Energy, Work, and Power

Matthew Williams • Physics • May 20, 2026

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Forms of Energy

Energy exists in many forms. All of them can be converted into other forms, but the total amount is always conserved.

Form	Description
Kinetic	Energy of a moving object
Gravitational potential	Energy stored by an object's height in a gravitational field
Elastic potential	Energy stored in a stretched or compressed spring
Chemical	Energy stored in chemical bonds (e.g. food, fuel, batteries)
Electrical	Energy carried by moving charges
Thermal (heat)	Energy associated with the random motion of particles
Sound	Energy carried by mechanical vibrations through a medium
Electromagnetic	Energy carried by electromagnetic waves (light, infrared, etc.)
Nuclear	Energy stored in atomic nuclei

Work

Work is done when a force moves an object in the direction of the force. Work is a transfer of energy.

$$W = F \times d$$

where W is work in joules (J), F is the applied force in newtons (N), and d

is the displacement in metres (m) in the direction of the force.

If the force and displacement are not parallel, only the component of the force along the direction of motion does work:

$$W = Fd\cos\theta$$

where θ is the angle between the force and displacement. One joule equals one newton-metre (1 J = 1 N m).

Kinetic and Gravitational Potential Energy

Kinetic energy (KE) is the energy of a moving object:

$$E_k = \frac{1}{2}mv^2$$

where m is mass (kg) and v is speed (m s^{-1}). Units: J.

Gravitational potential energy (GPE) is the energy stored by lifting an object against gravity:

$$E_p = mgh$$

where m is mass (kg), $g = 10$ N kg^{-1}, and h is the height gained (m). Units: J.

Conservation of Energy

Energy cannot be created or destroyed, only converted from one form to another. In a closed system, the total energy is constant.

A common application: when an object falls freely from height h, all its GPE converts to KE at the bottom (assuming no air resistance):

$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh}$$

Free fall, speed on landing (2017 Paper 02, Q4)

An amusement park carriage free-falls from rest and reaches a speed of 64.8 km h^{-1}. Find the time of fall and the distance fallen. [g = 10 m s^{-2}]

Step 1: Convert speed to m s^{-1}.

$$v = \frac{64.8}{3.6} = 18\text{m s}^{-1}$$

Step 2: Time of fall (from $v = u + at$ with $u = 0$, $a = g = 10$ m s^{-2}):

$$t = \frac{v}{g} = \frac{18}{10} = 1.8\text{s}$$

Step 3: Distance fallen (from $v^2 = u^2 + 2as$ with $u = 0$):

$$s = \frac{v^2}{2g} = \frac{18^2}{2 \times 10} = \frac{324}{20} = 16.2\text{m}$$

Power

Power is the rate of energy transfer (or rate of doing work):

$$P = \frac{E}{t} = \frac{W}{t}$$

Units: watts (W), where 1 W = 1 J s^{-1}.

For a force moving at constant velocity:

$$P = Fv$$

Efficiency

Real machines always lose some energy, usually as heat due to friction or as sound. **Efficiency** measures how much of the input energy is usefully transferred:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

Efficiency can never exceed 100% for a real machine. An incandescent light bulb converts about 5% of electrical energy to light and 95% to heat. An LED achieves around 30-50% efficiency.

Alternative Energy Sources

Fossil fuels are finite and their combustion releases CO, contributing to the greenhouse effect. Alternative energy sources are increasingly important, especially in the Caribbean where fossil fuels must be imported.

Source	Principle	Caribbean relevance
Solar	Photovoltaic cells convert sunlight to electricity; solar heaters absorb infrared radiation	High sunlight hours throughout the year
Wind	Turbines convert kinetic energy of wind to electricity	Consistent trade winds
Hydroelectric	Falling water drives turbines	Rivers and waterfalls in larger islands (Dominica)
Geothermal	Heat from volcanic activity drives steam turbines	Available in Eastern Caribbean volcanic islands
Tidal	Tidal movement drives turbines	Less developed; coastline required
Nuclear	Fission of uranium releases heat to drive turbines	Not currently used in the Caribbean

Wind turbine efficiency (2023 Paper 02, Q2)

Air of mass 8.5 kg passes through a wind turbine per second with kinetic energy of 2500 J. The generator output power is 1350 W.

Part (i), Speed of air:

$$E_k = \frac{1}{2}mv^2 \implies v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 2500}{8.5}} = \sqrt{588.2} \approx 24.3\,\text{m s}^{-1}$$

Part (ii), Input power (energy transferred per second = kinetic energy per second):

$$P_{\text{in}} = 2500\,\text{W}$$

Part (iii), Efficiency:

$$\text{efficiency} = \frac{1350}{2500} \times 100 = 54\%$$

📝 **Exam Tip**

Caribbean-context questions on alternative energy appear regularly in Paper 02. When evaluating hydroelectricity or geothermal energy, be specific about where in the Caribbean each source is viable. Dominica and St Lucia have hydroelectric potential; Montserrat, Guadeloupe, and Nevis have geothermal potential.