Shells That Solve

Design protection that still allows movement

ZOO.5.3 "Enrichment: Use an engineering design process to develop a biomimicry of an arthropod's exoskeleton to meet a human need.*"

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline the human need and design requirements, circle two crab features that inspired the pad, and number the prototype, tests, and revision in the order they occurred. These marks will help you trace how the team used an exoskeleton idea to improve its design.

A Knee Pad Inspired by a Crab

1. At a bicycle-repair shop, mechanics often kneel on concrete to reach low parts. A pad could reduce painful impacts, but a stiff shield might prevent a mechanic from bending a knee. A team looked to a crab's exoskeleton for ideas. A crab has a hard outer covering made largely of chitin and proteins; much of its shell is strengthened with minerals. Its legs have hard sections connected by more flexible joints. The team focused on this combination of protection and movement, not on copying the crab's exact shape. Their design goal was a light, affordable knee pad that could bend during work.

2. The team sketched a sleeve with small, overlapping plastic plates above a padded fabric layer. Gaps between plates let the sleeve bend, while overlap kept much of the knee covered when the wearer moved. Plastic stood in for the crab's rigid shell, and fabric at the gaps played the role of flexible joints. The team chose materials they could cut and sew. To evaluate the prototype, they planned two checks: drop the same small weight from the same height onto each pad and record the force on a sensor beneath it. They also checked how far a volunteer could bend a knee. A foam pad served as a comparison.

3. The first prototype sent less force to the sensor than the foam pad, but its plates caught on one another during a deep bend. The team rounded the plate corners and widened the gaps slightly. In a second trial, the pad still sent less force to the sensor than foam, and the volunteer bent the knee farther than before. The team kept the revised version for further tests, including repeated bending and cleaning. These checks mattered because a protective pad that jams during work would not meet the original need, even if it performed well in a drop test.

2 ANSWER WITH EVIDENCE

Use the passage

1. What human need did the team address, and why would a stiff shield fail to meet it fully?

2. How did the team turn two features of the crab's exoskeleton into parts of the knee pad?

3. Why did the team need both a drop test and a bend check? How did they make the drop test a fair comparison?

4. Which result led the team to revise its prototype, and what evidence showed that the revision worked better?

3 YOUR TURN

Your own words

Design a device for a human need other than knee protection. In 5 to 6 sentences, name an arthropod exoskeleton feature, explain how your device copies its function, set two design criteria, describe a fair test, and state a change you would make if one criterion fails.

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PART 1 · READ AND MARK

Underline the human need and design requirements, circle two crab features that inspired the pad, and number the prototype, tests, and revision in the order they occurred. These marks will help you trace how the team used an exoskeleton idea to improve its design. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	What human need did the team address, and why would a stiff shield fail to meet it fully?	**Mechanics needed protection from impacts while kneeling. A stiff shield could stop them from bending a knee during work.**
2	How did the team turn two features of the crab's exoskeleton into parts of the knee pad?	**The plastic plates copied the protection of hard shell sections. Fabric at the gaps copied the movement allowed by flexible joints.**
3	Why did the team need both a drop test and a bend check? How did they make the drop test a fair comparison?	**The drop test checked impact protection, while the bend check tested movement. The team used the same weight and drop height for each pad and compared the prototype with a foam pad.**
4	Which result led the team to revise its prototype, and what evidence showed that the revision worked better?	**The plates caught during a deep bend. After the team rounded their corners and widened the gaps, the volunteer bent farther, and the pad still sent less force to the sensor than foam.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

A camera case needs to protect a camera while opening quickly. Inspired by a beetle's hard wing covers, I would put two hinged, rigid panels over a padded case. The case should reduce impact force by at least 20 percent compared with a padded case without panels and open in under three seconds. I would drop the same weight from the same height onto each closed case and compare sensor readings beneath them. I would also time several openings of my case. If it opened too slowly, I would move the hinges outward and test it again.

Accept other accurate connections between hard exoskeleton sections, flexible joints, and the pad's parts. For the open task, look for a distinct human need, a functional exoskeleton analogy, two testable criteria, a fair test, and a revision tied to a possible failure.