Material World Review – Applied Science and Technology (AST)

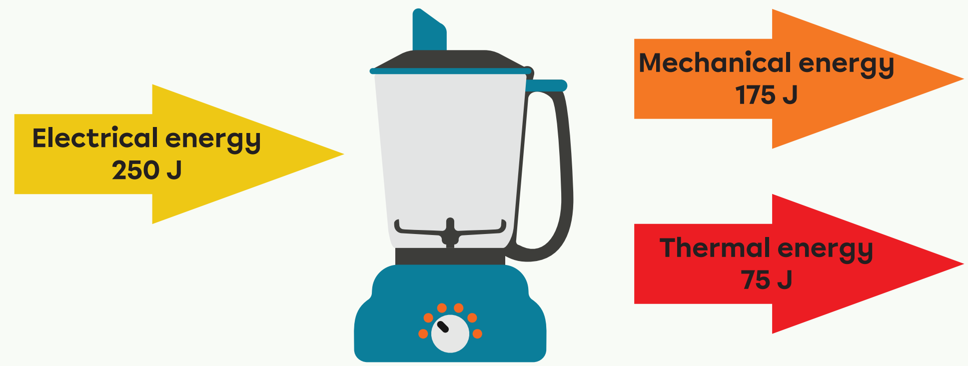
This summary provides a quick overview of the Material World concepts that may be assessed during the AST ministry exam. To explore a topic in more detail, scan its QR code. To see the summary of the Earth and Space and the Technological World, scan the large QR code at the bottom left.

Law of Conservation of Energy

Energy cannot be created nor destroyed. It can only be **transferred** or **transformed**.

Thermal energy transfer from coffee to hand

Transformation of electrical energy into mechanical and thermal energy



$$\text{Energy consumed} = \text{Useful energy} + \text{Dissipated energy}$$

$$250\ \text{J} = 175\ \text{J} + 75\ \text{J}$$

$$250\ \text{J} = 250\ \text{J}$$

Energy Efficiency

Example: A toaster consumes 270 000 J of electrical energy and transforms it into 197 100 J of useful thermal energy. What is the energy efficiency of the toaster?

$$\text{Energy efficiency} = \ ?\ \%$$

$$E_{\text{consumed}} = 270\ 000\ \text{J}$$

$$E_{\text{useful}} = 197\ 100\ \text{J}$$

$$\text{Energy efficiency} = \frac{E_{\text{useful}}}{E_{\text{consumed}}} \times 100$$

$$\text{Energy efficiency} = \frac{197\ 100\ \text{J}}{270\ 000\ \text{J}} \times 100$$

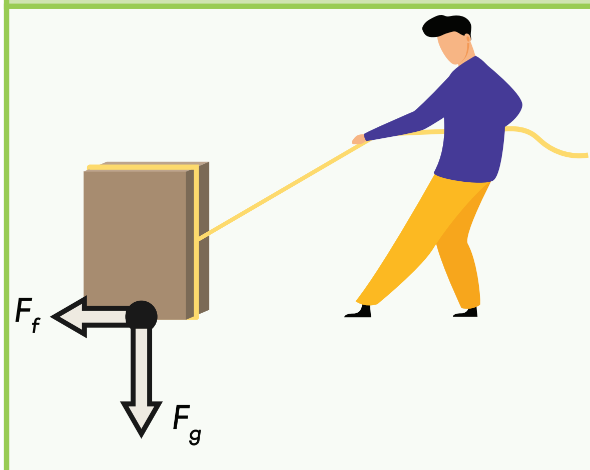
$$\text{Energy efficiency} \approx 73\ \%$$

Force

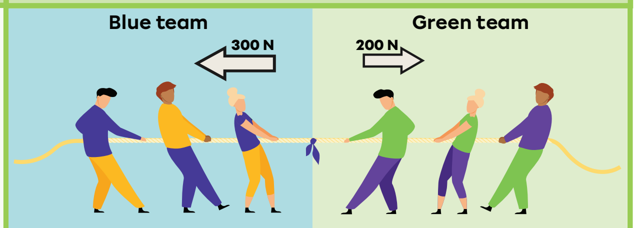
A **force** can deform an object, set it in motion, or modify its movement.

Type of Force	Description
Gravitational (F_g)	Force of attraction between two bodies
Friction (F_f)	Force that opposes the motion of an object on a surface
Magnetic	Force of attraction or repulsion between two magnetic poles

Example 1: Traction of a box on the ground



Example 2: Tug-of-war game

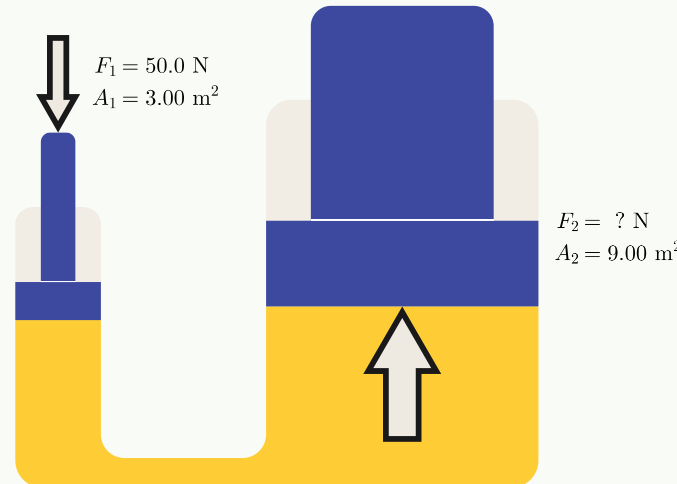


The rope is set in motion by a resultant force of 100 N to the left.

To stop the rope and regain balance, the green team must apply another 100 N to the right. The resultant force would become zero (0 N).

Pascal's Principle

A variation in pressure applied at a point in an enclosed fluid is distributed uniformly in all directions.



$$P_1 = \frac{F_1}{A_1} \qquad P_2 = \frac{F_2}{A_2}$$

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_2 = \frac{F_1 \times A_2}{A_1}$$

$$F_2 = \frac{50.0\ \text{N} \times 9.00\ \text{m}^2}{3.00\ \text{m}^2}$$

$$F_2 = 150\ \text{N}$$

Speed, Distance, and Time (v=d/Δt)

Example: By car, it takes 3 hours to cover the 261 km between Quebec City and Montreal. What is the average speed of the car?

Kilometres per hour (km/h)

$$d = 261\ \text{km} \qquad \Delta t = 3\ \text{h} \qquad v = \ ?\ \text{km/h}$$

$$v = \frac{d}{\Delta t}$$

$$v = \frac{261\ \text{km}}{3\ \text{h}}$$

$$v = 87\ \text{km/h}$$

Metres per second (m/s)

$$d = 261\ \text{km} \times \frac{1\ 000\ \text{m}}{1\ \text{km}} = 261\ 000\ \text{m}$$

$$\Delta t = 3\ \text{h} \times \frac{3\ 600\ \text{s}}{1\ \text{h}} = 10\ 800\ \text{s}$$

$$v = \ ?\ \text{m/s}$$

$$v = \frac{d}{\Delta t}$$

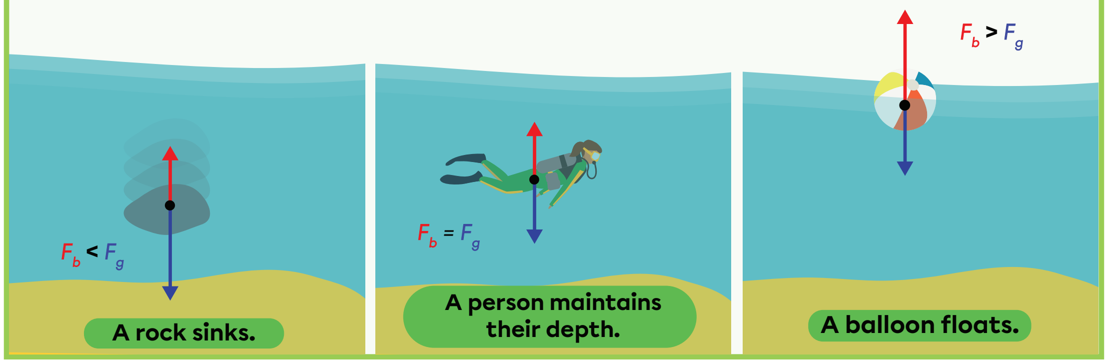
$$v = \frac{261\ 000\ \text{m}}{10\ 800\ \text{s}}$$

$$v \approx 24.2\ \text{m/s}$$

Archimedes' Principle

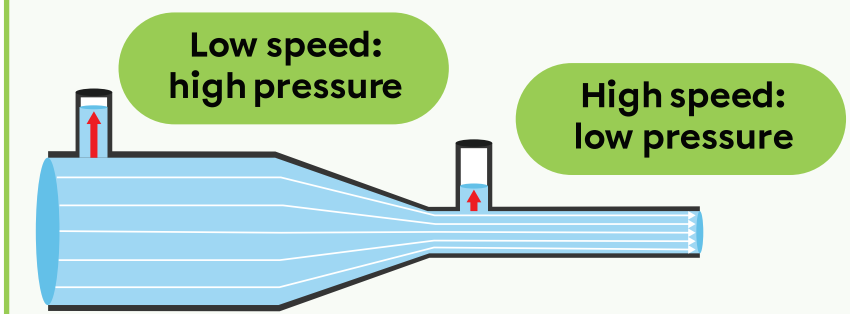
The **buoyant force (F_b)** is equal to the weight of the displaced fluid.

The object sinks, maintains its depth, or floats, depending on whether the buoyant force is smaller than, equal to, or greater than **the object's weight (F_g)**.



Bernoulli's Principle

The greater the speed of a fluid, the lesser the **pressure** perpendicular to its displacement.



Weight ($F_g = mg$)

Example: What is the weight of an 875 g rock on Earth?

$$m = 875\ \text{g} \times \frac{1\ \text{kg}}{1\ 000\ \text{g}} = 0.875\ \text{kg}$$

$$g = 9.8\ \text{N/kg}$$

$$F_g = \ ?\ \text{N}$$

$$F_g = mg$$

$$F_g = 0.875\ \text{kg} \times 9.8\ \text{N/kg}$$

$$F_g \approx 8.6\ \text{N}$$

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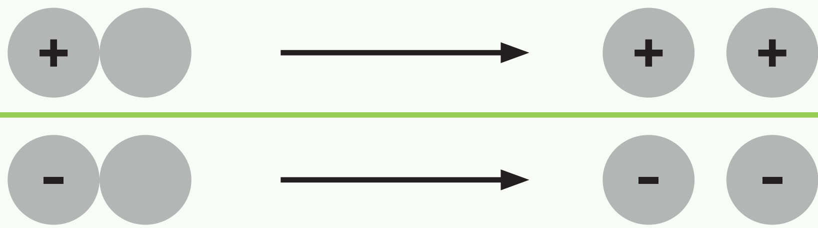
Static Electricity

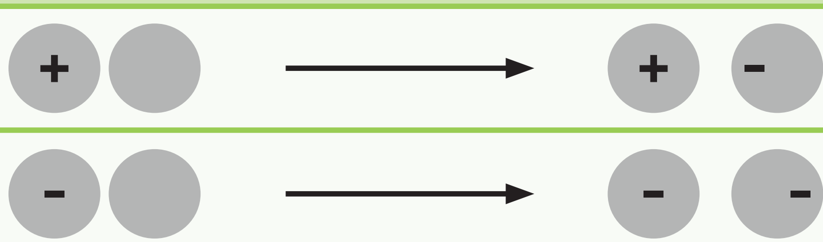
Law of Electric Charges
+ - = Attraction
+ + or - - = Repulsion

Conduction: Contact between a charged and a neutral object.



Friction: One object pulls electrons from the other.

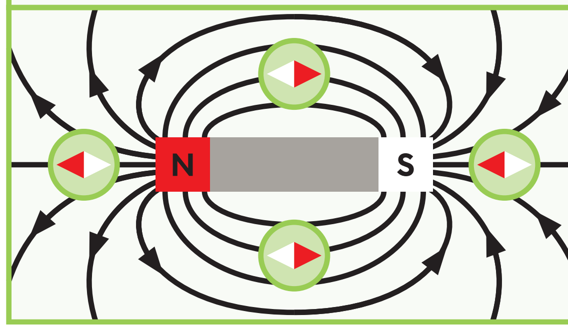
Induction: A nearby charge causes electrons to move temporarily.

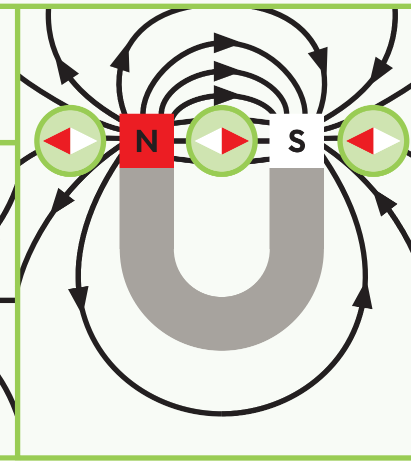


Magnetic Field Around Magnets

Magnetic field lines run from the magnetic north pole to the magnetic south pole.

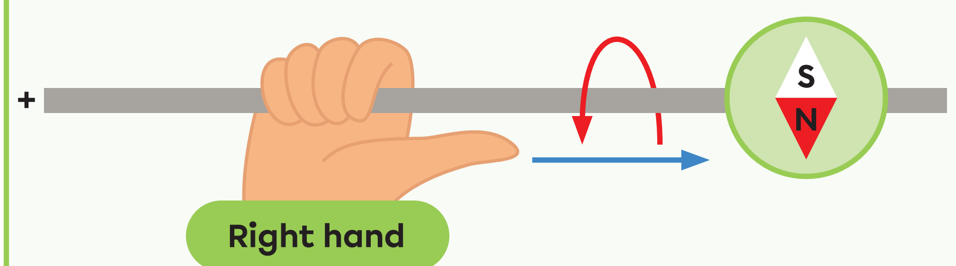
Attraction and repulsion of two poles
N-S = Attraction
N-N or S-S = Repulsion





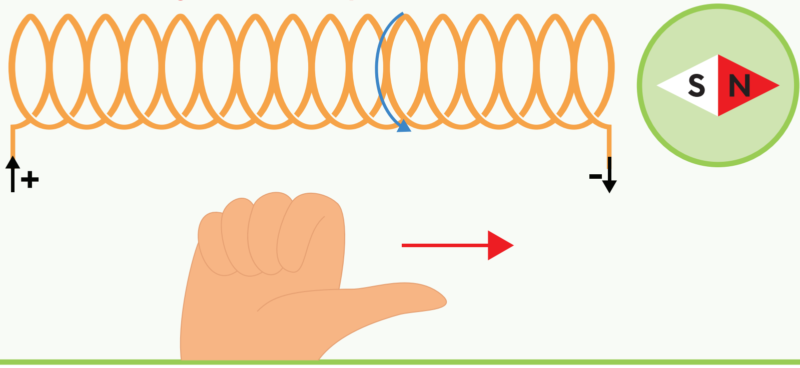
Magnetic Field Around a Straight Wire

- Thumb: conventional current direction
- Fingers: direction of the magnetic field lines



Magnetic Field Around a Solenoid (2nd Right-Hand Rule)

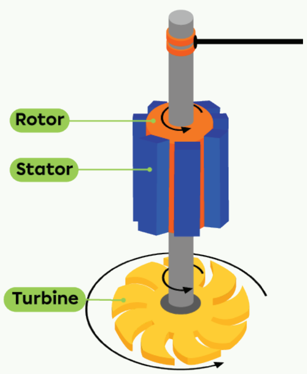
- Fingers: conventional current direction
- Thumb: **magnetic north pole of the solenoid**



3 ways to increase a solenoid's magnetic field strength

- Increase the number of loops (turns)
- Increase current intensity
- Transform the solenoid into an electromagnet by adding a ferromagnetic core (iron, nickel, or cobalt)

Electromagnetic Induction



In a turbine-generator unit, the rotation of a rotor in a fixed stator creates an electric current.

Rotor: rotating components made up of electromagnets

Stator: fixed components made up of copper bars

Chemical Reactions

Oxidation is a reaction in which an element of one of the reactants loses one or more electrons. This can happen in the presence of oxygen.

Example: Formation of iron (III) oxide (rust)

$4\ Fe_{(s)} + 3\ O_{2(g)} \rightarrow 2\ Fe_2O_{3(s)}$

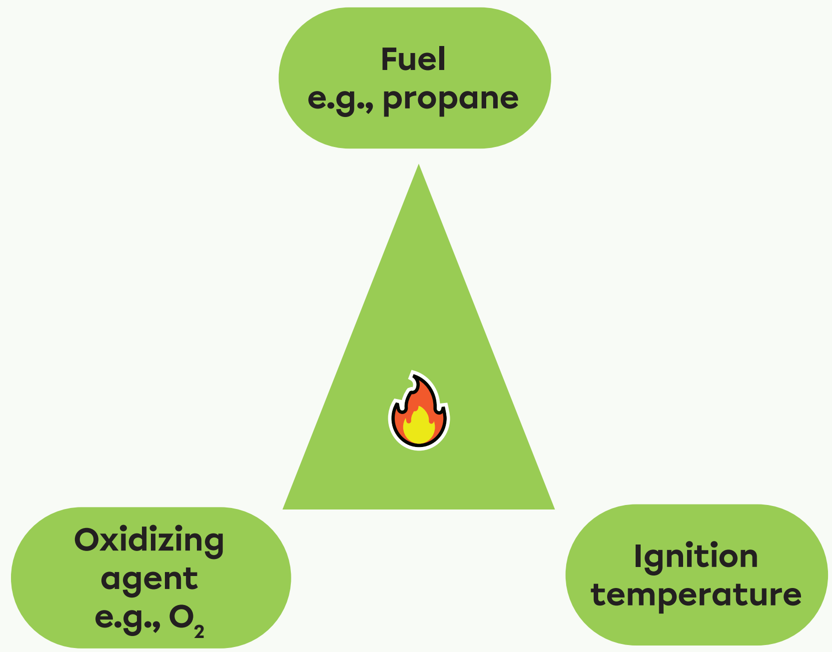
Combustion is an oxidation process that releases energy.

Example: Propane combustion

$C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)} + \text{Energy}$

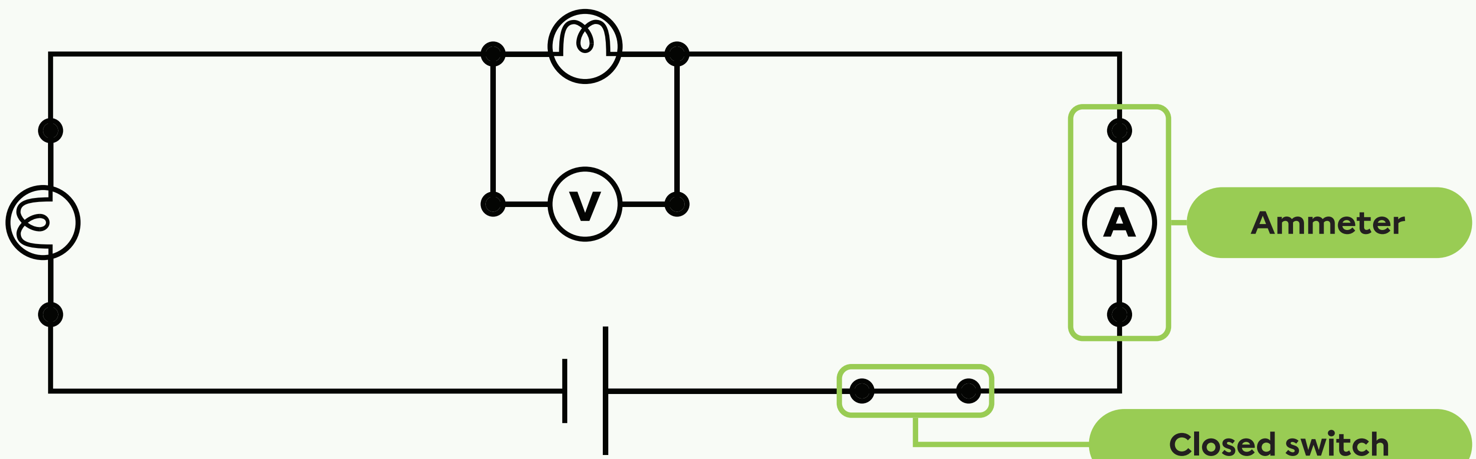
Fire Triangle

3 key elements of combustion

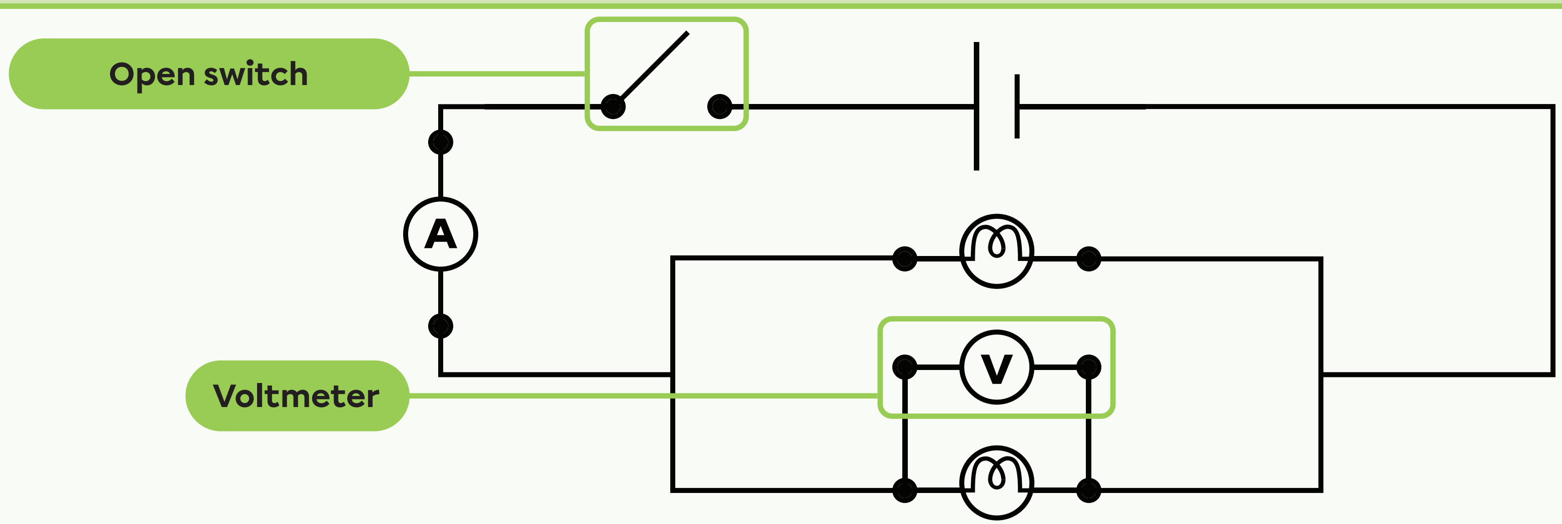


Electrical Circuits

Series circuit



Parallel circuit



Ohm's Law (V = RI)

Example: A toaster with a resistance of 12.0 Ω carries a current of 10 000 mA. What is the potential difference, or voltage, of the toaster's outlets?

$$R = 12.0\ \Omega$$
$$I = 10\ 000\ \text{mA} \times \frac{1\ \text{A}}{1\ 000\ \text{mA}} = 10.000\ \text{A}$$
$$V = \ ?\ \text{V}$$

$$V = RI$$

$$V = 12.0\ \Omega \times 10.000\ \text{A}$$
$$V = 120\ \text{V}$$

Electrical Power (P = VI)

Example: What is the electrical power of the toaster in the previous example?

$$V = 120\ \text{V}$$
$$I = 10.000\ \text{A}$$
$$P = \ ?\ \text{W}$$

$$P = VI$$
$$P = 120\ \text{V} \times 10.000\ \text{A}$$
$$P = 1\ 200\ \text{W or } 1.20\ \text{kW}$$

Electrical Energy Consumed (E = PΔt)

Example: The toaster runs for 3 min and 45 sec.
How much electrical energy does it consume?

Joules (J)

$$P = 1\ 200\ \text{W}$$
$$\Delta t = \left(3\ \text{min} \times \frac{60\ \text{s}}{1\ \text{min}}\right) + 45\ \text{s} = 225\ \text{s}$$
$$E = \ ?\ \text{J}$$
$$E = P\Delta t$$
$$E = 1\ 200\ \text{W} \times 225\ \text{s}$$
$$E = 270\ 000\ \text{J or } 270\ \text{kJ}$$

Kilowatt-hour (kWh)

$$P = 1.20\ \text{kW}$$
$$\Delta t = \left(3\ \text{min} \times \frac{1\ \text{h}}{60\ \text{min}}\right) + \left(45\ \text{sec} \times \frac{1\ \text{h}}{3\ 600\ \text{s}}\right) = 0.062\ 5\ \text{h}$$
$$E = \ ?\ \text{kWh}$$
$$E = P\Delta t$$
$$E = 1.20\ \text{kW} \times 0.062\ 5\ \text{h}$$
$$E = 0.075\ 0\ \text{kWh}$$