



SKJ Education

# LC HL PHYSICS FOUNDATION

PROGRAM: WEEK 3

# WORK, ENERGY & POWER

Steven James

[steven@skjeducation.com](mailto:steven@skjeducation.com)

[www.skjeducation.com](http://www.skjeducation.com)

## LC HL PHYSICS – FOUNDATION PROGRAM

### *Week 3: Work, Energy & Power*

#### Learning Objectives

- **3.1:** To define and calculate work done, kinetic energy, and potential energy.
- **3.2:** To apply the Principle of Conservation of Energy to solve problems involving energy transformations.
- **3.3:** To define power and perform calculations involving force, velocity, work and power.
- **3.4:** To define momentum and apply the Principle of Conservation of Momentum to collisions.

#### Key Terms - Week 3

- **Work Done:** The product of the force applied to an object and the displacement of the object in the direction of the force ( $W = F \times d \times \cos \theta$ ).
- **Kinetic Energy:** The energy an object possesses due to its motion ( $\frac{1}{2}mv^2$ ).
- **Potential Energy:** The energy an object possesses due to its position or configuration (e.g., gravitational potential energy:  $mgh$ ).
- **Principle of Conservation of Energy:** The total energy of an isolated system remains constant over time; energy is neither created nor destroyed, only transformed from one form to another.
- **Power:** The rate at which work is done or energy is transferred ( $P = \frac{W}{t}$  or  $P = F \times v$ ).
- **Momentum:** The product of an object's mass and velocity ( $p = mv$ ).
- **Principle of Conservation of Momentum:** The total momentum of a closed system remains constant over time, provided no external forces act on the system.

**Weekly Challenge:** Investigate a real-world example of energy transformation, such as a roller coaster or a hydroelectric power plant. Analyse the different forms of energy involved and how they are transformed, and share your findings on Google Classroom.



## WEEK 2 STUDY PLAN

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

### 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.

## C. Calculation Error Analysis: Forensic Physics

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

### Analysis Protocol

1. **Locate the Error:** Pinpoint the specific step or statement that is incorrect.
2. **Diagnose the Error:** Classify the error type: **Procedural Error** (miscalculation, incorrect formula application), **Conceptual Error** (misunderstanding a definition or principle), or **Omission Error** (incomplete conditions or overlooked restrictions).
3. **Explain the Misconception:** Articulate the underlying flawed reasoning or missing knowledge demonstrated by the error.
4. **Correct the Solution:** Provide the complete, accurate, and step-by-step mathematical solution.
5. **Metacognitive Reflection:** "This error (e.g., misinterpreting discriminant conditions) is subtle because the algebra might seem correct initially. What is one personal strategy I can adopt to ensure I never overlook a crucial detail like this under exam pressure (e.g., always double-checking discriminant inequalities)?"

### 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

### Exercise 1: Work Done by an Angled Force

**Question:** A 25 N force pulls a sled 15 m across ice at 30° above the horizontal. Calculate the work done by the force.

*Incorrect Calculation:*  $W = Fd \sin \theta = 25 \times 15 \times \sin 30^\circ = 188 \text{ J}$ .

#### Flawed Thinking

**Error Analysis:**

#### Correct Approach

**Correction:**

**Exercise 2: Kinetic Energy Formula Error**

**Question:** Find the kinetic energy of a 1.5 kg cart moving at  $4.0 \text{ m s}^{-1}$ .

*Incorrect Calculation:*  $E_k = mv^2 = 1.5 \times 4^2 = 24 \text{ J}$ .

Flawed Thinking

**Error Analysis:**

Correct Approach

**Correction:**

**Exercise 3: Gravitational Potential Energy Sign**

**Question:** A 3.0 kg rock is lifted 2.5 m vertically. Take  $g = 9.8 \text{ m s}^{-2}$ . Compute the change in gravitational potential energy.

*Incorrect Calculation:*  $\Delta U = -mgh = -(3.0)(9.8)(2.5) = -73.5 \text{ J}$ .

Flawed Thinking

**Error Analysis:**

Correct Approach

**Correction:**

**Exercise 4: Conservation of Energy Down a Ramp**

**Question:** A 2.0 kg block starts from rest atop a frictionless 5.0 m high slope. Find its speed at the bottom.

*Incorrect Calculation:*  $mgh = \frac{1}{2}mv^2 \Rightarrow v^2 = 2gh = 2(9.8)(5) = 98 \Rightarrow v = 9.9 \text{ m s}^{-1}$ .

Flawed Thinking

**Error Analysis:**

Correct Approach

**Correction:**

**Exercise 5: Elastic Potential Energy in a Spring**

**Question:** A spring ( $k = 120 \text{ N m}^{-1}$ ) is compressed 0.08 m. Calculate the stored energy.

*Incorrect Calculation:*  $E = \frac{1}{2}kx = \frac{1}{2}(120)(0.08) = 4.8 \text{ J}$ .

Flawed Thinking

**Error Analysis:**

Correct Approach

**Correction:**

**Exercise 6: Power from Work and Time**

**Question:** A motor does 18 kJ of work in 45 s. Determine its output power.

*Incorrect Calculation:*  $P = \frac{W}{t} = \frac{18}{45} = 0.40 \text{ W}$ .

Flawed Thinking

**Error Analysis:**

Correct Approach

**Correction:**

**Exercise 7: Power from Force and Velocity**

**Question:** A car travels at constant  $25 \text{ m s}^{-1}$  while the engine provides a driving force of  $1.2 \times 10^3 \text{ N}$ . Calculate the mechanical power delivered.

*Incorrect Calculation:*  $P = \frac{F}{v} = \frac{1.2 \times 10^3}{25} = 48 \text{ W}$ .

Flawed Thinking

**Error Analysis:**

Correct Approach

**Correction:**



### Exercise 8: Momentum Misinterpretation

**Question:** A 0.20 kg ball moves at  $8.0 \text{ m s}^{-1}$ . What is its momentum?

*Incorrect Calculation:*  $p = \frac{1}{2}mv^2 = \frac{1}{2}(0.20)(8^2) = 6.4 \text{ kg m s}^{-1}$ .

#### Flawed Thinking

**Error Analysis:**

#### Correct Approach

**Correction:**

### Exercise 9: Inelastic Collision – Final Velocity

**Question:** A 3.0 kg cart moving  $5.0 \text{ m s}^{-1}$  collides and sticks to a stationary 2.0 kg cart. Find their common velocity after collision.

*Incorrect Calculation:*  $v = \frac{m_2 u_2}{m_1 + m_2} = \frac{2 \times 0}{5} = 0 \text{ m s}^{-1}$ .

#### Flawed Thinking

**Error Analysis:**

#### Correct Approach

**Correction:**

### Exercise 10: Explosion – Conservation of Momentum

**Question:** A stationary firework explodes into two pieces: 0.3 kg moving  $12 \text{ m s}^{-1}$  east and 0.7 kg moving  $4 \text{ m s}^{-1}$  west. Verify momentum conservation.

*Incorrect Statement:* Initial momentum is zero; final momentum =  $0.3(12) + 0.7(4) = 3.6 + 2.8 = 6.4 \text{ kg m s}^{-1}$ . Therefore momentum is not conserved.

#### Flawed Thinking

**Error Analysis:**

#### Correct Approach

**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?

### Bonus Exercise

If you have finished these exercises in under 40 minutes, go and **apply your error analysis skills to *your work*** from earlier in the week!

## D. Weekend Assessment – Past Exam Questions

**Learning Focus:** Applying learning to exam questions under timed conditions.  
**Think deeply about these questions.**

### Assessment Instructions

Answer as many questions as you can in 60 minutes - try to solve them alone first before checking your notes!

### Past Exam Questions

#### Question 1 (2015, Q12(a))

- State Newton's second law of motion.
- A downhill skier of mass 71 kg started from rest and travelled 400 m with a loss of elevation of 90 m. What is the principal energy conversion taking place?
- Ignoring friction, calculate her maximum velocity after 400 m.
- She stops in 0.8 s by ploughing into a snow drift. What force does she exert on the snow drift?
- What force does the snow drift exert on her?

#### Question 2 (2018, Q6(c))

- State the principle of conservation of energy.
- What is meant by the centre of gravity of a body?
- Ashton's centre of gravity when standing is 98 cm above the ground. During a vault, his horizontal speed drops from  $9.2 \text{ m s}^{-1}$  to  $1.1 \text{ m s}^{-1}$ . What is the maximum height above the ground to which he can raise his centre of gravity?
- Draw a diagram to show the forces acting on Ashton at his highest point.

#### Question 3 (2004, Q6)

- Define force.
- Define momentum.
- State Newton's second law of motion.
- Hence, establish the relationship: force = mass  $\times$  acceleration.
- A pendulum bob of mass 10 g is raised 20 cm and swings into a block of mass 8.0 g at rest. Calculate the velocity of the bob just before the collision.
- Calculate the velocity of the block immediately after the collision.
- If the block moves 2.0 m before stopping, what was the average horizontal force acting on it?



**Question 4 (2012, Q6)**

- (i) Calculate the acceleration due to gravity at 31 km above the Earth's surface.
- (ii) What was the downward force on Kittinger (total mass 180 kg) at this height?
- (iii) Estimate how far he fell during the first 13 seconds. State your assumptions.
- (iv) What was his average speed during the next 4 minutes 36 seconds?
- (v) How much greater was the force on an 8.5 m parachute than on a 1.8 m parachute?
- (vi) Calculate the upthrust when he reached constant velocity.

**Question 5 (2023, Q13)**

- (i) For Turlough Hill's upper reservoir (volume  $2.3 \times 10^6 \text{ m}^3$ , height 321 m):
  - (a) Calculate the mass of water.
  - (b) Calculate the potential energy stored.
  - (c) Calculate the maximum power if emptied in 24 hours.
- (ii) State the main energy conversion as water flows (a) down the pipe, (b) through the generator.
- (iii) Explain why energy storage is essential when moving to renewable sources.



### 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 holidays!

### 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: