LESSON MAKER PRO

Chain Reaction Lab

Calculate, test, and improve a six-step machine.

HIGH SCHOOL · PHY.3.11

PHY.3.11 "Enrichment: Use an engineering design process to design and build a themed Rube Goldberg-type machine that has six or more steps and complete a desired task (e.g., pop a balloon, fill a bottle, shoot a projectile..."

NAME _____ DATE _____

USEFUL ENERGY AND EFFICIENCY

A machine's efficiency compares the energy used for its desired task with the energy put into the machine: efficiency = useful output energy / input energy × 100%. To find the energy needed to raise an object, use gravitational potential energy = mass × 10 N/kg × height. Count only the energy that completes the desired task as useful output.

WORKED EXAMPLE

A machine receives 18 J of energy and uses 9 J to complete its task. What is its efficiency?

1. Efficiency = useful output energy / input energy × 100%.
2. Substitute: efficiency = 9 J / 18 J × 100%.
3. Divide, then multiply: efficiency = 0.5 × 100%.

Answer: 50%

PRACTICE 6 problems

1 A chain reaction receives 30 J of energy and uses 6 J to ring a bell. What is its efficiency?

ANSWER _____

2 A machine receives 16 J of energy and delivers 12 J to its final task. What is its efficiency?

ANSWER _____

3 A machine receives 80 J of energy and is 20% efficient. How much useful output energy does it deliver?

ANSWER _____

4 A machine raises a 0.2 kg object by 0.35 m. How much useful output energy does this task require? Use 10 N/kg for gravity.

ANSWER _____

5 A machine raises a 0.3 kg object by 0.4 m. How much useful output energy does this task require? Use 10 N/kg for gravity.

ANSWER _____

6 A prototype receives 20 J and delivers 4 J to its task. After a change, it receives 20 J and delivers 8 J. By how many percentage points did its efficiency increase?

ANSWER _____

APPLY IT Show your work

1 For game night, you plan a six-step arcade machine: a ball rolls down a ramp, knocks over dominoes, trips a lever, releases a marble, drops the marble into a cup, and uses the cup to lift a prize. The steps take 4, 5, 6, 3, 4, and 2 seconds. The machine receives 14 J of energy and lifts a 0.2 kg prize by 0.35 m. It must finish within 25 seconds. Does the plan meet the time limit, and what is its efficiency? Use 10 N/kg for gravity.

WORK SPACE

ANSWER _____

2 Your team is testing two versions of a six-step, space-themed machine that raises a banner. Each version must finish within 28 seconds. Use the test results to choose the version that meets the time limit and has the greater efficiency. State both versions' efficiencies.

BANNER MACHINE TEST RESULTS

Version	Input energy	Useful output energy	Time
First build	24 J	6 J	29 s
Revised build	20 J	8 J	26 s

ANSWER _____

CHALLENGE One step up

Design a six-step, themed machine to raise a 0.5 kg sign by 0.4 m. Its total input energy is 20 J. The machine must complete its task within 20 seconds, and you have 30 minutes to build, test, and revise it. Write six numbered steps that could make the sign rise, assign a time to each step, and total the times. Draft the text for a poster showing at least two energy transformations, the useful output energy, and the efficiency. Use 10 N/kg for gravity. Then give a build, test, and revision schedule that fits 30 minutes and name one change you would test if the sign does not reach its target height.

WORK SPACE AND ANSWER

Chain Reaction Lab

PART 1 · PRACTICE

#	PROBLEM	ANSWER
1	A chain reaction receives 30 J of energy and uses 6 J to ring a bell. What is its efficiency?	**20%**
2	A machine receives 16 J of energy and delivers 12 J to its final task. What is its efficiency?	**75%**
3	A machine receives 80 J of energy and is 20% efficient. How much useful output energy does it deliver?	**16 J**
4	A machine raises a 0.2 kg object by 0.35 m. How much useful output energy does this task require? Use 10 N/kg for gravity.	**0.7 J**
5	A machine raises a 0.3 kg object by 0.4 m. How much useful output energy does this task require? Use 10 N/kg for gravity.	**1.2 J**
6	A prototype receives 20 J and delivers 4 J to its task. After a change, it receives 20 J and delivers 8 J. By how many percentage points did its efficiency increase?	**20 percentage points**

PART 2 · APPLY IT

1. **Yes. The steps take 24 seconds, and the efficiency is 5%.** Add the step times to get 24 seconds, which is within the 25-second limit. The useful output is 0.2 × 10 × 0.35 = 0.7 J, so efficiency = 0.7 / 14 × 100% = 5%.
2. **Choose the revised build. The first build is 25% efficient and takes too long; the revised build is 40% efficient and finishes within 28 seconds.** The efficiencies are 6 / 24 × 100% = 25% and 8 / 20 × 100% = 40%. Only the revised build meets the time limit.

CHALLENGE

Theme: space launch. (1) A raised ball rolls down a ramp, 2 s. (2) The ball knocks over dominoes, 3 s. (3) The last domino tilts a lever, 4 s. (4) The lever releases a raised weight, 2 s. (5) The falling weight turns a spool, 3 s. (6) The spool winds a string to raise the sign, 4 s. Total: 18 s, within the 20-second limit. Poster: The raised ball's gravitational potential energy becomes motion energy as it rolls. The raised weight's gravitational potential energy becomes motion energy in the turning spool, and the sign gains gravitational potential energy. Useful output = 0.5 × 10 × 0.4 = 2 J. Efficiency = 2 / 20 × 100% = 10%. Schedule: build for 20 minutes, test for 5 minutes, and revise for 5 minutes. If the sign does not rise 0.4 m, test a spool that winds more string per turn.

For the challenge, accept other physically plausible six-step designs, energy transformations, and revisions that meet all stated constraints. Step times must total no more than 20 seconds, and the build, test, and revision schedule must total no more than 30 minutes.