Year 8: Quadrilateral Linkages
Lesson 5: Cherry Picker

Australian Curriculum: Mathematics (Year 8)

ACMMG201: Develop the conditions for congruence of triangles.
- Solving problems using the properties of congruent figures.

ACMMG202: Establish properties of quadrilaterals using congruent triangles and angle properties.
- Establishing the properties of squares, rectangles, parallelograms, rhombuses, trapeziums and kites.
- Identifying properties related to side lengths, parallel sides, angles, diagonals and symmetry.

Lesson abstract

Students investigate the design and operation of an aerial work platform commonly called a cherry picker to see how the geometric properties of parallelograms contribute to how the work platform is maintained in a horizontal position and how changing shapes of the parallelograms allow the work platform to be manouvered into different positions. They construct a physical model and use a computer simulation of the cherry picker. They also see how articulated parallelograms are used in robotic arms in certain machinery and design a robotic arm for cake icing.

Mathematical purpose (for students)

A linkage constructed with both pairs of opposite sides equal is useful because its opposite sides remain parallel. Combining two or more parallelograms (articulated parallelograms) as in a cherry picker allows for accurate and flexible positioning of the work platform.

Mathematical purpose (for teachers)

The lesson provides an engaging context for students to make a physical model of a cherry picker and use a computer simulation to understand how the design based on parallelograms allows the work platform to remain horizontal while the changing shapes of the parallelograms allows flexible movement.
The task can be presented to students alongside the *Folding umbrella* and *Toolbox* activities. It is anticipated that the three activities together would require two 50–60 minute lessons. The slide show *ST1_Yr8_3c_IsItParallelogram.ppt* provides a stimulus for deductive reasoning, fitting well with the Australian Curriculum content ACMMG202 (see above). This is included with all three tasks in case only one of the tasks is undertaken.

Lesson Length 60 minutes approximately

Vocabulary Encountered
- vertical
- horizontal
- diagonal
- congruent
- articulated

Lesson Materials
- Slide show *ST1_Yr8_5a_CherryPickerImages.pptx*
- Geo Strips or similar (4 identical strips per pair of students)
- Paper fasteners (10 per pair of students)
- Connector brackets and work platform (one set per pair, or two per pair if students also design cake icing robot, with scissors to cut out)
- GeoGebra file *St1_Yr8_5b_CherryPicker.ggb*
- OR Geogebra Tube https://ggbm.at/EhRJEtrc
- Student Sheet 1 – Cherry Picker (1 per student, optional)

Mathematics by Inquiry is an initiative of, and funded by, the Australian Government Department of Education and Training

Australian Academy of Science

aamt

Introducing the Cherry Picker

Many machines include flexible arms constructed from two or more parallelogram linkages. These *articulated parallelograms* allow accurate control over position as well as direction. Articulated parallelogram linkages are used in construction machinery such as the aerial work platforms known as 'cherry pickers'. An early use of these elevated work platforms was for picking cherries in orchards.

The parallelogram linkages keep the platform horizontal whilst allowing very accurate control of the position of the work platform. The cherry picker also includes a telescopic boom. The two parallelograms are linked together by a connector bracket.

In this image, there are two parallelogram linkages between the base and the telescopic boom. A third parallelogram linkage connects the telescopic boom with the work platform.

Image courtesy of JLG Industries (Australia).

Identify important features of a cherry picker

- Show students images of a cherry picker in the slide show *ST1_Yr8_5a_CherryPickerImages.pptx*. Cherry pickers are commonly seen around building sites. Students may have seen one in action recently.
- Discuss what the cherry picker is for and how it works. What are its key features?

Expected Student Responses

- The cherry picker is designed to move a work platform, especially to reach something high.
- The cherry picker has a stable base so that it doesn't slip.
- For safety, the work platform stays horizontal.
- The work platform can move sideways but not too far, so that stability is maintained.
- The cherry picker folds up neatly for storage.
- Students may also suggest that angles in the connectors are important to maintain horizontal positioning of the work platform.

Making a physical model

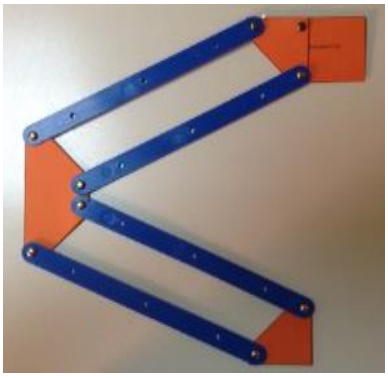
Students now make a simplified cherry picker with only 2 arms. The 2-dimensional model can be made using Geo Strips to represent the arms and pieces of card to represent connectors and the work platform, using paper fasteners to connect the various components together.

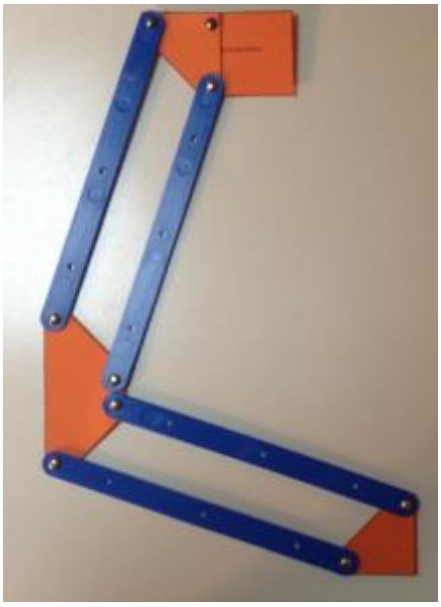
The cherry picker model is shown here with Geo Strips for the arms. The rigidity of Geo Strips makes it easier to assemble and move the model compared with using strips cut from card for the arms.

Ask students to observe some geometric features in their models, including as they move. It is not necessary for students to observe parallelograms at this stage: just equal and parallel line segments.

Expected Student Responses

- The pairs of blue arms are always parallel and of equal length.
- The facing sides of the connectors are always parallel.
- The distances between the connection points are equal (and do not change).
- There are pairs of equal angles in the connectors (about 40 - 45 degrees).
- The pairs of bars forming the arms make parallelograms with the connector edges.





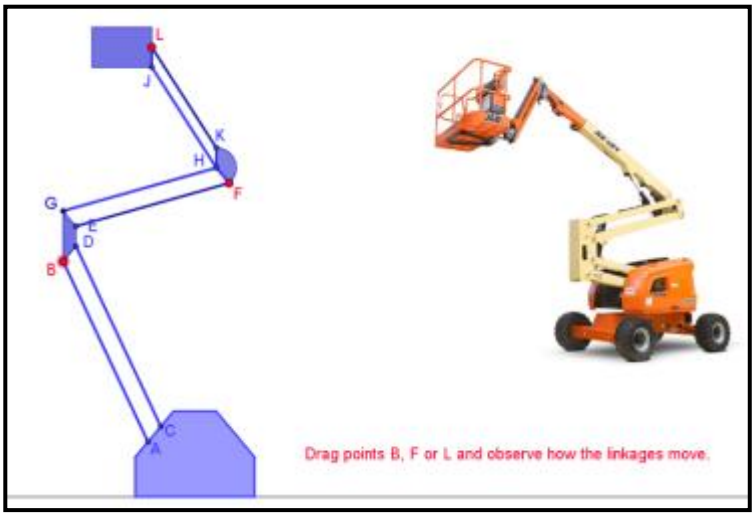
Using a computer simulation

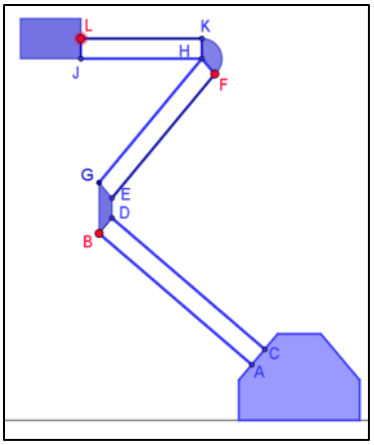
The simulation shows a three arm cherry picker, without a telescopic boom. Three different points in the GeoGebra simulation *St1_Yr8_5b_CherryPicker.ggb* can be dragged so students can see the flexibility in positioning the work platform and see how the articulated parallelograms and the connectors enable the work platform to remain horizontal.

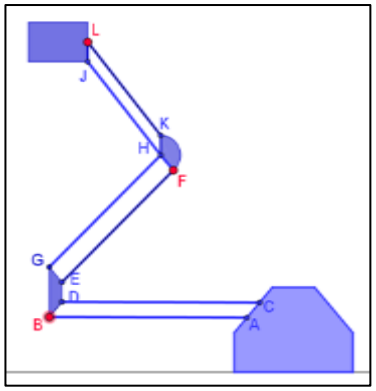
Using the model, students can observe

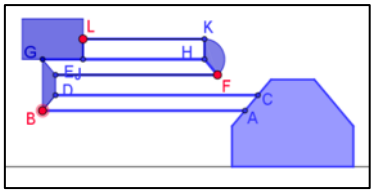
- How high the platform can go.
- How far away from the base the platform can go.
- If the platform can go below the level of the base.
- How the cherry picker can be lowered for compact storage and transport.

They can also see the parallelogram linkages more clearly, so at this point, the discussion can make the geometry precise.









Pick-and-Place Robots

Many 'pick-and-place' robots designed to pick up an object and place it in a different position incorporate parallelogram linkages into the robotic arms. The following video shows a robot in action picking up and placing batteries in sets.

http://thekidshouldseethis.com/post/two-ultra-fast-robots-pick-place-batteries-to-form-group-patterns

The construction toy *Vex-robotics Pick-and-drop machine* is a good example of parallelogram linkages in operation in a robot. The robot can be seen in action on the Hexbug website and on the Australian Geographic website:

https://www.hexbug.com/vex-robotics-pick-drop-ball-machine.html

http://shop.australiangeographic.com.au/vex-robotics-pick-and-drop-ball-machine-by-hexbug.html

Keeping the Work Platform Horizontal

Why does the work platform remain horizontal?

Using the labels on the computer simulation:

- The bars AB and CD are of equal length, and the lengths of AC and BD are designed to be equal.
- Therefore the quadrilateral ABDC has two pairs of sides of equal length, and hence it is a parallelogram.
- Similarly quadrilaterals GEHF and HJLK are parallelograms.
- The angles in the connectors are chosen so that the platform wall is held vertically.

Deductive Reasoning

Two directions for deductive reasoning arise from keeping the work platform horizontal.

(a) The quadrilaterals are constructed so that they have two pairs of sides of equal length. Why does this make them parallelograms?

(b) How have the connectors been designed so that the platform is held vertically – in particular, what are the relationships between the angles?

To follow path (a), use the deductive reasoning resources that are supplied with the lessons *Folding Umbrella* or *Toolbox* and the slide show *ST1_Yr8_3c_IsItParallelogram.ppt*. The reasoning requires the use of congruent triangles.

To follow path (b) requires parallel line properties.

- First look at the two arm linkage of the physical model.
- For extension, students could work out how the connectors are constructed for the three arm linkage in the computer simulation.

Conclusion

- Articulated parallelograms are used in the cherry picker to give flexible movement and to keep the work platform horizontal.
- These designs use the geometry of quadrilaterals and parallel lines.

Designing a Cake Icing Robot

A large bakery makes hundreds of cup-cakes. A robotic arm constructed from a double parallelogram linkage moves over the trays of cupcakes, squirting icing on top of the cakes. The icing nozzle must always remain in a vertical position.

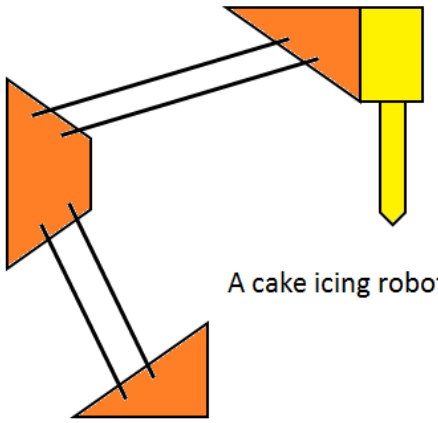
The lower parallelogram linkage is attached to a table by the lowest connector.

Students are asked to construct a model of the robotic arm showing how the parallelogram linkages could be connected to ensure that the icing nozzle stays vertical.

Students will need a second set of connectors and more Geo Strips and paper fasteners for their models.

Students will need to think carefully about the angles at which the two parallelogram linkages are connected and the careful placement of the paper fasteners in the connectors. There may be several possible ways of connecting the two parallelograms but the angles chosen will influence how the upper parallelogram is connected to the icing nozzle.

One solution is shown below.



A cake icing robot.

Cherry Picker

Name: _____

Many tools and construction work platforms include flexible arms constructed from two or more parallelogram linkages. These '**articulated parallelograms**' allow accurate control over position as well as direction.

These elevated work platforms are often called cherry pickers as they were first used in orchards.

Making a physical model

- Carefully cut out the connectors from card and make holes for the paper fasteners in the positions marked.
- In this model there is no telescopic boom – the work platform connects directly to the parallelogram linkage via a connector.
- Connect the Geo Strips and connectors to make a double parallelogram linkage so that the work platform connected to the linkage will always stay horizontal.

Using a computer simulation

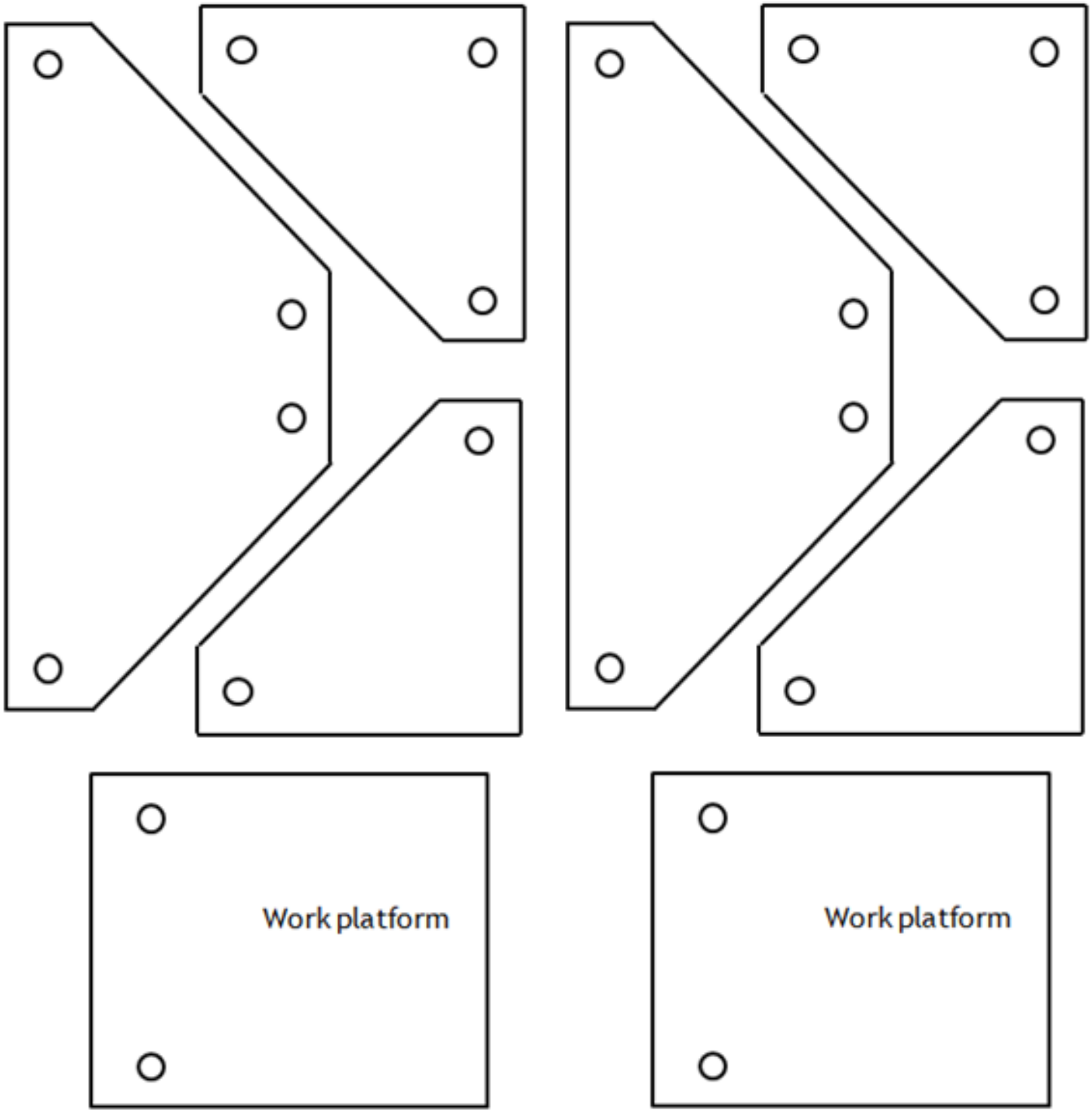
- Open the GeoGebra file *Cherry Picker*. This shows a simulation of the cherry picker.
- Drag points B, F or L to observe how the parallelogram linkages control the movement of the work platform. Observe:
    - How high the platform can go.
    - How far away from the base the platform can go.
    - If the platform can go below the level of the base.
    - How the cherry picker can be lowered for compact storage and transport.
- Why do the arms form parallelograms? Explain how the design of the cherry picker ensures that parallelograms are formed.

Design a double parallelogram linkage arm for a cake icing robot

A large bakery makes hundreds of cup-cakes. A robotic arm constructed from a double parallelogram linkage moves over the trays of cupcakes, squirting icing on top of the cakes. The icing nozzle must always remain in a vertical position.

- Construct a model of the robotic arm showing how the parallelogram linkages could be connected to ensure that the icing nozzle stays vertical.
    - You will need strips of equal length for the arms, another set of connectors, 8-10 paper fasteners, some extra card to make an icing nozzle.

Mathematics by Inquiry is an initiative of, and funded by, the Australian Government Department of Education and Training

Australian Academy of Science

Template for Cherry Picker Brackets (2 sets)