SKJ Education

LC HL PHYSICS

FOUNDATION PROGRAM: WEEK 1

INTRODUCTION TO PHYSICS

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LC HL PHYSICS – FOUNDATION PROGRAM

Week 1: Introduction to Physics

Learning Objectives

- **1.1:** To recall physical quantities from JC Science and their SI units.
- **1.2:** To explain the difference between fundamental and derived units.
- **1.3:** To use scientific notation and prefixes accurately.
- **1.4:** To understand of the nature of scalar and vector quantities.
- **1.5:** To use key formulae in physics, convert units and correct significant figures and units.

Key Terms - Week 1

- **Physics:** The scientific study of matter, energy, and the interactions between them.
- **Physical Quantity:** A property of a material or system that can be quantified by measurement (e.g., mass, length, time).
- **SI Units (Système International):** The internationally agreed standard system of units for scientific measurement.
- **Fundamental Units:** The seven base SI units from which *all others are derived* (metre (m), kilogram (kg), second (s), ampere (A), kelvin (K), mole (mol), candela (cd)).
- **Derived Units:** Units that are combinations of fundamental units (e.g., Newton $(N) = kg \times m \times s^{-2}$, Joule $(J) = kg \times m^2 \times s^{-2}$).
- **Scientific Notation:** A method of expressing numbers as a value between 1 and 10 multiplied by a power of 10 (e.g., 602,000,000,000,000,000,000,000 = 6.02×10^{23}).
- **Prefix:** A symbol added to a unit to scale it by a power of 10 (e.g., kilo (k) = 10^3, milli (m) = 10^{-3}, micro (μ) = 10^{-6}).
- **Scalar Quantity:** A physical quantity that has **magnitude only** (e.g., mass, speed, energy, time).
- **Vector Quantity:** A physical quantity that has **both magnitude and direction** (e.g., displacement, velocity, force, acceleration).
- **Significant Figures:** The digits in a measurement that are known with certainty plus the first uncertain digit. They indicate the **precision of the measurement**.

Weekly *Challenge*: As you work through this week's material, try to **identify at least 3 examples of physics principles** at work in your ***daily life*** (video games, sports, cooking, etc.). Share your findings in our Google Classroom!

WEEK 1 STUDY PLAN

Day	Activities & Time Commitment	✓	Rating (1-10)
Monday	- Review Learning Objectives (5 min) - Rank your current ability (5 min) - Review Key Terms (10 min) - Complete Exercise A1 (15 min) *Focus: PREPARATION*		
Tuesday	- Complete Exercises A2 & A3 (60 min) - 1-hour online lesson (60 min) *Focus: QUESTIONING*		
Wednesday	- Reflect on content so far (what has been challenging?) (10 min) - Plan remaining study sessions (10 min) *Focus: PROCESSING*		
Thursday	- Complete Exercise B (50 min) *Focus: EXPERIMENTAL THINKING*		
Friday	- Complete Exercise C (40 min) *Focus: ERROR ANALYSIS*		
Saturday	- Complete Exam Question Assessment (D) (60 min) *Focus: EXECUTION*		
Sunday	- Correct assessment (30 min) - Complete self-reflection (15 min) - Plan next week (15 min) *Focus: REFLECTION & RECHARGING*		

Study Tips for Success

- **Active Recall:** After studying, close your notes and write down **everything you remember**. Force your brain to grow.
- **Spaced Repetition:** Review concepts **multiple times** over several days.
- **Physics in Action:** Look for **real-world examples** of the concepts you're learning.
- **Ask Questions:** Don't hesitate to ask for help when concepts are unclear. Reach out via *Google Classroom* or email; *steven@skjeducation.com*.
- **Celebrate Progress:** **Acknowledge your improvements**, no matter how small.

A1. Proficiency Drills

Learning Focus: Foundational concepts of **scalars vs. vectors**, **unit** conversions, and basic physics **definitions**.

Part 1: Scalars vs. Vectors - What's the Difference?

Key Concepts

Scalar Quantities: Have **magnitude** (size) only. Just a **number** and a **unit**.
Examples: Time (5 ms), Mass (65 kg), Temperature (20 °C), Energy (100 kJ).
Vector Quantities: Have **both magnitude and direction**. This is crucial!
Examples: Force (20 N downwards), Velocity (10 m/s East), Displacement (5 km North-West).
Memory Tip: You can't have a negative scalar (e.g., -5 kg of mass is nonsense), but you can have a **negative vector**. The negative sign indicates **direction opposite** to the one you called positive.

Task #1: Classify these quantities by completing the table below.

Physical Quantity	**Scalar or Vector**	**Reasoning**	**Unit**
Speed			
Displacement			
Distance			
Acceleration			
Temperature			
Energy			
Momentum			

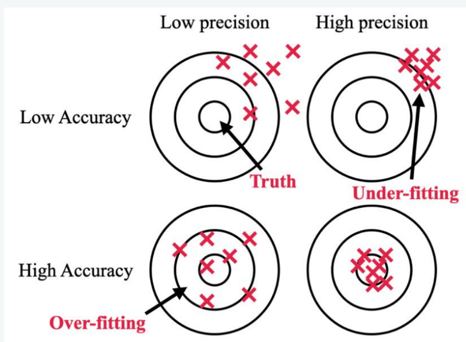
Part 2: Units & Prefixes - The Ruler of the Universe

Essential Knowledge

Physics is all about **accuracy and precision**. We use **SI Units** (*Système International*) to ensure **consistency**. Getting units right is 50% of the battle!

Base Units You MUST Know:

- **Length:** metre (m)
- **Mass:** kilogram (kg)
- **Time:** second (s)
- **Electric Current:** ampere (A)
- **Temperature:** kelvin (K)



Prefix	Symbol	Multiplier	Example
giga-	G	$\times 10^9$	GHz (Gigahertz)
mega-	M	$\times 10^6$	MW (Megawatt)
kilo-	k	$\times 10^3$	km (kilometre)
centi-	c	$\times 10^{-2}$	cm (centimetre)
milli-	m	$\times 10^{-3}$	mm (millimetre)
micro-	μ	$\times 10^{-6}$	μm (micrometre)
nano-	n	$\times 10^{-9}$	nm (nanometre)

Task #2: Convert these units. Show your work!

1. 5.2 cm = ____________________ m
2. 4 GHz = ____________________ Hz
3. 0.08 A = ____________________ mA
4. 250 mL = ____________________ L
5. 3.6 km/h = ____________________ m/s
6. 1000 kg/m^3 = ____________________ g/cm^3
7. 2.5 hours = ____________________ seconds
8. 5000 J = ____________________ kJ
9. 0.05 m^2 = ____________________ cm^2
10. 120 km = ____________________ miles (use 1 mile = 1.6 km)

Part 3: Key Definitions - Speak Like a Physicist

Physics Vocabulary

- **Velocity:** Speed in a given direction. (Vector)
- **Displacement:** Distance in a given direction. (Vector)
- **Acceleration:** The rate of change of velocity. (Vector) It's not just speeding up! Slowing down (i.e., deceleration) is also *negative* acceleration.
- **Force:** Anything that causes an object to accelerate. (Vector)
- **Energy:** The ability to do work. (Scalar)

Task #3: A car drives 5.00 km East, turns around, then drives 3.00 km West. The trip takes 0.200 hours.

Journey Analysis

Question	Your Answer
a) What is the total **distance** travelled?	[ ] km
b) What is its final **displacement**?	[ ] km [ ]
c) What is its average **speed**?	[ ] km/h
d) What is its average **velocity**?	[ ] km/h [ ]

Answers:

- **Task #1:** 1. S, 2. S, 3. V, 4. S, 5. V
- **Task #2:**
  1. 0.052 m
  2. 4×10^9 Hz
  3. 80 mA
  4. 0.250 L
  5. 1.0 m/s
  6. 1.000 g/cm^3
  7. 9.0×10^3 s
  8. 5.000 kJ
  9. 5×10^2 cm^2
  10. 75.0 miles
- **Task #3:** a) 8.00 km, b) 2.00 km East, c) 40.0 km/h, d) 10.0 km/h East

Task #4: Challenge Questions

Attempt as many questions as quickly as possible in time left in your study session. Pay close attention to the **significant figures** and **units** in your answer.

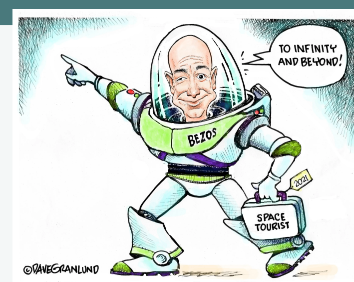
1. A runner ran around a circular track of radius 0.159 km at a constant speed. Calculate the distance of one lap in metres.
2. The runner took 5.00 minutes to run a lap, calculate her (average) speed in metres per second and her average velocity.
3. Mario is exactly 32 pixels tall. By taking Mario's height "in real-life" (if he were a real person) to be exactly 160 cm, convert 1.00 m into pixels.
4. Rachel ran 3.0 km North and then turned and ran 4.0 km East. In total her journey took 30.0 minutes. Calculate her average velocity.
5. Americans use a unit called mpg (miles per gallon) for their cars. That is, a car with an mpg of 25.4 will travel 25.4 miles on 1 gallon of fuel. In Europe, we use l/100 km (the number of liters of fuel needed to travel exactly 100 km). Convert 25.4 from the American unit to the European unit and round your answer to the nearest whole number. One American gallon is equal to approximately 3.8 litres. One mile is equal to approximately 1.6 kilometers.
6. A 330 mL Bulmer's Apple Cider is marketed as 0.0% alcohol. As a physics student, you know that this does not mean it is exactly 0% alcohol, i.e, it is not guaranteed to be completely free of alcohol. Calculate the limit of alcohol allowed in this bottle so that it does not violate the advertised claim. Give your answer in mm^3 and remember that 1 m^3 is exactly 1 000 litres.
7. Clarence, Roger, and Viktor are flying a plane with an average velocity vector of 905 km h^{-1} exactly North-East. They travelled North for 1.00 hour and then travelled East for 1.00 hour at a constant speed. Roger asks Viktor for. Calculate their average speed. Roger thought it was 905 km h^{-1}, why is this not the average speed?

A2. Worked Example & Questions

Learning Focus: Applying vector concepts to **real-world problems** and developing **problem-solving strategies**.

Scenario

A drone delivers a package: it travels 1200 m North, then 500 m West.
Total flight time: 85 seconds.
Question: Calculate its **average speed** and **average velocity**.



Solution Framework:

1. **Decode & Define:** "Speed is scalar (distance/time). Velocity is vector (displacement/time). Displacement requires **vector addition**."
2. **Plan:** $c = \frac{d}{t}$, $v = \frac{s}{t}$ (where c is speed and s is displacement). Pythagorean theorem needed.
3. **Execute:**
   - $d = 1200 + 500 = 1700$ m
   - $s = \sqrt{1200^2 + 500^2} = 1300$ m (Direction: 22.6° W of N)
   - $c = \frac{1700}{85} = 20$ m/s
   - $v = \frac{1300}{85} \approx 15.3$ m/s at 22.6° W of N
4. **Evaluate:** "The magnitude of velocity (15.3 m/s) is **less than** speed (20 m/s). This is a **necessary outcome** of the path **not being a straight line**. The answer includes direction, confirming its vector nature."

Test Yourself

1. **(Knowledge)** Define the term *vector quantity*. Provide one example not mentioned above.
2. **(Application)** The wavelength of a green light is 550 nanometres (nm). Express this in metres (m), using scientific notation.
3. **(Analysis)** A car travels 5 km East and then 3 km North.
   a) Calculate the **total distance** travelled.
   b) Calculate the magnitude and direction of the **total displacement**.
   c) Explain, with reference to your calculations, the fundamental difference **between distance and displacement**.
4. **(Synthesis)** A student claims: "If I run a full 400m lap on a track and finish where I started, my average velocity is zero, but my average speed is not." Is this statement valid? **Justify your reasoning**.

A3. Thinking Like a Physicist – Challenging Assumptions

Learning Focus: Developing **critical thinking skills** and applying physics concepts to **novel situations**.

1. **Where the ?%#& are you going:** Force is a vector. *But why is direction so crucial?* Imagine pushing a door near the handle vs. pushing it right next to the hinges. The magnitude of force is the same, but the effect is drastically different. Can you describe another real-world example where ignoring the vector nature of a quantity leads to a complete failure to describe the situation?

   Task 1

   Sketch two diagrams of the same object. In one, show a force vector causing it to **accelerate**. In the other, show a force vector of equal magnitude but opposite direction causing it to **decelerate**. ***Annotate your diagrams*** with as much detail as you can.

2. **Double Standards:** Our unit of time is the second. *But this is a human convention.* What if we defined a new fundamental unit of time, the "tick," where **1 tick = 2 seconds**? What would happen to the value of universal constants, like the speed of light? How would this change the form of fundamental equations like F = ma or $E = mc^2$? Think about what was mentioned this week, how it would be affected.

   Task 2

   Brainstorm the pros and cons of defining units based on universal constants (as we do now) vs. **tangible human-scale phenomena** (e.g., "1 beat" = average human heart rate at rest). *What's the weirdest unit you can come up with?*

3. **Let's have a pointless debate:** Imagine you and your friends are playing darts, trying to hit the bull's eye. Your friend hits the triple 16 three times. One of your friends says "Wow, that was *so **accurate***". Another says "Wow, that was *so **precise***." They argue about who is right for the next 3 hours. Who was correct?

   Task 3

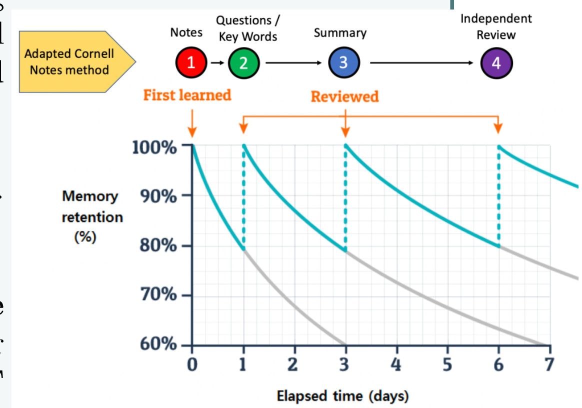
   Come up with three real-life scenarios demonstrating where confusing **accuracy** with **precision**, or vice versa, could have bad consequences.

B. Memory Retention & Learning Experiment

Learning Focus: Understanding **how memory works** and **applying the scientific method** to understand memory retention.

The Forgetting Curve Experiment

In week 1, we are not reviewing any formal LC Physics experiments. Instead, we will conduct an interesting experiment of our own. This will explore how well your brain can remember key physics definitions and formulae over time.



Watch the following video, then attempt the quiz below. [**CLICK HERE FOR VIDEO**]

Do not look at the quiz before starting the YouTube video. DO NOT CHECK your score. For the **next 5 days**, attempt this quiz, but **DO NOT check your score**. **Do not do *any more physics*** during this experiment. Fill in your scores after finishing the experiment below.

Day	**Time to complete quiz (minutes and seconds)**	**Score (%)**
Day 0 (Start)		
Day 1		
Day 2		
Day 3		
Day 4		
Day 5		

This experiment explores something very interesting about our brains, known as the forgetting curve. Check out this video: [**CLICK HERE FOR VIDEO**]

Quiz: 4 parts - Take quiz via Google Classroom

Quiz Components

Definitions: 4-5 important physics definitions
Formulae: 4-5 important physics formulae
Random: 1-2 completely random questions about the video
Calculations: 1-2 scalar/vector calculations

C. Calculation Error Analysis: Forensic Physics

Learning Focus: Developing **critical analysis skills** by identifying and correcting common physics **misconceptions** and **calculation errors**.

Analysis Tips

1. **Locate the Error:** Is there anything wrong with this statement/calculation?
2. **Diagnose the Error:** Is this a **Procedural Error** (miscalculation), a **Conceptual Error** (misunderstanding), or an **Omission Error** (incomplete answer)?
3. **Explain the Misconception:** What does the answer reveal about their understanding of how to *communicate* this idea?
4. **Correct the Solution:** Provide the complete, textbook-quality answer.
5. **Metacognitive Reflection:** "This error is subtle because the number is right. What is one personal strategy I can adopt to ensure I never overlook a crucial detail like this under exam pressure? (e.g., always underlining vector directions in the question if you often forget about directions)."

Forensic Physics Task

Your job isn't to find the right answer, but to find the **flaw in the thinking**. Explain ***why*** each statement/calculation is wrong and **correct them**.

Error Analysis Exercises

Statement: "I just ran 100 metres in 12 seconds. My velocity was 8.33 m/s."

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Statement: "The weight of the object is 50 kg."

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Statement: "The car was travelling at a constant speed of 60 km/h around a sharp bend. Since its speed wasn't changing, its acceleration was zero."

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Unit Conversion: Convert 25 cm² into m².
Incorrect Calculation: $25\text{cm}^2 = 25 \times 10^{-2}\text{m}^2 = 0.25\text{m}^2$

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Significant Figures: A rectangle is 12.5 m long and 3.4 m wide. Calculate its area.
Incorrect Calculation: Area $= 12.5 \times 3.4 = 42.5\text{m}^2$

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Scientific Notation: Calculate $(3.0 \times 10^8) \times (2.0 \times 10^{-3})$.
Incorrect Calculation: $(3.0 \times 10^8) \times (2.0 \times 10^{-3}) = 6.0 \times 10^{-24}$

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Vector Magnitude: A person walks 3 km East and then 4 km North. Find the displacement.
Incorrect Calculation: Displacement $= 3\text{km} + 4\text{km} = 7\text{km}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Formula Application: Calculate the speed of a car that travels 100 m in 5 s.
Incorrect Calculation: Speed $= \frac{100\text{m}}{5\text{s}} = 20\text{km/h}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Significant Figures (Subtraction): Subtract 10.45 s from 11.5 s.
Incorrect Calculation: $11.5 - 10.45 = 1.05 \rightarrow 1.1\text{s}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Scientific Notation (Division): Calculate $(8.0 \times 10^4)/(2.0 \times 10^2)$.
Incorrect Calculation: $(8.0 \times 10^4)/(2.0 \times 10^2) = 2.0 \times 10^4$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Essential Physics Formulas required for Q12-15

- Newton's Second Law: $F_{\text{net}} = m \times a$
- Conservation of Momentum: $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$
- Law of Universal Gravitation: $F = \frac{G m_1 m_2}{r^2}$
- Wave Equation: $v = f \times \lambda$
- Drag Force: $F_{\text{drag}} = \frac{1}{2} C A \rho v^2$
- Ideal Gas Law: $PV = nRT$
- Ohm's Law: $V = I \times R$
- Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Density: A rock has a mass of 1.5 kg and a volume of 500 cm^3. Calculate density in kg/m^3.
Incorrect Calculation: Density $= \frac{1.5\text{kg}}{500\text{cm}^3} = 0.003\text{kg/cm}^3$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Conservation of Momentum: A 5 kg object moving at 3 m/s to the right collides head-on and sticks to a stationary 2 kg object. Calculate their velocity after the collision.
Incorrect Calculation: $(5\text{kg} \times 3\text{m/s}) + (2\text{kg} \times 0\text{m/s}) = (5\text{kg} + 2\text{kg}) \times v$
$15 = 7v \rightarrow v \approx 2.14\text{m/s}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Drag Force: Calculate the drag force acting on a ball (cross-sectional area A = 0.0200 m^2) moving at 12.0 m/s through air (density $\rho = 1.2 kg/m^3$). The drag coefficient is 0.500.
Incorrect Calculation: $F_{\text{drag}} = \frac{1}{2} \times 0.02 \times 1.2 \times (12)^2 = (0.5)(0.02)(1.2)(144) = 1.728\text{N}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Ideal Gas Law: Find the pressure exerted by 0.500 moles of an ideal gas at a temperature of 27.0°C in a 2.00000 m³ container (R = 8.314 J/mol · K).
Incorrect Calculation: $P \times 2 = 0.5 \times 8.31 \times 27$
$P \approx \frac{112.185}{2} \approx 56.1\text{Pa}$

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Combined Heat Calculation: Calculate the total energy required to heat 2.00 kg of ice at -10.0°C until it becomes water at 20.0°C. ($c_{\text{ice}} = 2100\text{J/kg} \cdot \text{K}$, $c_{\text{water}} = 4200\text{J/kg} \cdot \text{K}$, $L_{\text{fusion}} = 3.34 \times 10^5\text{J/kg}$)
Incorrect Calculation:

$$\begin{aligned} Q_{\text{total}} &= (2\text{kg} \times 2100\text{J/kg} \cdot \text{K} \times 30\text{K}) \\ &+ (2\text{kg} \times 3.34 \times 10^5\text{J/kg}) \\ &+ (2\text{kg} \times 4200\text{J/kg} \cdot \text{K} \times 20\text{K}) \\ Q_{\text{total}} &= 126,000 + 668,000 + 168,000 = 962,000\text{J} \end{aligned}$$

Flawed Thinking	Correct Approach
Error Analysis:	**Correction:**

Reflection Time
You have seen some of the common errors and misconceptions that come up in this topic. Here are some important questions to **ask yourself**:

- **What surprised you? *Why*?**
- **What did you find difficult to grasp? *Why*?**
- **Did you recognise any of *your own mistakes* during the exercise?**
- **What is the most important thing *you have learned* this week?**

D. Weekend Assessment – Past Exam Questions

Learning Focus: Applying all week's learning to authentic exam questions under timed conditions.

Assessment Instructions

These are all from past Q5's (definition/short questions). Answer as many as you can in 60 minutes. The answers are provided in the right column in white font - try to solve them first before checking!

Past Exam Questions

Question	Answer
1. An airplane starts from rest on a runway and reaches a velocity of 290 km $hour^{-1}$ in 33 s. Calculate the acceleration of the airplane in terms of g, the acceleration due to gravity.	
2. Explain the term *solar constant*.	
3. Uranus has a mass of 8.7×10^{25} kg and a radius of 25 400 km. Calculate the acceleration due to gravity on Uranus.	
4. Draw a diagram to show how a ray of light can be turned through 90° using a 45°-90°-45° prism.	
5. What is meant by potential difference?	
6. Calculate the power output of a resistor of resistance 3.4 Ω when a potential difference of 55 V is maintained across it.	
7. A proton experiences a force of 4.59×10^{-16} N when it moves with velocity v perpendicular to a magnetic field of flux density 18.5 mT. Calculate v.	
8. An athlete weighing 850 N runs up a stairs in 6 seconds. If the vertical height of the stairs is 2.5 m, calculate the average power generated by the athlete.	

Question	Answer
9. State Archimedes' principle.	
10. Calculate the length of a pendulum that has a period of one second.	
11. A solid copper cube of side 5 cm rests on a horizontal table. Find the pressure exerted by the cube on the table. density of copper $= 8960$ kg m^{-3}	
12. What is meant by the U-value of a material?	
13. Iron has a density of 7.87 g cm^{-3}. An iron sphere has a mass of 500 g. Calculate the radius of the sphere in cm.	
14. Calculate how many electronvolts are in a kilowatt-hour.	
15. Draw a labelled diagram to show the forces acting on a piece of wood floating at rest.	
16. Define acceleration. Hence, derive the expression $v = u + at$.	
17. A ball is kicked with an initial velocity of 20 m s^{-1} at an angle of 50° to the horizontal. Calculate the horizontal distance it travels in 1.2 seconds.	

Self-Assessment

After completing the assessment:

- Grade your work honestly
- Identify areas needing improvement
- Scan and submit via Google Classroom
- Reflect on your performance in your weekly reflection

Another excellent week of work completed - ***well done!*** You are another step closer to *smashing your exams*, and another week closer to your summer holdiays!

Weekly Reflection Zone

What worked well this week?

What challenges did I face?

What surprised me the most this week?

Key physics concepts I want to review:

Goals for next week: