GLEN TUTORIALS

Comprehensive Study Notes & Solutions Manual | Grade 9 IGCSE Physics

Subject: Physics (0625 / 0972) **Chapter 6:** Energy Stores & Transfers **Target:** IGCSE Board Exams

📌 CHAPTER KEY WORDS & DEFINITIONS

- **Principle of Conservation of Energy:** Energy cannot be created or destroyed, only transferred from one store to another. The total energy of an isolated system remains constant.
- **Chemical Potential Energy:** Energy stored in chemical bonds of substances (such as fuels, food, and batteries) released during chemical reactions.
- **Gravitational Potential Energy (GPE):** Energy stored in an object due to its vertical position/height in a gravitational field.
- **Kinetic Energy (KE):** Energy stored in a moving object due to its mass and velocity.
- **Nuclear Potential Energy:** Energy stored in the nucleus of an atom released during nuclear fission or fusion.
- **Efficiency:** The fraction or percentage of total input energy/power that is converted into useful output energy/power.
- **Sankey Diagram:** A scaled flow diagram where arrow width represents the relative amount of energy transferred at each step.

💡 KEY FORMULAS TO REMEMBER FOR EXAMS

- **Kinetic Energy:** $E_k = ½ m v^2$
- **Mass from KE:** $m = 2 E_k / v^2$
- **Change in GPE:** $\Delta E_p = m g \Delta h$
- **Mass from GPE:** $m = \Delta E_p / (g \Delta h)$
- **Efficiency (%):** *(Useful Energy Output / Total Energy Input) × 100*
- **Power Efficiency (%):** *(Useful Power Output / Total Power Input) × 100*

EXERCISE 6.1: ENERGY STORES & TRANSFERS

Topic Focus: Identifying Energy Stores, Energy Transfers, and Conservation Principles

Question 1 [Focus]

FOCUS

Question Statement: Sometimes, energy is being stored (chemical energy is an example). Sometimes, energy is being transferred from one object to another or from place to place. Complete the table. The first example has been done for you.

Description	Store of Energy
energy in a stretched spring/elastic	**elastic potential** *(Given)*
energy in the nucleus of a uranium atom	**nuclear potential energy** (or **nuclear energy**)
energy in diesel fuel	**chemical potential energy** (or **chemical energy**)
energy of a ball held above your head	**gravitational potential energy**
energy of a hot cup of coffee	**thermal energy** (or **internal energy**)

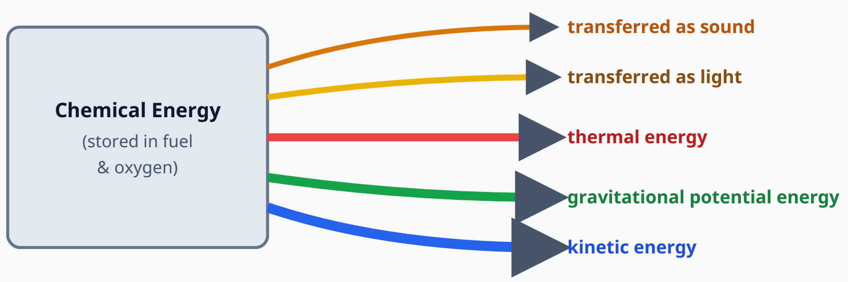
⚡ **EXAM TIP**

Always use the precise terminology expected by IGCSE examiners: state **'gravitational potential energy'** rather than just 'potential energy', and specify **'chemical potential energy'** or **'elastic potential energy'**.

Question 2 [Focus]

FOCUS

Question Statement: Figure 6.1 shows a rocket being launched into space, and the energy transfers that are involved. In the table, explain how you know that each of these energy changes is happening. The first one has been done for you.



Energy transfer: chemical energy to ...	How we can tell
sound	*The rocket launch is very noisy. (Given)*

Energy transfer: chemical energy to ...	How we can tell
light	**A bright flame** / **bright light** is visible from the rocket's engines during launch.
thermal energy	**The exhaust gases and rocket engines become extremely hot**, releasing heat into the atmosphere.
gravitational potential energy	**The rocket gains height/altitude** above the surface of the Earth.
kinetic energy	**The rocket accelerates/moves upward at high velocity**.

Question 3 [Practice]

PRACTICE

Question Statement: Explain how the energy flow diagram in Figure 6.1 shows that the principle of conservation of energy is obeyed in these energy changes.

Detailed Answer:

In a Sankey or energy flow diagram, the **width of each arrow** is directly proportional to the amount of energy being transferred.

The energy flow diagram demonstrates the **Principle of Conservation of Energy** because:

- The total width of the initial arrow representing **input chemical energy** is exactly equal to the **combined width of all five output arrows** (sound + light + thermal + gravitational potential + kinetic energy).
- This shows that no energy is created or destroyed during the launch; all chemical energy stored in the fuel is completely accounted for by the output energy stores and pathways:

$$\text{Total Chemical Energy Input} = \text{Sound} + \text{Light} + \text{Thermal} + \text{GPE} + \text{KE Output}$$

Question 4 [Practice]

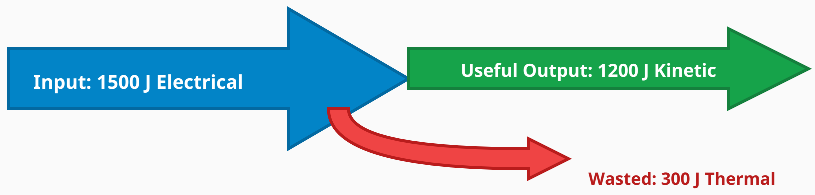
PRACTICE

Question Statement: A washing machine has a motor that turns the drum. In a particular washing machine, the motor is supplied with $1500\ J$ of energy each second. Of this, $1200\ J$ of energy is used to turn the drum. The rest is wasted as thermal energy. Draw an energy flow diagram for the washing machine.

Step-by-Step Calculation & Working:

- **Total Energy Input:** $1500\ J$ (Electrical energy supplied to motor per second)
- **Useful Energy Output:** $1200\ J$ (Kinetic energy to turn the drum)
- **Wasted Thermal Energy:** $1500\ J - 1200\ J = 300\ J$ (Heat generated by friction/resistance)

Energy Flow Diagram (Sankey Representation):



Question 5 [Practice]

PRACTICE

Question Statement: An energy flow diagram can be used to represent energy changes. Figure 6.2 shows the energy changes in a light bulb each second. A coal-fired power station is used to provide the electricity. On the diagram, in the correct place, write in the amount of light produced each second.

Given values from diagram (Figure 6.2): Chemical energy input = $12.0\ J$; Heat wasted = $8.4\ J$.

Calculation:

$$\text{Useful Light Energy} = \text{Total Chemical Energy Input} - \text{Wasted Heat Energy}$$
$$\text{Useful Light Energy} = 12.0\ \text{J} - 8.4\ \text{J} = \mathbf{3.6\ J}$$

Answer: The amount of light energy produced each second is **3.6 J** (written on the straight light arrow of the diagram).

Question 6 [Challenge]

CHALLENGE

Question Statement: A learner argues that a car running on petrol or diesel is more efficient in winter than in summer. Explain why the learner might say this.

Detailed Explanation:

- In an internal combustion engine, a significant portion of fuel energy is "wasted" as **thermal energy (heat)** in the engine block and exhaust.
- During **winter**, cold ambient temperatures require heating inside the car cabin. The car uses this waste engine heat to warm the interior (via the cabin heater/demister).
- Because heat that would otherwise be discarded into the surroundings is now serving a **useful purpose** (heating the passengers), the total proportion of fuel energy converted into useful output increases. Hence, the overall practical efficiency of the car system is higher in winter.

Question 7 (a & b) [Challenge]

CHALLENGE

Question Statement:

a) Draw a Sankey Diagram to show the following. A low-energy light bulb is 85% efficient and the wasted energy is thermal. It receives power from a National Grid that is 92% efficient. It is supplied by a power station that is 60% efficient. Assume all wasted energy is thermal. Show your diagram with an input energy of $100\ J$.

b) Calculate the overall efficiency of the system from generation to light bulb.

Step-by-Step Multi-Stage Energy Tracking (Input = 100 J):

1. **Stage 1: Power Station (60% efficient)**
   - Input Energy = $100\ J$
   - Useful Output to National Grid = $100\ J \times 0.60 = 60\ J$
   - Wasted Thermal Energy = $100\ J - 60\ J = 40\ J$
2. **Stage 2: National Grid (92% efficient)**
   - Input Energy = $60\ J$
   - Useful Output to Light Bulb = $60\ J \times 0.92 = 55.2\ J$
   - Wasted Thermal Energy = $60\ J - 55.2\ J = 4.8\ J$
3. **Stage 3: Light Bulb (85% efficient)**
   - Input Energy = $55.2\ J$
   - Useful Light Energy Output = $55.2\ J \times 0.85 = 46.92\ J$
   - Wasted Thermal Energy = $55.2\ J - 46.92\ J = 8.28\ J$

Total Energy Accounting:

- **Final Useful Output (Light):** $46.92\ J$
- **Total Wasted Thermal Energy:** $40\ J + 4.8\ J + 8.28\ J = 53.08\ J$

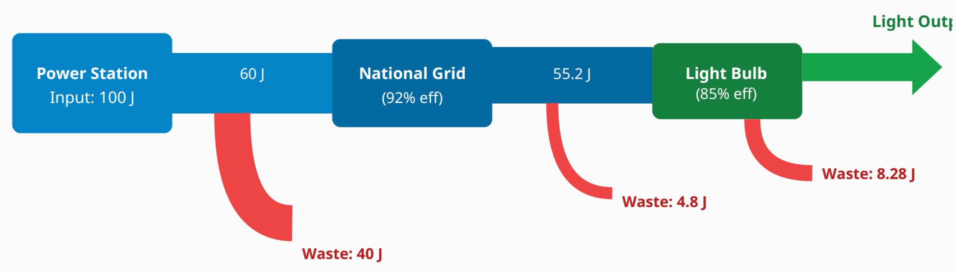
- **Total Input Energy:** $46.92\ J + 53.08\ J = 100.0\ J$ (Energy Conserved!)

Answer (b) - Overall Efficiency Calculation:

$$\text{Overall Efficiency} = (\text{Useful Light Energy Output} / \text{Total Power Station Input}) \times 100\%$$
$$\text{Overall Efficiency} = (46.92\text{ J} / 100\text{ J}) \times 100\% = \mathbf{46.92\%}\ (\text{or} \sim\mathbf{47\%})$$

Alternative Multiplicative Method: $\text{Overall Efficiency} = 0.60 \times 0.92 \times 0.85 = 0.4692 = \mathbf{46.92\%}$

Sankey Diagram Representation:



EXERCISE 6.2: ENERGY TRANSFERS AND EFFICIENCY

Topic Focus: Quantifying Efficiency, Power Stations, and Energy Dissipation

Questions 1 & 2 [Focus]

FOCUS

Question 1 Statement: A washing machine has a motor that turns the drum. In a particular washing machine, the motor is supplied with *1200 J* of energy each second. Of this, *900 J* of energy is used to turn the drum. The rest is wasted as thermal energy. Calculate the amount of energy wasted each second.

Answer 1:

$$\text{Wasted Thermal Energy} = \text{Total Energy Supplied} - \text{Useful Kinetic Energy}$$
$$\text{Wasted Thermal Energy} = 1200\text{ J} - 900\text{ J} = \mathbf{300\text{ J}}\text{ each second}$$

Question 2a Statement: Calculate the efficiency of the motor in the washing machine. Give your answer as a percentage.

Answer 2a:

$$\text{Efficiency} = (\text{Useful Energy Output} / \text{Total Energy Input}) \times 100\%$$
$$\text{Efficiency} = (900\text{ J} / 1200\text{ J}) \times 100\% = 0.75 \times 100\% = \mathbf{75\%}$$

Question 2b Statement: Explain why we say that energy from the washing machine is 'wasted' as thermal energy.

Answer 2b:

The primary intended purpose of the washing machine motor is to **mechanically turn the drum** to wash clothes. Any thermal energy produced due to friction in moving parts or electrical resistance in wires dissipates into the surroundings without contributing to cleaning clothes. Because this energy cannot be recovered or used for the machine's primary purpose, it is classified as **wasted energy**.

Question 3 (a & b) [Practice]

PRACTICE

Question Statement:

- A gas-fired power station is supplied with *1000 MJ* of energy each second and produces *450 MJ* of electrical energy.
- A coal-fired power station is supplied with *600 MJ* of energy each second and produces *150 MJ* of electrical energy.

a) Which power station is more efficient?
b) Calculate the efficiency of each power station.

Calculations & Answers:

1. **Gas-Fired Power Station Efficiency:**

$$\text{Efficiency}_{gas} = (\text{Useful Electrical Output / Total Energy Input}) \times 100\%$$
$$\text{Efficiency}_{gas} = (450\text{ MJ} / 1000\text{ MJ}) \times 100\% = \mathbf{45\%}$$

2. **Coal-Fired Power Station Efficiency:**

$$\text{Efficiency}_{coal} = (\text{Useful Electrical Output / Total Energy Input}) \times 100\%$$
$$\text{Efficiency}_{coal} = (150\text{ MJ} / 600\text{ MJ}) \times 100\% = \mathbf{25\%}$$

Conclusion for (a): The **gas-fired power station** is more efficient (*45%* compared to *25%* for coal).

Question 4 [Practice]

PRACTICE

Question Statement: Figure 6.3 shows the energy transfers in a light bulb each second. A coal-fired power station is used to provide the electricity. Calculate the efficiency of the bulb.
(From Figure 6.3: Chemical energy input = 12.0 J, Light energy produced = 3.6 J, Heat wasted = 8.4 J)

Calculation:

$$\text{Efficiency} = (\text{Useful Light Energy Output / Total Chemical Energy Input}) \times 100\%$$
$$\text{Efficiency} = (3.6\text{ J} / 12.0\text{ J}) \times 100\% = 0.30 \times 100\% = \mathbf{30\%}$$

Question 5 (a & b) [Challenge]

CHALLENGE

Question Statement:

a) Draw an energy flow diagram for the following power transmission system:

- solar panel (*20%* efficient)

- solar inverter (converts DC to AC, *95%* efficient)
- step-up transformer (*95%* efficient)
- overhead power transmission cable (*95%* efficient)
- step-down transformer (*95%* efficient)

Assume that there is *1000 J* of solar energy arriving at the solar panel.

b) What is the overall efficiency of the power transmission system?

Step-by-Step Energy Flow Calculations (Input = 1000 J):

Component	Efficiency	Input Energy	Useful Output Energy	Wasted Energy
1. Solar Panel	20%	1000 J	1000 × 0.20 = **200 J**	800 J
2. Solar Inverter	95%	200 J	200 × 0.95 = **190 J**	10 J
3. Step-up Transformer	95%	190 J	190 × 0.95 = **180.5 J**	9.5 J
4. Overhead Cable	95%	180.5 J	180.5 × 0.95 = **171.475 J**	9.025 J
5. Step-down Transformer	95%	171.475 J	171.475 × 0.95 = **162.90 J**	8.575 J

Answer (b) - Overall System Efficiency:

$$\text{Overall Efficiency} = (\text{Final Useful Output} / \text{Initial Solar Input}) \times 100\%$$
$$\text{Overall Efficiency} = (162.90\text{ J} / 1000\text{ J}) \times 100\% = \mathbf{16.29\%} \text{ (or } \mathbf{16.3\%}\text{)}$$

Direct Product Calculation: $0.20 \times (0.95)^4 = 0.20 \times 0.8145 = 0.1629 = \mathbf{16.29\%}$

EXERCISE 6.3: ENERGY CONSERVATION & CALCULATIONS

Topic Focus: Kinetic Energy, Gravitational Potential Energy, and Conservation Formulae

Question 1 [Focus]

FOCUS

Question Statement: State the equations for kinetic energy and change in gravitational potential energy, with mass as the subject for each.

a) Kinetic Energy Rearrangement for Mass (*m*):

Standard Equation: $\text{k.e.} = \frac{1}{2} m v^2$

Multiply both sides by 2: $2 \times \text{k.e.} = m v^2$

Divide by v^2: $\mathbf{m = (2 \times \text{k.e.}) / v^2}$

b) Change in GPE Rearrangement for Mass (*m*):

Standard Equation: $\Delta\text{g.p.e.} = m g \Delta h$

Divide by $(g \times \Delta h)$: $\mathbf{m = \Delta\text{g.p.e.} / (g \times \Delta h)}$

Question 2 [Practice]

PRACTICE

Question Statement: Calculate the kinetic energy of a car of mass *600 kg* travelling at *25 m/s*.

Given Data: Mass $m = 600\ kg$, Velocity $v = 25\ m/s$

Formula & Working:

$\text{k.e.} = \frac{1}{2} m v^2$

$\text{k.e.} = \frac{1}{2} \times 600\ \text{kg} \times (25\ \text{m/s})^2$

$\text{k.e.} = 300 \times 625 =$ **187,500 J** (or **187.5 kJ**)

Question 3 [Practice]

PRACTICE

Question Statement: A walker carrying a *20 kg* backpack climbs to the top of a mountain *2500 m* high. Calculate the gain in gravitational potential energy of the pack. (Acceleration due to gravity $g = 10\ m/s^2$).

Given Data: Mass $m = 20\ kg$, Height $\Delta h = 2500\ m$, $g = 10\ m/s^2$

Formula & Working:

$$\Delta \text{g.p.e.} = \text{m g } \Delta \text{h}$$
$$\Delta \text{g.p.e.} = 20 \text{ kg} \times 10 \text{ m/s}^2 \times 2500 \text{ m}$$
$$\Delta \text{g.p.e.} = \mathbf{500{,}000\ J} \text{ (or } \mathbf{500\ kJ} \text{ / } \mathbf{0.5\ MJ}\text{)}$$

Question 4 [Challenge]

CHALLENGE

Question Statement: The car in Question 2 slows down to a speed of *12 m/s*. By how much has its kinetic energy decreased?

> ⚡ **EXAM TIP & CRITICAL WARNING**
>
> When calculating the change in kinetic energy when an object changes speed from v_1 to v_2:
>
> **CORRECT:** $\Delta k.e. = ½\, m\, v_1^2 - ½\, m\, v_2^2$
>
> **INCORRECT:** $\Delta k.e. \neq ½\, m\, (v_1 - v_2)^2$

Calculation Steps:

1. **Initial Kinetic Energy ($v_1 = 25\ m/s$):**
   $k.e._{initial} = ½ \times 600 \times 25^2 = 187{,}500\ J$
2. **Final Kinetic Energy ($v_2 = 12\ m/s$):**
   $k.e._{final} = ½ \times 600 \times 12^2 = 300 \times 144 = 43{,}200\ J$
3. **Decrease in Kinetic Energy ($\Delta k.e.$):**

$$\text{Decrease in k.e.} = 187{,}500 \text{ J} - 43{,}200 \text{ J} = \mathbf{144{,}300\ J} \text{ (or } \mathbf{144.3\ kJ}\text{)}$$

Question 5 **[Challenge]** CHALLENGE

Question Statement: A girl throws a ball upwards (Figure 6.4). The ball has a mass of $0.20\ kg$ and it leaves her hand with a speed of $8.0\ m/s$. Determine how high it will rise.

Method & Principle:

Assuming air resistance is negligible, the total kinetic energy as the ball leaves the hand is completely transferred into gravitational potential energy at its highest point.

$$\text{g.p.e. at highest point} = \text{k.e. at lowest point}$$
$$m\ g\ h = \tfrac{1}{2}\ m\ v^2$$

Step-by-Step Calculation:

1. **Initial KE at release:**
   $k.e. = \tfrac{1}{2} \times 0.20\ kg \times (8.0\ m/s)^2 = 0.10 \times 64 = 6.4\ J$
2. **Equating KE to GPE:**
   $m\ g\ h = 6.4\ J$
   $0.20\ kg \times 10\ m/s^2 \times h = 6.4\ J$
   $2.0 \times h = 6.4$
3. **Solving for Height (*h*):**

   $$h = 6.4 / 2.0 = \mathbf{3.2\ m}$$

(Note: If $g = 9.8\ m/s^2$ is used, $h = 6.4 / (0.2 \times 9.8) = \mathbf{3.27\ m}$).

Question 6 [Challenge]

CHALLENGE

Question Statement: In a game, a toy car, which is initially stationary, slides down a slope. The top of the slope is $2.0\ m$ higher than the foot of the slope. Determine how fast the car will be moving when it reaches the foot. (Assume that all of its g.p.e. is transferred to k.e.).

Principle & Derivation:

By Conservation of Energy (assuming frictionless surface and zero air resistance):

$$\text{Loss in g.p.e.} = \text{Gain in k.e.}$$
$$m\,g\,h = \tfrac{1}{2}\,m\,v^2$$

Notice that mass (m) appears on both sides of the equation and cancels out:

$$g\,h = \tfrac{1}{2}\,v^2 \Rightarrow v^2 = 2\,g\,h \Rightarrow \mathbf{v = \sqrt{(2\,g\,h)}}$$

Step-by-Step Substitution:

- Given height $h = 2.0\ m$
- Acceleration due to gravity $g = 10\ m/s^2$

$$v = \sqrt{(2 \times 10\ \text{m/s}^2 \times 2.0\ \text{m})}$$
$$v = \sqrt{(40)} = \mathbf{6.32\ m/s}\ \text{(to 3 s.f.)}$$

(Note: If $g = 9.8\ m/s^2$ is used: $v = \sqrt{(2 \times 9.8 \times 2.0)} = \sqrt{(39.2)} = \mathbf{6.26\ m/s}$).

🎓 FINAL EXAM REVISION CHECKLIST

- ✔ Always write out the formula before substituting numbers to secure method marks.
- ✔ Double check units: Mass in kg, Speed in m/s, Height in m, Energy in J or kJ.
- ✔ Remember that efficiency is a ratio (or percentage) and has **no physical units**.
- ✔ In Sankey diagrams, input width MUST equal total output width (useful + wasted).