LESSON MAKER PRO

Energy Output Lab

Measure efficiency, test constraints, and choose the stronger design.

HIGH SCHOOL · HS-PS3-3

HS-PS3-3 "Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices..."

NAME _____ DATE _____

MEASURE DEVICE EFFICIENCY

Efficiency tells how much of a device's input energy becomes useful output energy. Use efficiency = useful output energy / input energy x 100%, then compare the result with any required constraint.

WORKED EXAMPLE

A small water turbine receives 240 J of moving-water energy and produces 180 J of useful electrical energy. What is its efficiency?

1. Efficiency = useful output / input x 100%
2. Efficiency = 180 / 240 x 100%
3. 180 / 240 = 3 / 4
4. 3 / 4 x 100% = 75%

Answer: 75% efficient

PRACTICE 6 problems

1 A generator receives 200 J of wind energy and produces 50 J of useful electrical energy. Find its efficiency.

ANSWER _____

2 A solar oven receives 150 J of sunlight and transfers 90 J of useful thermal energy to food. Find its efficiency.

ANSWER _____

3 A device has an input of 80 J and is 50% efficient. How much useful output energy does it produce?

ANSWER _____

4 A pedal-powered charger receives 300 J of mechanical energy and produces 210 J of useful electrical energy. Find its efficiency.

ANSWER _____

5 A hand-crank generator receives 400 J of mechanical energy and produces 260 J of useful electrical energy. The design must be at least 65% efficient. Does it meet the constraint?

ANSWER _____

6 Design A receives 100 J and produces 40 J of useful output. Design B receives 160 J and produces 96 J of useful output. Which design is more efficient?

ANSWER _____

APPLY IT Show your work

1 Students are designing a solar phone-charging station for an outdoor school event. The station receives 6000 J of sunlight and produces 900 J of useful electrical energy. After a redesign, it produces 1200 J of useful electrical energy from the same input. Find each efficiency. The station must be at least 18% efficient. Does the redesigned station meet the constraint?

WORK SPACE

ANSWER _____

2 A student builds a wind-powered battery charger for an e-bike light. During a test, it receives 2500 J of wind energy and delivers 1750 J of useful electrical energy. The light needs at least 2000 J of useful energy during the same test. Find the charger's efficiency and decide whether it meets the output requirement.

WORK SPACE

ANSWER _____

CHALLENGE One step up

A robotics club must submit a wind-powered device that delivers at least 190 J of useful electrical energy. Design A receives 360 J of wind energy and delivers 216 J. Design B receives 280 J and delivers 196 J. Both designs meet the output requirement, but the club wants the higher-efficiency design. Which design should the club submit? Explain using calculations. Then design, build and refine a small motor winch using only a teacher-provided geared DC motor, current-limited low-voltage source, joulemeter, spool, thread, cardboard supports, tape, a 10 g load and ruler. Teacher checks wiring. Goal: lift the load at least 10 cm using at most 5 J of electrical input; keep lift height below 20 cm. Sketch and build your support/spool design. Measure input energy with the joulemeter and vertical rise with the ruler; stop at the energy limit or height limit. Compute useful output as 0.010 kg × 9.8 N/kg × rise in metres. Describe motion or slipping, change one design feature, and repeat with the same load and limits. On separate paper, submit both designs, actual input/output values, efficiency, observations and whether the refinement helped. Disconnect power before adjustments.

WORK SPACE AND ANSWER

ANSWER KEY

Energy Output Lab

PART 1 · PRACTICE

#	PROBLEM	ANSWER
1	A generator receives 200 J of wind energy and produces 50 J of useful electrical energy. Find its efficiency.	**25%**
2	A solar oven receives 150 J of sunlight and transfers 90 J of useful thermal energy to food. Find its efficiency.	**60%**
3	A device has an input of 80 J and is 50% efficient. How much useful output energy does it produce?	**40 J**
4	A pedal-powered charger receives 300 J of mechanical energy and produces 210 J of useful electrical energy. Find its efficiency.	**70%**
5	A hand-crank generator receives 400 J of mechanical energy and produces 260 J of useful electrical energy. The design must be at least 65% efficient. Does it meet the constraint?	**Yes. Its efficiency is 65%, so it meets the constraint.**
6	Design A receives 100 J and produces 40 J of useful output. Design B receives 160 J and produces 96 J of useful output. Which design is more efficient?	**Design B. Design A is 40% efficient, and Design B is 60% efficient.**

PART 2 · APPLY IT

1. **Original: 15%. Redesigned: 20%. Yes, the redesigned station meets the 18% constraint.** Divide each useful output by 6000 J and multiply by 100%. The redesign has 20% efficiency, which is greater than 18%.
2. **70% efficient. No, it is 250 J below the required useful output.** 1750 / 2500 x 100% = 70%. Compare 1750 J with the required 2000 J to find that the charger is 250 J short.

CHALLENGE

Submit Design B. Design A is 216 / 360 x 100% = 60% efficient. Design B is 196 / 280 x 100% = 70% efficient. Both deliver at least 190 J, but Design B has the higher efficiency. The learner must supply a built and tested winch plus a refinement and retest. At a 0.10 m rise, useful output is 0.0098 J; use the learner's actual rise and input for output and efficiency. Electrical energy becomes motor motion and increased gravitational potential energy of the load–Earth system, with some energy dispersed thermally. A successful test reaches at least 0.10 m within 5 J; actual outcomes may fail the criterion.

Accept equivalent fraction work and correctly labeled units. For constraint questions, students should state both the calculated efficiency or output and whether the device meets the requirement. Teacher supplies and checks every listed component, including a joulemeter sensitive enough for this energy range. Require actual construction and two records, not a story about someone else's device. Evaluate total measured output for total measured input; do not infer input from battery rating or compare watt readings directly with joules. Use metres and kilograms; compare efficiencies if measured inputs differ. Accept unsuccessful refinements with evidence and a next step. No additional materials purchase or unsupervised wiring is assigned.