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S4 New Curriculum Physics

Theme: Electricity

Chapter 4 – Electric Energy, distribution and consumption



Source of electric supply

Electricity can be generated from a variety of sources, broadly categorized into **renewable** and **non-renewable** types.

Renewable Sources

These are naturally replenished and generally more environmentally friendly:

- **Hydropower:** Uses flowing water (like rivers or dams) to spin turbines. It's main source of electricity in Uganda.
- **Solar Power:** Converts sunlight into electricity using photovoltaic cells.

- **Wind Power:** Wind turbines harness the kinetic energy of wind to generate electricity.
- **Biomass:** Organic materials like wood, crop waste, or animal manure are burned or processed to produce power.
- **Geothermal:** Taps into the Earth's internal heat to generate steam and drive turbines.

Non-Renewable Sources

These are finite and often contribute to pollution and greenhouse gas emissions:

- **Coal:** Burned to produce steam that turns turbines. It's cheap but highly polluting.
- **Natural Gas:** Cleaner than coal, it's used in gas turbines and combined-cycle plants.
- **Oil:** Less common for electricity now, but still used in some regions.
- **Nuclear:** Uses uranium fission to produce heat and generate electricity. Low emissions but raises concerns about waste and safety.

Hydroelectricity generation in Uganda

The following are the main hydroelectricity dams in Uganda

- **Karuma Hydroelectric Power Station** – 600 MW (the largest in Uganda)
- **Isimba Hydroelectric Power Station** – 183 MW
- **Bujagali Power Station** – 250 MW
- **Nalubaale (formerly Owen Falls) Power Station** – 180 MW
- **Kiira Power Station** – 200 MW
- **Muzizi Hydroelectric Power Station** – 44.7 MW (under development)

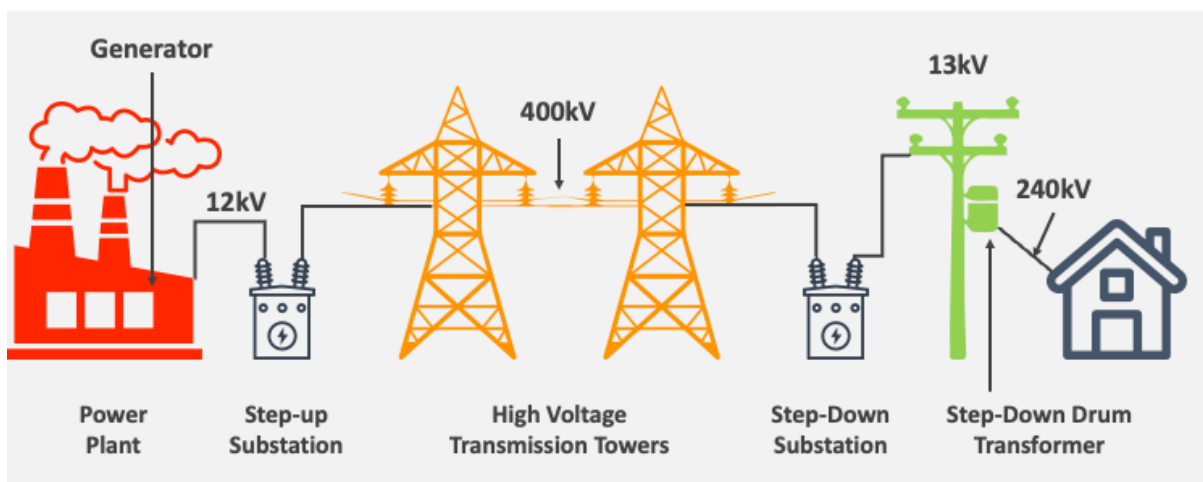
Benefits of dams to local community

1. **Access to Electricity:** Communities near hydroelectric dams have improved access to power which have improved their daily life and business
2. **Job Opportunities:** From construction to maintenance, dams create employment. Locals may find work as laborers, technicians, or in support services like transport and catering.
3. **Improved Infrastructure:** Dam projects provide improved social services such as new or upgraded roads, bridges, schools, and health centers—either as part of the project or as compensation for land use and resettlement.
4. **Flood Control:** By regulating river flow, dams help reduce the risk of seasonal flooding, protecting homes, crops, and infrastructure downstream.
5. **Tourism and Recreation: Reservoirs** have become hubs for fishing, boating, or eco-tourism, offering new income streams **for locals.**

Disadvantages of electric dams to local communities

1. **Displacement of People:** Large dam projects often require the relocation of entire communities. Families may lose ancestral land, homes, and cultural sites, and resettlement programs don't always provide adequate compensation or support.
2. **Loss of Livelihoods:** Communities that rely on fishing, farming, or grazing near rivers can be severely affected. Dams alter water flow, reduce fish populations, and flood fertile land, disrupting traditional ways of life.
3. **Environmental Degradation:** Flooding large areas for reservoirs have destroyed forests, wetlands, and wildlife habitats. This not only affects biodiversity but also the ecosystem services locals depend on, like clean water and fertile soil.
4. **Health Risks:** Stagnant water in reservoirs can become breeding grounds for mosquitoes, increasing the risk of diseases like malaria. Poor sanitation in resettlement areas can also lead to outbreaks of waterborne illnesses.
5. **Cultural and Social Disruption:** Relocation can fracture communities, erode social networks, and lead to loss of cultural identity. Sacred sites and burial grounds may be submerged or inaccessible.

Stages of power transmission from the source to the user



Electricity takes quite the journey from its source to your light switch! Here's a step-by-step breakdown of how power is transmitted from generation to end users:

1. **Generation:** Electricity is first produced at power plants using sources like hydropower, solar, coal, or nuclear energy. The voltage at this stage is relatively low—typically between 5 and 34.5 kilovolts (kV).
2. **Step-Up Transformation:** To travel long distances efficiently, the voltage is increased using a *step-up transformer*. This reduces energy loss during transmission. Voltages can be boosted to 115 kV, 230 kV, or even higher.
3. **Transmission:** High-voltage electricity travels through transmission lines—those tall towers you see stretching across the countryside. These lines carry power over hundreds of kilometers to substations near populated areas.

4. **Step-Down Transformation:** At regional substations, the voltage is reduced using *step-down transformers* to safer levels for local distribution—typically between 11 kV and 33 kV.
5. **Distribution:** Electricity is then routed through smaller distribution lines, often the ones you see on poles in your neighborhood. Before entering homes or businesses, the voltage is stepped down again—usually to 240V, 220V or 110V depending on the country.
6. **End Use: Finally,** the electricity reaches your home, powering everything from your phone charger to your refrigerator.

Advantages of a.c. over d.c

- a.c. is tepped up or down easily
- a.c. can be transmitted over long distance
- a.c. can easily be converted to direct current
- a.c. is easy to generate

Domestic electric appliance

A domestic electric appliance is any device powered by electricity that helps with household tasks—making daily life more convenient, efficient, or comfortable.

Classification of domestic appliances

Domestic electric appliances can be classified based on the type of energy transformation they perform.

1. **Electrical to Heat Energy,** examples are
 - **Electric kettle**
 - **Iron**
 - **Toaster**
 - **Electric cooker**
 - **Hair dryer**
2. **Electrical to Mechanical Energy:** These use electricity to produce movement or mechanical force:
 - **Washing machine**
 - **Blender**
 - **Electric fan**
 - **Vacuum cleaner**
 - **Food processor**
3. **Electrical to Light Energy:** These devices convert electricity directly into light:

- **Light bulbs (LED, fluorescent, incandescent)**
 - **Table lamps**
 - **Torch/flashlight**
 - **Decorative lighting**
4. **Electrical to Sound Energy:** Used mainly for communication and entertainment:
- **Radio**
 - **Television**
 - **Speakers**
 - **Alarm clock**
5. **Electrical to Multiple Forms:** Some appliances transform electricity into more than one type of energy:
- **Television** – light, sound, and sometimes heat
 - **Microwave oven** – heat, light, and mechanical (via turntable)
 - **Refrigerator** – mechanical (compressor), heat exchange, and sometimes light

Dangers of electricity

Electricity is incredibly useful—but when mishandled, it can be dangerous, even deadly. Here are some of the most common risks:

1. **Electric Shock:** Contact with live wires or faulty appliances can send current through the body, causing pain, muscle spasms, burns, or even cardiac arrest in severe cases.
2. **Electrical Fires:** Overloaded circuits, faulty wiring, or short circuits can ignite fires. Many household fires around the world are caused by preventable electrical faults.
3. **Burns:** Electrical burns can occur externally at the skin or internally along the path of the current. High-voltage contact can cause severe tissue damage.
4. **Electrocution:** This is a fatal electric shock, often resulting from direct contact with high-voltage equipment, downed power lines, or mishandled appliances.
5. **Damage to Property or Devices:** Power surges or poorly grounded systems can destroy electronics, damage wiring, or overload appliances.
6. **Explosion Risk:** In flammable environments (like fuel depots or certain factories), a spark from electrical equipment can cause explosions.
7. **Arc Flash:** This is a sudden, intense burst of electrical energy caused by a short circuit through the air. It can cause burns, blindness, or hearing loss, even without direct contact.

How to minimize dangers of electricity at home

Minimizing the dangers of electricity at home starts with a bit of know-how and a healthy respect for what electricity can do. Here are some smart and practical ways to stay safe:

- 1. Avoid Overloading Outlets:** Plugging too many devices into one socket can cause overheating and fires. Use power strips with surge protection and spread out your appliances across multiple outlets.
- 2. Keep Water Away from Electrical Devices:** Never use electrical appliances near sinks, bathtubs, or other sources of water—especially items like hair dryers, radios, or phone chargers.
- 3. Check for Damaged Wires or Cords:** Frayed or exposed wires can shock or start fires. Replace damaged cords immediately and never run cables under carpets where they can wear down unseen.
- 4. Unplug When Not in Use:** Unplugging appliances when they're not needed saves energy and reduces risk. This is especially important for heat-producing appliances like irons and kettles.
- 5. Use the Right Bulbs and Fuses:** Always match bulbs to the correct wattage for the fixture. And if a fuse keeps blowing, don't just replace it—find out why.
- 6. Childproof with Covers and Tamper-Resistant Outlets:** For homes with kids, safety covers on outlets and properly secured cords are essential to prevent curious fingers from finding danger.
- 7. Install a Residual Current Device (RCD):** Also known as a ground fault circuit interrupter (GFCI), this safety device cuts power if it detects an electrical fault. It's especially useful in kitchens, bathrooms, or outdoor areas.
- 8. Hire a Qualified Electrician:** Whether you're wiring a new room or fixing a faulty switch, a certified professional should handle electrical work. DIY shortcuts can lead to big problems.
- 9. Teach Household Members Electrical Safety:** Make sure everyone knows not to mix water and electricity, how to switch off power during emergencies, and to report any odd buzzing, flickering, or burning smells.

Components of domestic wiring

Domestic electrical wiring systems are designed to safely distribute power throughout a home. Here are the main components that make it all work:

- 1. Service Line:** This is the connection from the power utility electricity pole to your home.

It usually enters through a meter that tracks electricity usage.

Some components of domestic wiring



Electric meter



Main Switch



Socket



Switches

2. **Main Switch (Consumer Unit or Distribution Board):** Acts as the control center for electricity in your home. It includes:
 - A **main circuit breaker** to shut off power for the whole house
 - **Individual circuit breakers** or fuses for specific circuits (lights, sockets, appliances)
3. **Wiring (Cables):** These carry electric current through walls, ceilings, and floors. Common types include:
 - **Live (or phase) wire** – carries current to appliances
 - **Neutral wire** – completes the circuit back to the source
 - **Earth (or ground) wire** – provides a safety path for stray electricity
4. **Sockets (Outlets):** Allow you to plug in appliances. Some may be grounded or have switches for extra safety.
5. **Switches:** Used to control lighting or power to sockets. Can be single-pole, double-pole, or even dimmer switches.
6. **Lighting Points:** Include fixtures and bulbs, as well as ceiling or wall mount fittings.
7. **Earth Leakage Circuit Breaker (ELCB) or Residual Current Device (RCD):** Protects people from electric shock by cutting power if it detects a current leak to earth.
8. **Conduits or Trunking:** Protect wires from damage and help organize them neatly within the building structure.
9. **Earthing System:** Connects appliances and outlets to a grounding rod outside the house, preventing electrical shocks in case of faults.
10. **Fuse:** A fuse is an electrical safety device that protects electrical circuits from the effects of excessive currents. A fuse consists of a metal wire or strip that melts and interrupts the circuit when the current exceeds a certain level. This prevents fires or other dangers caused by overcurrent.
11. **Circuit breaker:** A circuit breaker is an electrical safety device, a switch that automatically interrupts the current of an overloaded electric circuit, ground faults, or short circuits. Circuit breakers "trip", shut off, current flow after protective relays detect a fault. Unlike fuses that were used previously, circuit breakers are not usually damaged so they can be reset as opposed to being replaced.

Commercial unit of electricity

The commercial unit of electrical energy is **kilowatt hour (kWh)**

A kilowatt hour is the electrical energy used by a 1000W appliance in 1 hour.

Relationship between kWh and joule (J)

$$\begin{aligned}
 1\text{kWh} &= 1000\text{W} \times 1\text{h} \\
 &= 1000\text{Js}^{-1} \times 60 \times 60\text{s} \quad (\text{since } 1000\text{W} = 1000\text{Js}^{-1} \text{ and } 1\text{h} = 60 \times 60\text{s}) \\
 &= 3,600,000\text{J} = 3.6 \times 10^6\text{J}
 \end{aligned}$$

When calculating the total cost of electricity the following should be noted:

- (i) Total power consumed should be expressed in kiloWatt (kW)
- (ii) Total time taken should be expressed in hours
- (iii) Then

Total cost = Total power (P) in **kW** x Time in **hours** (t) x Cost per unit

Note: Kilowatt hour is usually called unit.

Example 9

Calculate the cost of running four 60W lamps and five 100W lamps for 5 hours if electrical energy costs 10/= per unit.

Total power = $4 \times 60 + 5 \times 100 = 240 + 500 = 740\text{W}$

For commercial

Total power in kW = $\frac{740}{1000} \text{ kW}$

Total time = 5 hours

Cost per unit = 10 /=

Total Cost = $\frac{740}{1000} \times 5 \times 10$

= 37/=

Note; An electric lamp marked 240V; 60W means that when the lamp is connected to a 240V supply, it dissipates energy at the rate of 60J s^{-1}

Example 10

A lamp of 100W is run for 5 hours on 250V mains. Find (a) current taken from the mains

$V = 250\text{V}$, Power = 100w

Watt = Volt x Ampere

$100 = 250 \times \text{Ampere}$

$\frac{100}{250} = \text{Ampere}$

Amp = 0.4A is the current taken.

(b). resistance of the lamp filament

Power = $I^2 R$

$100 = 0.4 \times 0.4 \times R$

$100 = 0.16 \times R$

$\frac{100}{0.16} = R$

$625\Omega = R$

(c) Energy dissipated in 5 hours

Energy = VIt

$V = 250\text{V}$ $I = 0.4\text{A}$ $t = 5 \times 3600\text{s}$

Energy = $250 \times 0.4 \times 5 \times 3600$

= $1.8 \times 10^6 \text{J}$

(d) Cost of the energy consumed if the cost per unit is 60/=

Total power = 100W

For commercial

Total power = $100\text{W} = \frac{100}{1000} = 0.1\text{kW}$

Total time = 5 hours

$$\begin{aligned}\text{Cost} &= 0.1 \times 5 \times 60 \\ &= 30/= \end{aligned}$$

Trial 8

1. A 2kW electric heater is used for 10 hours each week and a 100 W lamp is used for 10 hours each day. Find
 - (i) the total energy consumed each week. [27kWh]
 - (ii) total cost for each week if each unit cost sh100 [2700/=]

2. A house contains the following appliances; 2.0kW electric kettle, 30W DVD player, five 75W bulbs, two 100W bulbs and 3.5kW fridge. If the fridge is used for 5h , kettle for 45minutes , 100W bulb for 10h , 75W bulb for 10h and DVD player for 5h calculate the
 - (i) Total electrical energy consumed in a day. [24.9kWh]
 - (ii) Cost of electricity used in a month of 30 days. If the cost per unit is sh.400 [298,800/=]

How to save energy at home

1. **Turn off what you're not using:** It sounds obvious, but it's a biggie: lights, TVs, fans, and chargers should all be turned off when not in use. Even standby mode can use power—called "phantom load."
2. **Switch to Energy-Efficient Appliances:** Look for appliances with energy-saving labels (like ENERGY STAR). They might cost a bit more upfront, but they save electricity and money in the long run.
3. **Use LED Bulbs:** Replace incandescent or CFL bulbs with **LEDs**, which use up to 80% less energy and last much longer.
4. **Smart Cooking Habit:** Use lids to cook food faster; Match pot size to burner; Cook in batches to reduce multiple uses of the stove.
5. **Unplug Idle Devices:** Chargers, TVs, microwaves, and other electronics continue to draw power when plugged in. A power strip with a switch makes it easy to shut off multiple items at once.
6. **Air-dry when you can:** Whether it's your clothes or your dishes, skipping the dryer and air-drying saves quite a bit of power.
7. **Maximize Natural Light:** Open your curtains during the day instead of turning on lights, and consider painting walls lighter colors to reflect more daylight.
8. **Use Fans Wisely:** Fans don't cool rooms, they cool people. So turn them off when you leave the room—and if you're using both fans and A/C, raise the thermostat to save energy.
9. **Seal Leaks and Insulate:** Good insulation keeps heat in during cooler months and out during hotter ones, reducing how much you use heaters or air conditioners.
10. **Choose Solar Where Possible:** Solar panels, solar water heaters, or even solar lamps can drastically cut your electricity dependence—especially in sunny places like Uganda.

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Thanks

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