)$
 $= (6.0 \text{kg})(2.4525 \text{m/s}^2 + 9.8 \text{m/s}^2)$
 $= 73.575 \text{N}$
 $\approx 74 \text{N}$
No direction required

Figure 1.10: Pulley question example

1.11 Inclined plane with Friction

To deal with inclined planes with friction, you need to determine the direction that the system will likely to accelerate.

Think of this as **tug of war** between these 2 forces,. Whichever force has a greater magnitude will be the direction that the system will likely to **accelerate**

1.11.1 How to determine the direction that the system will likely to accelerate

Look at the **forces** acting on the system. (Active forces are forces that are *trying to make the system move*) **Do not include internal forces**

Along the potential line of the system's acceleration:

- Find the sum of the active forces, which are in one Dimension
- Find the sum of the active forces which are acting in the opposite direction

Compare the magnitude of these two force sums, and whichever direction has the larger magnitude of active forces is the directions that system is likely to accelerate

1.11.2 Example template

Active forces[label directions]

Calculate for it

Process...

Active forces[Label directions]

Calculate for it

∴ the system will more likely to move in which direction. The friction will move ...