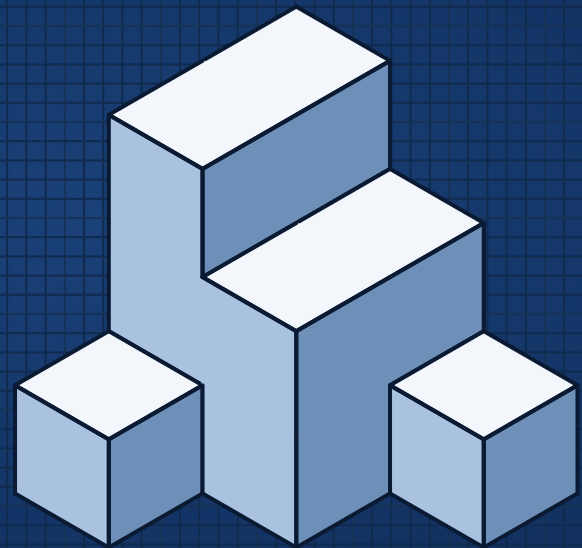
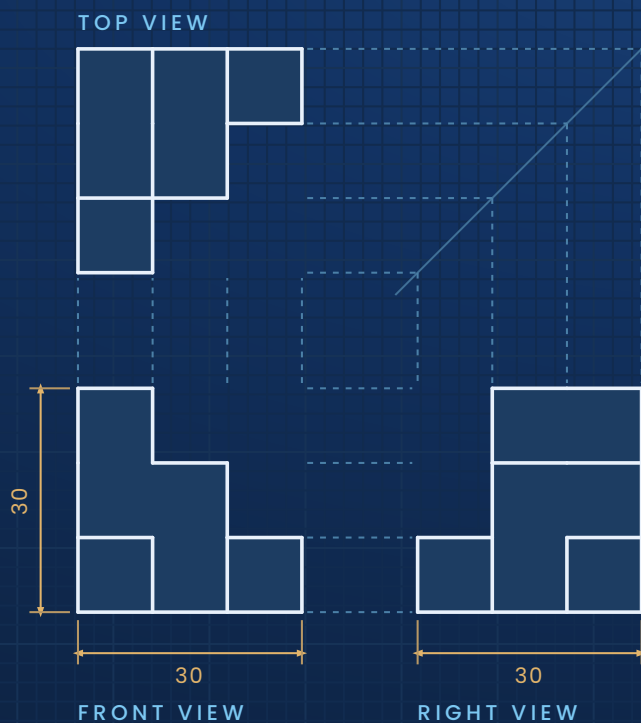


Spatial Reasoning for Engineers

Practice tests in rotation, paper folding,
orthographic projection and
cross-sections, in the style of the PSVT:R,
MCT and DAT



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COMPANION APP INCLUDED

Unlimited practice · Timed tests · 3D viewer

AUTHOR

Dr Irfan Hilmy

Lecturer in Mechanical Engineering

CONTENTS

330+ puzzles

12 chapters · 2 full tests

PROJECTION



EDITION

Standard Colour

Edition

Spatial Reasoning for Engineers

Practice tests in rotation, folding, orthographic projection and cross-sections

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Reasoning for Engineers series, Book 1.

First edition, 2026. ISBN 9798178892442 (paperback, standard colour)

This book is an independent practice resource. It is not affiliated with, endorsed by, or a substitute for the Purdue Spatial Visualization Test: Rotations (PSVT:R), the Mental Cutting Test, the Dental Admission Test, the Differential Aptitude Tests, the Armed Services Vocational Aptitude Battery (ASVAB), the Kit of Factor-Referenced Cognitive Tests of the Educational Testing Service (ETS), or any other official test. Test names are used only to describe question formats and belong to their respective owners. Scores in this book are for self-assessment and are not comparable with scores on any official test.

Every puzzle in this book was generated by computer, and each answer was checked by computation to be the only correct option.

hilmybox.com

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How to use this book

Spatial skill improves with practice, often quickly. This book is built around a simple plan: test, train, retest.

1. **Take Practice Test A first**, before reading the chapters. Allow 60 minutes. Mark it with the answer key and write down your score for each of the 12 sections.
2. **Train with the chapters**. Start with your weakest sections. Each chapter explains one task, gives a strategy, works one example and ends with a practice set of 10 questions and a fully explained answer key.
3. **Take Practice Test B** when you have worked through the chapters. It has the same question types at the same difficulty, so you can compare section by section.

The book moves from flat shapes to solids. Part I trains 2D skills. Part II connects flat drawings to 3D objects. Part III works entirely in 3D. Within each practice set, questions get harder as you go.

How each chapter works

Every chapter follows the same five steps, based on the 5E teaching model:

1 Engage	A question to get you thinking, and why engineers need the skill.
2 Explore	Two Try it first questions, before any explanation, plus a hands-on option.
3 Explain	The rules of the task, a strategy, a worked example, and the answers to Try it first.
4 Elaborate	A practice set of 10 questions, then an engineering application task.
5 Evaluate	A fully explained answer key, a model answer for the application, and a short reflection.

Companion app. This book has a free companion app with unlimited practice questions, timed tests and a 3D viewer. The address, and how to get your personal password, are on page 139, in the section "Companion app".

Timings are practice targets, not official limits. Some people find the 2D chapters easy and the 3D chapters hard, or the reverse. That is normal: spatial ability is several related skills, not one.

About the author

Dr Irfan Hilmy is a mechanical engineering lecturer at the Higher Colleges of Technology in Fujairah, UAE. He has about 30 years of teaching, training and research experience in Indonesia, the United Kingdom, Malaysia and the UAE, and holds a PhD in Mechanical and Aerospace Engineering from the University of Surrey. He teaches engineering drawing, CAD/CAM and mechanical design. He builds free browser-based engineering tools and spatial-reasoning games at hilmybox.com, including Cubist, a 3D projection puzzle that accompanies Chapters 7 and 8.

PART I

Thinking in 2D

Flat shapes: turning, flipping, folding, fitting and finding.

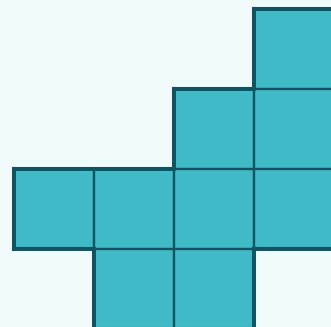
01 Rotation and Mirror Images

02 Angles and Proportions

03 Paper Folding and Hole Punching

04 Shape Assembly

05 Hidden Figures



01

PART I • CHAPTER 1

Rotation and Mirror Images



1 ENGAGE

In this chapter, we learn to see the difference between a shape that is rotated and a shape that is flipped over. This is the most basic form of mental rotation. Almost every spatial test starts with this task.

Look at your left hand and your right hand. They match finger by finger, but no rotation can change one into the other. Why is that?

Why engineers need it

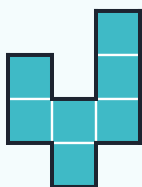
Many engineering parts are made in a left-hand version and a right-hand version. Examples are brackets, door hinges, car body panels and gear pairs. The two versions look similar, but we cannot rotate one to get the other. One is the mirror image of the other. If a drawing for the wrong hand is sent to the workshop, the result is a costly mistake. For this reason, an engineer must see the difference quickly.

2 EXPLORE

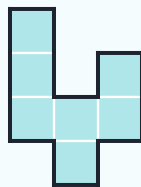
Try it first

Try these two questions before you read further. Do not worry if your answers are wrong. Notice the method that you used.

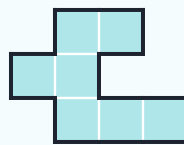
T1 Which option is the target shape rotated, without flipping?



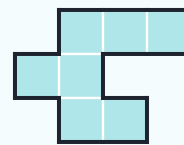
TARGET



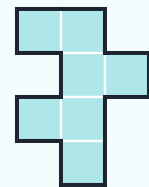
A



B

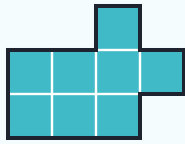


C

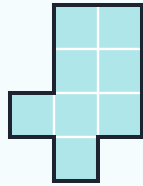


D

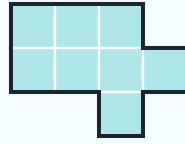
T2 Which option is the target shape rotated, without flipping?



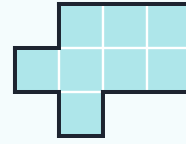
TARGET



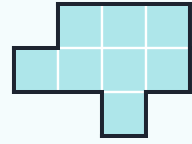
A



B



C



D

Hands-on option: Cut the target shape of T1 from squared paper. Rotate it on the table, then turn it over, and compare it with the options each time.

3 EXPLAIN

The task

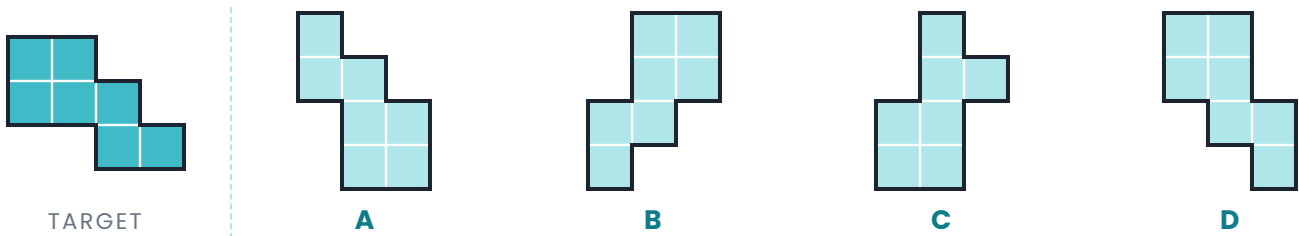
Each question shows a **target** shape made of squares. Only one of the four options is the target rotated on the page, by 90° , 180° or 270° . The other options are mirror images, which means they are flipped over. From question 6, one option may also be a slightly different shape. The size of the shape does not change.

Strategy: Anchor, then rotate

1. **Choose an anchor.** Find the most special feature of the target, for example the longest arm, a single square or an L-shaped corner.
2. **Rotate the anchor first.** In your mind, rotate each option until its anchor points in the same direction as the anchor of the target.
3. **Check one side.** When the anchors are in the same direction, look at a feature on one side of the anchor. If this feature is on the opposite side, the option is a mirror image.
4. **Do not flip.** If you need to turn the shape over in your mind to make it match, the option is wrong.

Worked example

Which option is the target shape rotated, without flipping?



Answer: B is the target turned 90° clockwise. A is a mirror image (flipped), not a rotation; C is a different shape: one square has moved; D is a mirror image (flipped), not a rotation. Put the anchor of each option in the same direction as the anchor of the target. Then check on which side the other squares are.

Check your Try it first answers

- **T1: B.** B is the target turned 90° clockwise. A is a mirror image (flipped), not a rotation; C is a mirror image (flipped), not a rotation; D is a different shape: one square has moved.
- **T2: C.** C is the target turned 180°. A is a mirror image (flipped), not a rotation; B is a mirror image (flipped), not a rotation; D is a different shape: one square has moved.

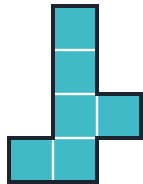
Compare your method with the strategy above. Which step did you already use, and which step was new for you?

4 ELABORATE

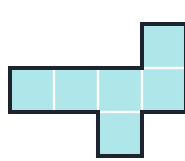
Practice set 1 · 10 questions · aim for 6 minutes

Before you start, rate your confidence with this task from 1 (not at all) to 5 (very): ____

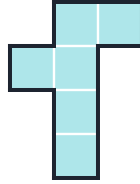
1 Which option is the target shape rotated, without flipping?



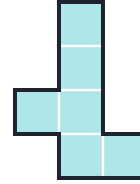
TARGET



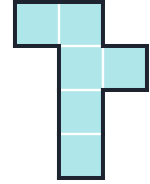
A



B

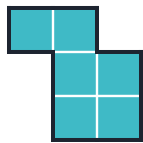


C

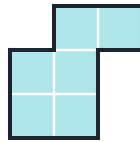


D

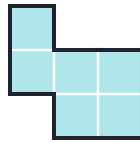
2 Which option is the target shape rotated, without flipping?



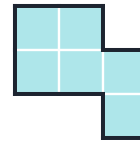
TARGET



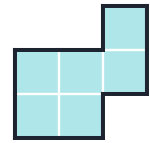
A



B

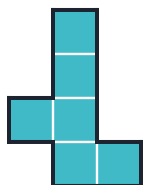


C

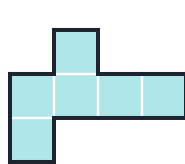


D

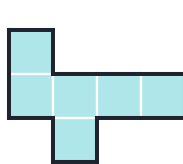
3 Which option is the target shape rotated, without flipping?



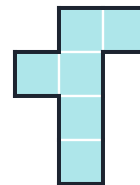
TARGET



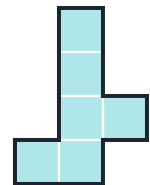
A



B

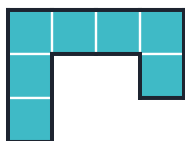


C

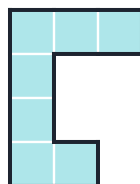


D

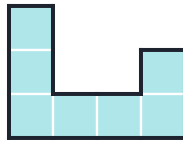
4 Which option is the target shape rotated, without flipping?



TARGET



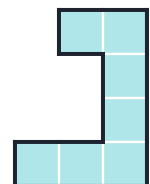
A



B

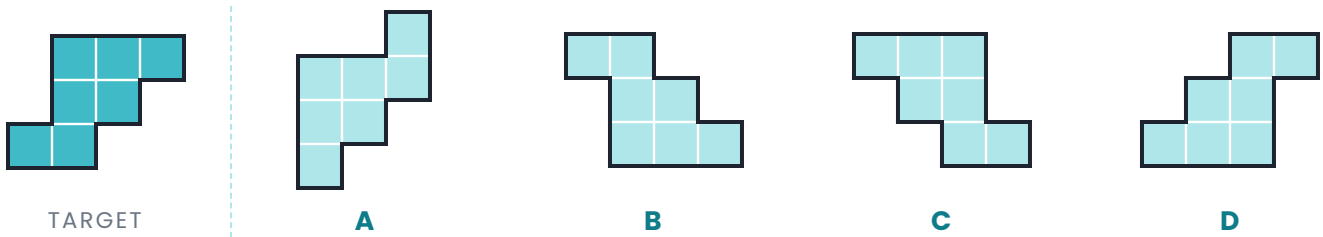


C

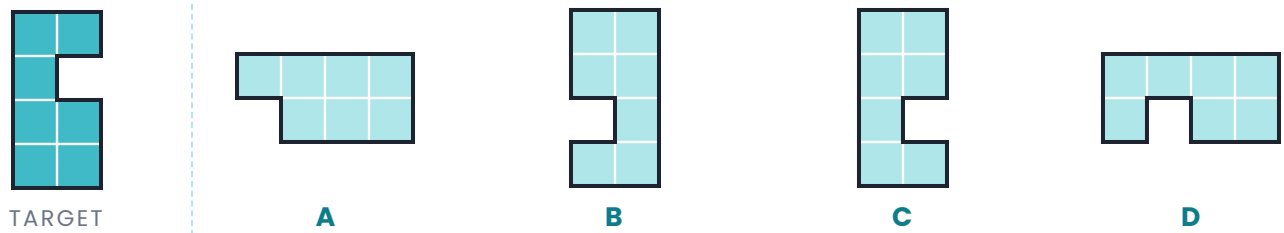


D

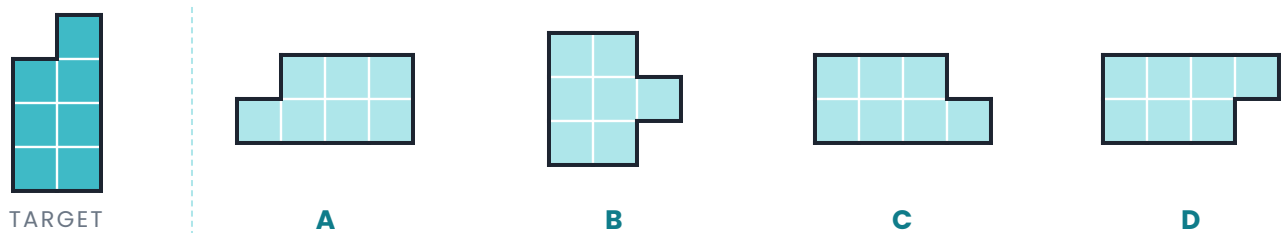
5 Which option is the target shape rotated, without flipping?



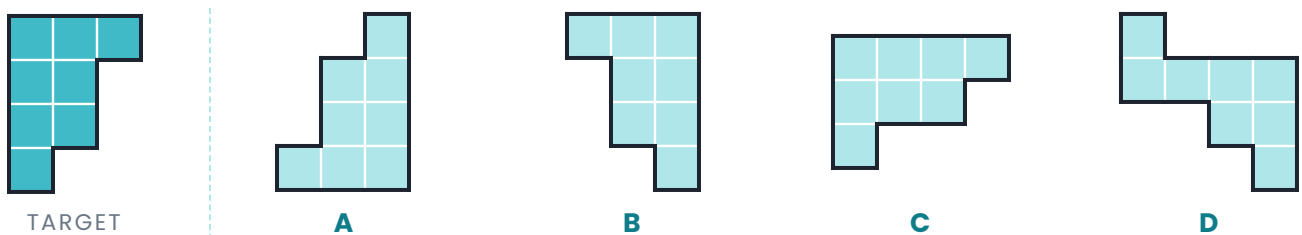
6 Which option is the target shape rotated, without flipping?



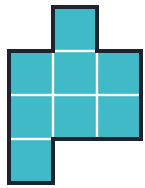
7 Which option is the target shape rotated, without flipping?



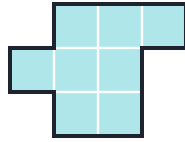
8 Which option is the target shape rotated, without flipping?



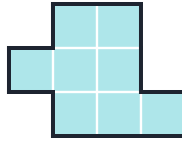
- 9 Which option is the target shape rotated, without flipping?



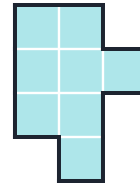
TARGET



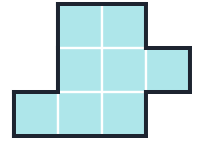
A



B

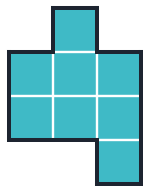


C

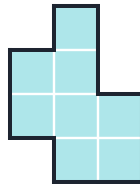


D

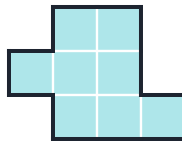
- 10 Which option is the target shape rotated, without flipping?



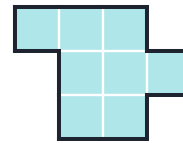
TARGET



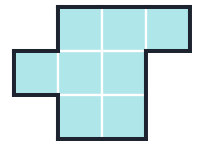
A



B



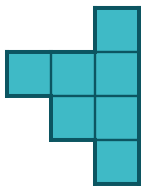
C



D

Engineering application

A drawing shows the **left-hand** version of a mounting plate. The plate is countersunk on its top face only, so it cannot be turned over. Sketch the **right-hand** version on squared paper. Can we simply rotate a left-hand plate on the bench and use it as the right-hand plate?



Left-hand plate

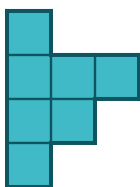
A model answer is in the Evaluate section.

5 EVALUATE

Answers: Practice set 1

Q	ANS	EXPLANATION
1	B	B is the target turned 180°. A is a mirror image (flipped), not a rotation; C is a mirror image (flipped), not a rotation; D is a mirror image (flipped), not a rotation.
2	D	D is the target turned 90° clockwise. A is a mirror image (flipped), not a rotation; B is a mirror image (flipped), not a rotation; C is a mirror image (flipped), not a rotation.
3	A	A is the target turned 90° clockwise. B is a mirror image (flipped), not a rotation; C is a mirror image (flipped), not a rotation; D is a mirror image (flipped), not a rotation.
4	C	C is the target turned 90° clockwise. A is a mirror image (flipped), not a rotation; B is a mirror image (flipped), not a rotation; D is a mirror image (flipped), not a rotation.
5	D	D is the target turned 180°. A is a mirror image (flipped), not a rotation; B is a mirror image (flipped), not a rotation; C is a mirror image (flipped), not a rotation.
6	B	B is the target turned 180°. A is a different shape: one square has moved; C is a mirror image (flipped), not a rotation; D is a mirror image (flipped), not a rotation.
7	C	C is the target turned 90° clockwise. A is a mirror image (flipped), not a rotation; B is a different shape: one square has moved; D is a mirror image (flipped), not a rotation.
8	A	A is the target turned 180°. B is a mirror image (flipped), not a rotation; C is a mirror image (flipped), not a rotation; D is a different shape: one square has moved.
9	B	B is the target turned 90° anticlockwise. A is a mirror image (flipped), not a rotation; C is a different shape: one square has moved; D is a mirror image (flipped), not a rotation.
10	D	D is the target turned 90° anticlockwise. A is a different shape: one square has moved; B is a mirror image (flipped), not a rotation; C is a mirror image (flipped), not a rotation.

Engineering application: model answer



Right-hand plate

The right-hand plate is the mirror image. No. The outline has no line of symmetry, so rotating it can never give its mirror image. Also, because of the countersinks, the plate cannot be turned over. It is a separate part and needs its own drawing and part number.

Reflect and next steps

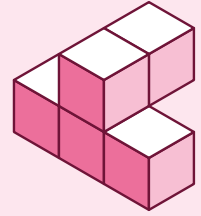
Score: _____ / 10. Confidence now, from 1 to 5: _____. If your confidence increased more than your score, or the opposite, look again at the questions that you answered wrongly.

8 or more correct: continue to Chapter 2. 5 to 7 correct: do the set again with the anchor method, and say the anchor aloud. 4 or fewer: cut the target shapes from squared paper and rotate them by hand for a few questions. Holding the real shape helps you to build the picture in your mind.

A

PART IV • PRACTICE TESTS

Practice Test A



60 questions in 12 sections of 5, one section per chapter. Allow 60 minutes.

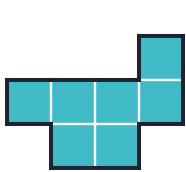
Instructions

- Work in a quiet place and time yourself. Stop at 60 minutes, even if you have not finished.
- Choose one answer for each question. Record your answers on a separate sheet or the answer grid at the end of the test.
- Do not use a ruler, a protractor or blocks during the test. You may use them afterwards to check your mistakes.
- The rules for each question type are the ones given in its chapter.
- Take this test before you start the chapters, to find your strong and weak sections.

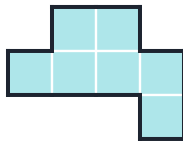
SECTION 1 Rotation and Mirror Images

Questions 1–5

1 Which option is the target shape rotated, without flipping?



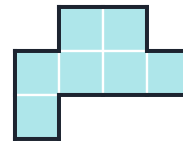
TARGET



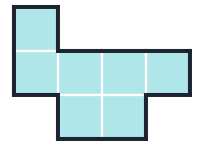
A



B

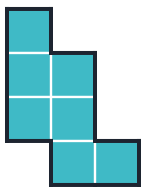


C

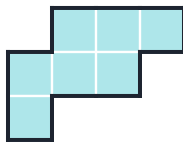


D

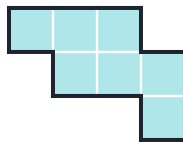
2 Which option is the target shape rotated, without flipping?



TARGET



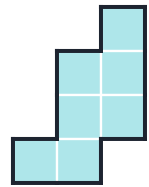
A



B

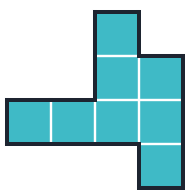


C

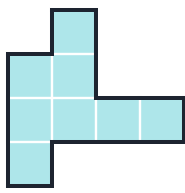


D

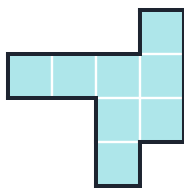
3 Which option is the target shape rotated, without flipping?



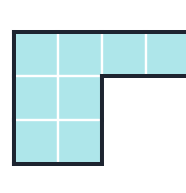
TARGET



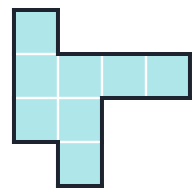
A



B

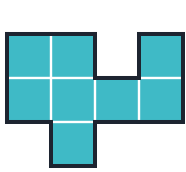


C

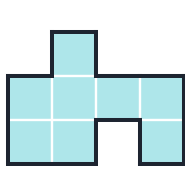


D

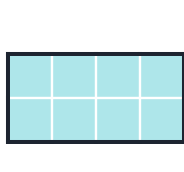
4 Which option is the target shape rotated, without flipping?



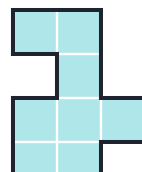
TARGET



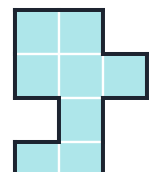
A



B

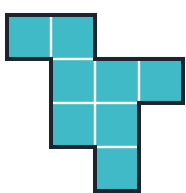


C

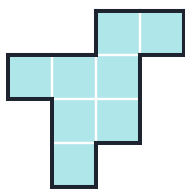


D

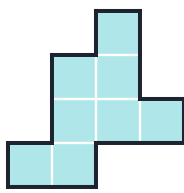
5 Which option is the target shape rotated, without flipping?



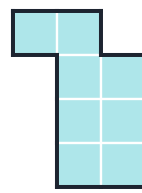
TARGET



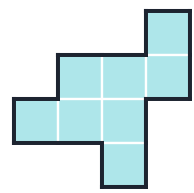
A



B



C



D

SECTION 2 Angles and Proportions

Questions 6–10

6 Rank the four angles from **smallest to largest**.



1



2



3



4

A 2 – 4 – 1 – 3

B 1 – 2 – 4 – 3

C 2 – 1 – 4 – 3

D 3 – 1 – 4 – 2

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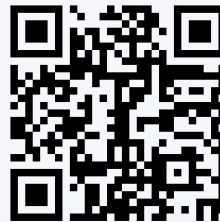
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