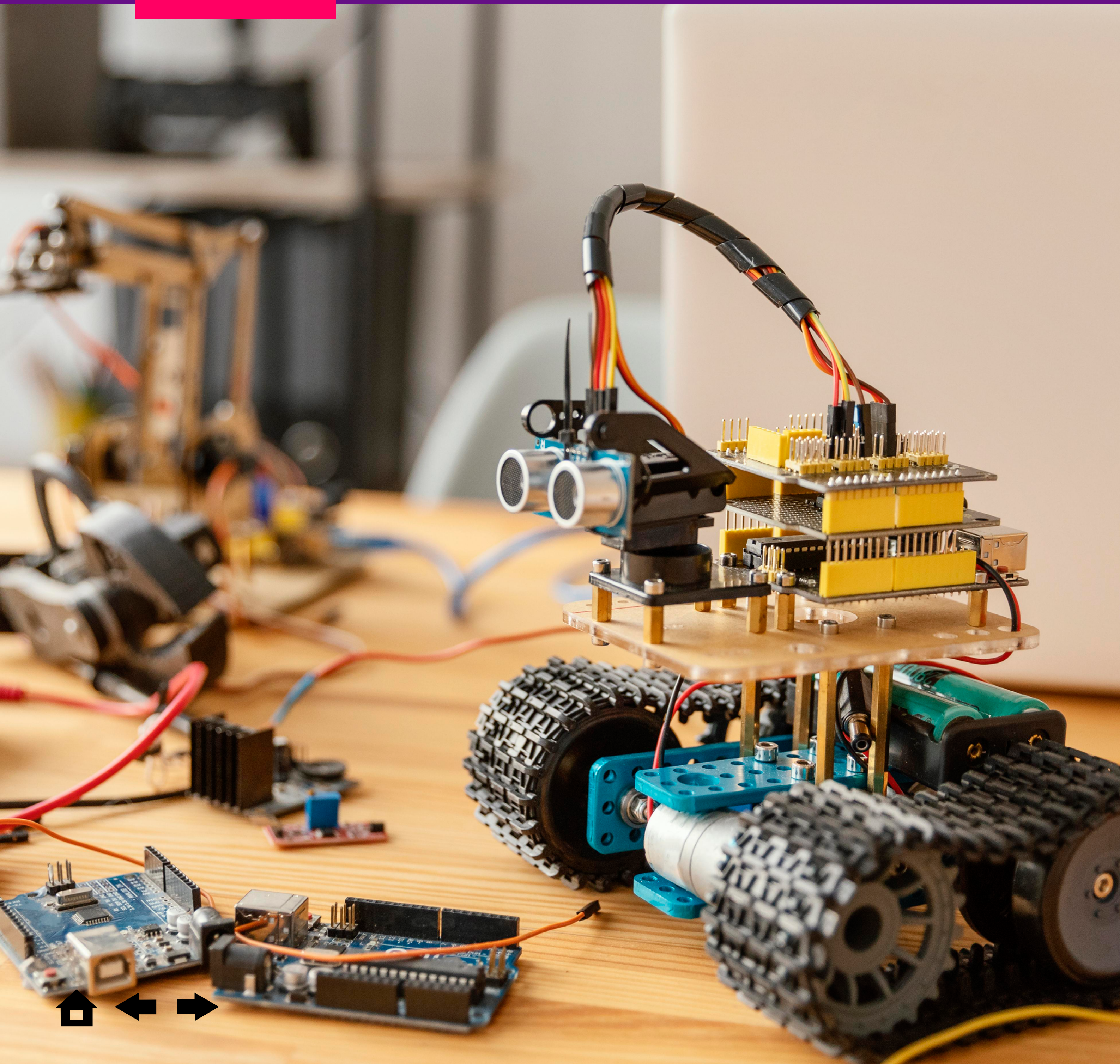
SECTION 7

ROBOT CONSTRUCTION



ROBOT CONSTRUCTION AND PROGRAMMING

Robot Construction

Introduction

This section focuses on Robot Construction. You will gain the knowledge and practical skills necessary to design and build your own robots. You will gain an understanding of the impact of mass and centre of gravity on robot stability when constructing robots using both prefabricated kits like the Lego/Arduino kits and everyday materials. You will explore the science behind stable structures and the basic mechanics behind gears, levers, and axles. By the end of the section, you should be able to design and build robots that can undertake simple tasks and move around a range of environments.

At the end of this section, you will be able to:

1. Describe the effect of mass and centre of gravity on the stability of a structure or robot and strategies for designing systems that can withstand forces.
2. Build structures for a specified use case and test them for stability and ability to withstand forces.
3. Sit in groups and create robots using robotic kits and/or local materials to implement basic mechanics for actuations that make use of the following:

   GEARS (Gear Ratios, Compound Gear Systems, changing angle of rotation using gears, using worm gears)

   VEHICLES (Driving robots with single motors, Driving robots with two motors)

   MOVING WITHOUT TIRES (Walking Machines)

   ARMS, WINGS & OTHERS (Flapping Wings, Gripping Figures, Lifting Mechanisms)

Key Ideas:

- **Mass and Centre of Gravity**: Mass refers to the amount of matter an object contains, while the centre of gravity is the point where the entire weight of an object is considered to be concentrated.
- **Stability**: It is the ability of a robot to maintain its balance when subjected to internal and external forces.

ROBOT CONSTRUCTION - DESIGNING STABLE STRUCTURES AND UNDERSTANDING MASS AND CENTRE OF GRAVITY

Building a robot with a structure that can withstand forces and maintain its stability is an important design consideration. In this section you will examine the design processes, principles of rigid bodies, and strategies for creating robots, vehicles, and other machines or devices with moving parts that help them to withstand various forces.

Understanding Rigid Bodies and Stable Structures

In robotics, a rigid body refers to an object that does not deform under external forces. Designing stable structures involves ensuring that the robot's parts are rigidly connected, preventing unnecessary movements that may affect stability during operation. Figure 18.1 shows some examples of rigid robot designs.

Fig. 7.1: Robots with rigid structures and structures that lack rigidity (Charbel Dalely, Tawk Gursel Alici, *Comparison of the proposed robotic arm system and related designs.* | *download scientific diagram* 2021)

Designing Stable Structures:

Fig. 7.2: Robotic arm showing optimised weight distribution (*Standard Bots. (2023, October 4). https://standardbots.com/blog/how-much-does-a-robot-arm-cost*)

To create stable structures for robots and machines:

1. **Plan the framework**: Carefully plan the robot's framework/body to ensure that it provides sufficient support and rigidity for all moving parts and components.
2. **Choose sturdy materials**: Select materials that are strong and rigid enough to withstand the anticipated forces and loads.
3. **Optimise weight distribution**: Distribute the robot's mass evenly to maintain a low centre of gravity, promoting stability during movement and operation.

Understanding Mass and Centre of Gravity:

Mass refers to the amount of matter an object contains. It is different to weight because mass does not change. Because weight is the force of gravity acting on the mass it can change depending on where you are. For example, your weight would be different of the moon, but your mass is the same.

Centre of gravity is the point in an object where its weight is evenly balanced. If you balance a metre ruler on your finger that is the point where the centre of gravity is found. The centre of gravity depends on the distribution of weight in an object. Tall objects with more weight concentrated to the top are not very stable and may fall over.

Understanding these principles is critical for designing stable structures that can withstand forces and perform optimally.

Effects of Mass and Centre of Gravity on Robot Stability

The mass and centre of gravity of a robot play a key role in its stability. Here's how they impact a robot's ability to stay upright and function effectively:

Mass

1. **Higher mass:** A heavier robot is harder to knock over because it has more weight. But, if the robot is too heavy, it might be big and need stronger motors to move, which can make it less efficient.
2. **Lower mass:** A lighter robot can move quickly and uses less energy. But, it can tip over more easily, especially if its weight is not spread out evenly.

Centre of Gravity

1. **Lower Centre of Gravity:** A lower Centre of Gravity provides better stability. In robots, a lower Centre of Gravity means the weight is distributed closer to the base, making it more difficult to topple over.
2. **Higher Centre of Gravity:** A higher centre of gravity increases the risk of tipping. Robots with a high centre of gravity, like some bipedal robots, may require complex control systems or additional balancing mechanisms to maintain stability.

Fig. 7.3: Tightrope walking (*Indian tightrope Walker Stock Photos - Free & royalty-free stock photos from Dreamstime*)

Think of a balancing act. A tightrope walker with a heavy backpack (high mass) might be more difficult to push off balance compared to someone carrying a light bag. However, the walker with the heavy backpack also has a higher centre of gravity, making it easier to topple if they lean too far to one side.

Applying these concepts in robot design:

Robot designers consider both mass and centre of gravity to achieve the best stability. This can involve:

1. **Strategic placement of components:** Placing heavier components lower in the robot's body lowers the centre of gravity.
2. **Counterweights:** Adding weights to the opposite side of a heavy component can help balance the centre of gravity.
3. **Wide and sturdy base:** A wider base increases the robot's footprint, making it harder to tip.

By understanding the effects of mass and centre of gravity, robot designers can create robots that are both stable and functional, allowing them to perform their tasks effectively.

Activity 7.1

a. Sketch two robots with the same body mass but one with one leg and one that has four legs.
b. Explain the difference between the two robots in terms of their weight distribution and centre of gravity. Add labels to your sketches to show how the two properties impact on the stability of each robot.
c. State which of the robots has the greatest stability and explain why it is more stable.

Activity 7.2

Using your own materials or a robot construction kit build a chassis for a four wheeled robot designed to carry a tall, heavy box. The chassis must have a high stability to carry the box without it falling over.

a. Make a list of the things you considered to make the chassis as stable as possible.
b. Explain how you considered mass and centre of gravity in your design.
c. Test your design over different surfaces. You could pull it or fix motors to provide traction.
d. Record the results of your tests, suggest improvements which might make the chassis and its load more stable.

Activity 7.3

Collect images of robots with different designs from the Internet. How do their designs affect their stability? What measures have been put in place to improve their stability?

BUILDING AND TESTING ROBOT STRUCTURES: ENSURING STABILITY AND FORCE RESISTANCE

This part of section 7 will introduce you to more practical aspects of constructing robots. You will focus on ensuring the robot has stability and the ability to withstand forces right from the initial design and through to the building process.

Understanding Use Case Requirements

Before a robot is built, you have to know its specific purpose, use and functional requirements. This is essential for every robot design because it means that costly mistakes can be avoided.

Below are some factors that should be considered at the design stage before constructing a robot:

1. **Task and Environment**: Think about what the robot will do and where it will work. For example, a robot that needs to water plants will need a water tank, while a robot that just needs to move around a room won't need one.
2. **Load Capacity**: Consider how much weight the robot will carry. For example, a robot that carries books needs to be strong, but a robot that just delivers letters can be lighter.
3. **Mobility and Manoeuvrability**: Decide how the robot should move. For example, a robot that needs to clean tight spaces might need small wheels, while a robot that moves on a flat, open floor can use bigger wheels.

Selecting Suitable Materials

Based on what the robot will be used for, materials that provide the necessary strength, rigidity, and durability are chosen. Common materials used in robot construction include:

1. **Metals**: Aluminium and steel are strong yet light, making them perfect for building robot arms that need to lift heavy objects.
2. **Plastics**: Lightweight and flexible plastics are great for making small robots, like toy robots or prototypes that need to be built quickly.
3. **Composites**: Materials like carbon fibre are very strong and light, ideal for advanced robots like drones that need to fly and carry cameras.

Example of Building a Robot Car Chassis:

The links below will guide you in building a robot car chassis considering the use and materials.

Reference Link	QR Code
1. Follow the link below to build a robot car chassis using the Arduino Kit: https://randomnerdtutorials.com/build-robot-car-chassis-kit-arduino/	
2. Follow the link below to build a robot car chassis using the LEGO® EV3 Kit https://www.youtube.com/watch?v=LxJwJt_V7uI	

Testing for Stability and Force Resistance:

Once the robot structure is built, it is time to put it to the test. The following are tests that you can use to assess a robot's structure.

1. **Stability test:** Evaluate the robot's stability by simulating various movement scenarios, such as turning, accelerating, or stopping abruptly.
2. **Load test:** Test the robot's ability to withstand the expected load by gradually adding weight or applying force to critical points.
3. **Impact test:** Assess the robot's resistance to impacts or external forces that it may encounter in its intended environment.

Follow the links below to watch videos on testing the stability and force resistance of some robots

Reference link	QR code
a. https://www.youtube.com/watch?v=aFuA50H9uek	

Reference link	QR code
b. https://www.nist.gov/video/robotic-hand-performance-testing	

Activity 7.4

Read each of the following use cases:

Case 1 - Construction robots often work in harsh environments and need to handle heavy materials like bricks and steel beams.

Case 2 - Underwater robots are used for exploring the ocean or inspecting underwater structures, these robots must endure water pressure and currents.

Case 3 - Space robots are used in space missions. The robot that landed on the planet Mars, the Mars Rover, must withstand extreme temperatures, radiation, and the force of landing on a planet's surface.

a. List the forces which need to be considered when designing robots to work in each of the use cases.

b. Outline the materials that would be used in each of the use cases. Include the type, strength, thickness of materials and why these have been chosen for each use case.

c. Sketch designs for the structure of a robot for each use case and describe how you would test the stability and functionality of each one.

Activity 7.5

Design a robot arm which is designed to lift a load of 10Kg to a height of 2 metres.

1. Research and select suitable materials for the arm.
2. Use a virtual platform like Tinkercad to design the arm
3. Ensure the robot structure has strong connections.
4. Using the virtual platform Tinkercad, you can conduct several tests on your robot arm to ensure it functions correctly. Here are a few examples:

   Movement Test: Simulate the movement of the robot arm to check if all joints and motors are working as expected. You can test different angles and positions to ensure smooth operation.

Load Test: Test the robot arm's ability to lift and hold different weights. This helps you understand the maximum load capacity and identify any weak points in the design.

Range of Motion Test: Check the range of motion for each joint to ensure the arm can reach all necessary positions. This is important for tasks that require precise movements.

Collision Detection Test: Simulate scenarios where the robot arm might collide with objects. This helps in programming the arm to avoid obstacles and operate safely.

CREATING ROBOTS WITH BASIC MECHANICS - EXPLORING GEARS, VEHICLES AND MOVING MECHANISMS

This section focuses on exploring basic mechanics in robotics by creating simple robots. You will learn how to use gears, motors, and other components to build robots that move in different ways. Whether using kits or everyday materials, the goal is to understand how these parts work together to make robots move and perform tasks.

Understanding Gears Types

Gears are mechanical components used to transmit motion and power between rotating shafts. Gears are special wheels with teeth that mesh (fit together) with other gears. When one gear turns, it makes another gear turn thereby transmitting motion and power in robots to move parts, change speed, and even lift things.

Types of Gears:

Different types of gears offer specific advantages and applications based on their designs and functionalities. In the next section you will explore three common types of gears used in robotics, spur gears, bevel gears and worm gears.

1. **Spur Gears:** Spur gears are a type of gear with straight teeth that fit together directly to transfer power and movement. They are easy to make and very efficient at transferring movement. In robotics, spur gears are important because they help control how fast or slow parts of the robot move and how much force they use. Spur gears are the most commonly used type of gears because they are simple, reliable, and cost-effective.

   Applications in Robotics:

   i. **Robotic Arm Joints**: Spur gears help robotic arms move accurately, allowing them to pick up and handle objects with precision.

ii. **Gear Transmission**: They are used in robot gearboxes to transfer power from the motors to other moving parts, helping the robot operate smoothly.

Fig. 7.4: *Spur Gears (KHK USA Metric Gears. KHK. (n.d.))*

2. **Bevel Gears:** Bevel gears have teeth cut on cone-shaped surfaces and are used to transfer motion between shafts that meet at an angle, usually 90 degrees. They come in different types, like straight bevel gears and spiral bevel gears, and are great for changing the direction of movement in tight spaces.

Fig. 7.5: *Bevel Gears (Thomas J.S. Cross. (n.d.). (PDF) generation of non-circular spiral bevel gears by face-milling method. A spiral bevel set)*

Applications in Robotics:

i. **Differential Mechanisms**: Bevel gears are often used to help robots distribute power to the wheels, allowing for smooth turns.

Follow the link below to see the differential mechanism in action!

Reference Link	QR Code
https://www.youtube.com/watch?v=SOgoejxzF8c	

ii. **Gearboxes for Robotics with Non-parallel Shafts**: Bevel gears are used when the motor shaft and output shaft are not in the same plane or line up.

3. **Worm Gears:** Worm gears consist of a screw-like part (the worm) that meshes with a toothed wheel (gear). They provide high gear ratios, making them ideal for applications requiring a lot of force (torque) and reduced speed. Worm gears are highly efficient in one direction but have a lower efficiency in the reverse direction. As a result, they are commonly used in applications where moving in the backward (reverse) direction is not desired.

Fig. 7.6: Worm Gears (*Worm Gears*. Stahl Gear & Machine Co. (2021, February 11))

Reference Link	QR Code
Robot Gripper Mechanism using a worm gear in SolidWorks. https://www.youtube.com/watch?v=qKZLx1wtFCk	

Applications in Robotics:

1. **Robotic Arms and Grippers**: Worm gears give precise control and stop the parts from moving backward, making them ideal for arms and grippers.
2. **Lifting Mechanisms**: Worm gears help robots lift heavy objects with less effort.

In robotics, choosing the right gear depends on what the robot needs to do, such as controlling motion, changing direction and providing the right amount of power. Different gears are suited for different tasks, and as technology grows, new gear designs will continue to improve how robots work.

Activity 7.6: Build A Simple Gear System

- Objective: Understand how gears interact by building a model.
- Materials: Cardboard, scissors, toothpicks, glue, compass, pencil, A4 sheet and a ruler.
- Steps:
  1. With the supervision of your teacher and in a group of 3-5 members, cut out two gear shapes with different numbers of teeth.
  2. Connect them and observe how turning one affects the other.
- Discussion: How does changing the size of the gears affect their movement?

Follow the link below to watch a guide on how to undertake Activity 7.6:

LINK	QR CODE
Make your simple gear system (youtube.com)	

Understanding Gear Ratios

What Is a Gear Ratio?

The gear ratio tells us how many times one gear must turn for another to complete one rotation. The gear ratio represents the ratio of the number of teeth on the driving gear (the gear connected to the motor) to the number of teeth on the driven gear (the gear connected to the robot's output shaft). Gear ratios are crucial for controlling the speed and torque of robot movements.

How to Calculate Gear Ratios:

Step 1: Identify the Gears

Start by identifying the driving gear (Gear 1) and the driven gear (Gear 2). The driving gear is directly connected to the motor shaft, and the driven gear is connected to the robot's output shaft.

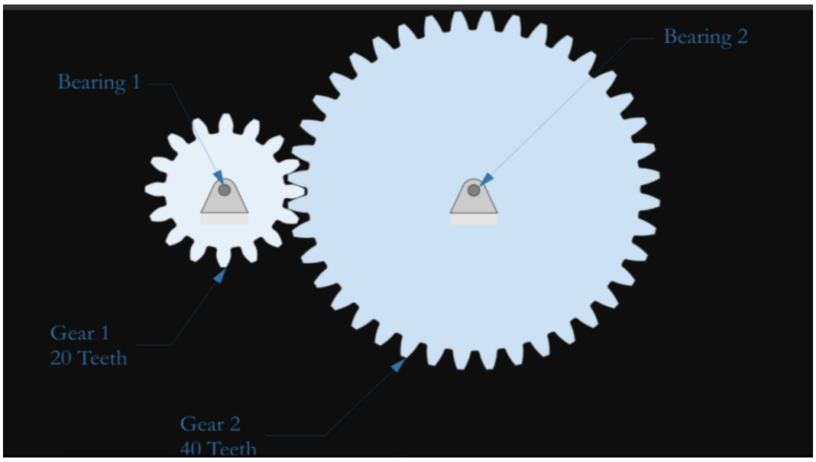


Fig. 7.7: Diagram showing Gear 1 with 20 teeth and Gear 2 with 40 teeth.

Step 2: Count the Teeth
Count the number of teeth on each gear. For example, Gear 1 (the driving gear) has 20 teeth, and Gear 2 (the driven gear) has 40 teeth.

Step 3: Calculate the Gear Ratio

To calculate the gear ratio, divide the number of teeth on Gear 2 by the number of teeth on Gear 1.

Gear Ratio = Number of teeth on driven gear / Number of teeth on driving gear

Gear Ratio = 40 / 20

This gives a figure of 2

The Gear Ratio = 2:1
This means that the driving gear has to rotate two full turns to move the driven gear ONCE.

Step 4: Interpret the Gear Ratio
The calculated gear ratio (2:1 in this case) represents how many times the driving gear (Gear 1) must rotate to make the driven gear (Gear 2) complete one full rotation. This ratio slows down the output movement to half the speed of the input.

Step 5: Speed and Torque Control
a. If the gear ratio is greater than 1 (e.g., 2:1), the output shaft will rotate at a slower speed than the motor shaft but with increased torque. This is known as a speed reduction gear, and it allows the robot to move slower but with more force.

b. If the gear ratio is less than 1 (e.g., 1:2), the output shaft will rotate at a faster speed than the motor shaft but with reduced torque. This is known as a speed-increasing gear that allows the robot to move faster but with less force.

Torque is a force that causes an object to rotate around an axis. Torque depends on the radius of the driving gear. The relationship between torque ((T)), force ((F)), and radius ((r)) is given by the formula: $T = Fr$

It is the force applied by the driving gear which generates the torque in the system. When a large drive gear moves a smaller gear, it requires less effort because the torque is distributed over a larger radius. Conversely, a small drive gear moving a larger gear requires more effort because the torque is concentrated over a smaller radius.

The gear ratio of a worm gear is determined by the number of teeth on the gear divided by the number of threads on the worm.

Activity 7.7: Calculate Gear Ratios

- **Objective:** Learn how gear ratios work.
- **Materials:** Gear models from Activity 1.
- **Steps:**
  1. Count the teeth on each gear.
  2. Calculate the ratio and predict how the gears will move.
- **Discussion:** How does the gear ratio change the speed and power of movement?

  Follow the links below to watch gear ratios in action.

LINK	QR Code
Everything about Gear ratio https://www.youtube.com/watch?v=40RX2HRKpwA	
Gear Ratio, Torque and Speed https://www.youtube.com/watch?v=R1cxzDKBFuU	

By selecting appropriate gear ratios, robotics engineers can tailor the robot's movements to suit specific applications, optimising speed and torque based on the robot's tasks and requirements. The calculated gear ratio plays a significant role in achieving efficient and precise motion control for various robotic systems.

Compound Gear Systems:

A compound gear system uses multiple gears to adjust speed and force (torque) for specific tasks in a robot. When designing such systems for different robot tasks it is important to carefully consider the desired speed, torque, and motion requirements.

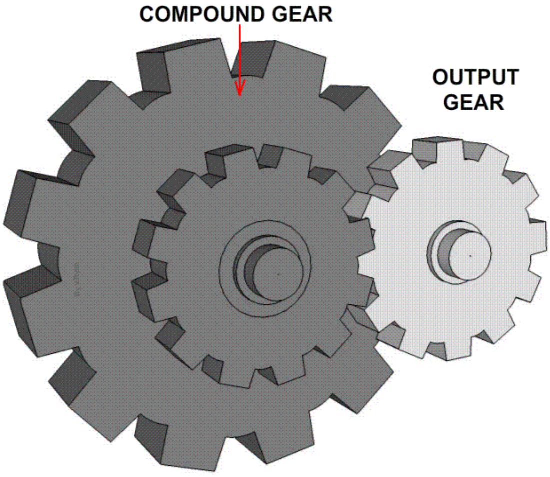


Fig. 7.8: Compound Gear Systems (V. Ryan (© 2010-16), *GEARS AND GEAR SYSTEMS*)

Steps to Design a Compound Gear System:

1. **Understand the Task Requirements**: Before designing the compound gear system, clearly define the robot task's speed and torque requirements. Determine the desired output speed and the amount of force or torque needed to perform the task effectively.
2. **Identify the Primary Motor and Output Shaft**: Identify the primary motor that will power the compound gear system. Determine the output shaft where the final motion or force will be delivered.
3. **Calculate the Gear Ratio**: Calculate the required gear ratio to achieve the desired output speed and torque. The gear ratio is the ratio of the number of teeth on the driven gear (output gear) to the number of teeth on the driving gear (input gear). The gear ratio determines how much the output shaft rotates concerning the input shaft.

   To calculate the gear ratio on systems that have more than two gears:

   Work out the ratios between intermeshed gears, then multiply the ratios.

   For example:

   To find the overall gear ratio across three gears, multiply the individual gear ratios: Overall Gear Ratio = Gear Ratio (Gear 1 to Gear 2) × Gear Ratio (Gear 2 to Gear 3)

   For example, if Gear 1 to Gear 2 has a ratio of 2:1 and Gear 2 to Gear 3 has a ratio of 3:1, the overall gear ratio would be 6:1.
4. **Choose Gear Types and Sizes**: Select the appropriate gear types based on the task requirements.

a. Spur gears: For transferring motion between parallel shafts.
b. Bevel gears: For changing direction between shafts at angles or the direction of rotation.
c. Worm gears: For big reductions in speed, and for handling heavy loads.

5. **Arrange Gear Components**: Arrange the gears in the compound gear system to achieve the desired gear ratio. The arrangement may involve multiple stages of gears, each providing a specific reduction or increase in speed and torque.
6. **Consider Efficiency and Backlash**: Keep in mind the efficiency of the gear system, as energy losses can occur during gear engagement. Additionally, account for backlash, which is the play or small gaps between the gear teeth. Minimising backlash ensures smoother and more precise movements.
7. **Ensure Adequate Support and Alignment**: Properly support and align the gears within the system. Use high-quality bearings to reduce friction and ensure smooth operation. Misalignment can lead to premature wear and reduced efficiency.
8. **Test and Optimise**: Once the compound gear system is assembled, test it under different load conditions to verify its performance. Make adjustments if necessary to achieve the desired output speed and torque.
9. **Consider Safety and Material Selection**: Pay attention to safety considerations, especially when dealing with high torque applications. Choose materials that can withstand the forces and loads involved in the robot task.
10. **Iterate and Improve**: Robot design is an iterative process (doing it again to refine the design). Continuously gather feedback and data from the robot's performance to identify areas for improvement. Modify the compound gear system as needed to achieve better results.

Determining Angle of Rotation using Gears:

When two gears mesh, they transmit motion from one to the other. The number of teeth on each gear determines the gear ratio, which affects the angle of rotation. By choosing gears with different tooth counts, you can alter the output angle of rotation relative to the input angle.

For example,

If a small gear (with fewer teeth) drives a larger gear (with more teeth), the larger gear will rotate more slowly producing a greater angle of rotation. In a robot gripper mechanism, a small driving gear and a larger gear will make the gripper open wider.

Conversely, if a larger gear drives a smaller gear, the smaller gear will rotate more quickly but with a smaller angle of rotation. In a robot gripper mechanism, a large driving gear and a smaller gear will make the gripper open narrower.

This principle is often used in robotic arms and manipulators to control the precise movement of end-effectors or grippers.

Converting Rotational Motion into Linear Motion:

Rack and Pinion Mechanism: One common way to convert rotational motion into linear motion is by using a rack and pinion mechanism. The pinion (a gear) meshes with a linear gear known as a rack. As the pinion rotates, it causes the rack to move linearly.

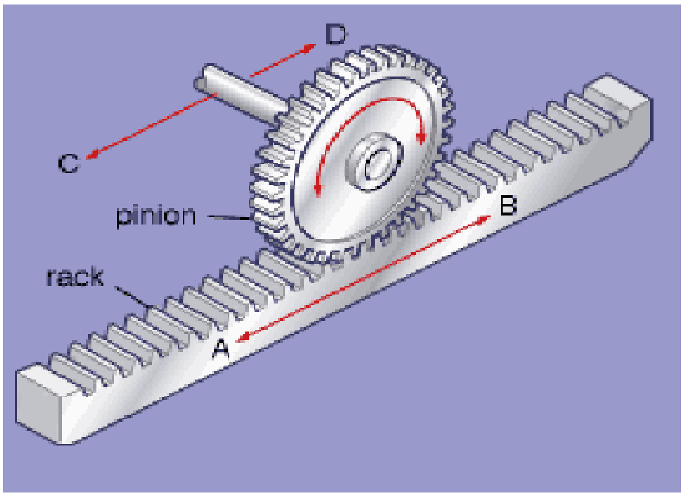


Fig. 7.9: Rack and Pinion Mechanism (*Britannica, T. Editors of Encyclopaedia (2007, April 4)*)

This mechanism is commonly employed in various robotic systems, such as CNC (computer numerical control) machines, linear actuators, and steering systems in vehicles.

Converting Linear Motion into Rotational Motion:

Lead Screw Mechanism: Another way gears can transform motion is by converting linear motion into rotational motion using a lead screw mechanism. A lead screw is a threaded rod that rotates within a nut.

Operation:

Rotating Shaft: When the screw shaft rotates, the nut moves linearly along the shaft. This is because the threads on the nut and the screw shaft engage, converting the rotational motion into linear motion.

Stationary Shaft: Alternatively, the shaft can remain stationary while the nut is rotated. In this case, the nut moves along the shaft, again converting rotational motion into linear motion.

Fig. 7.10: Lead Screw Mechanism

Lead screws are frequently used in robotic systems for precise positioning, lifting mechanisms, and in combination with motors to achieve linear motion.

If the nut is not held in place (captive), it will rotate along with the screw shaft instead of translating linearly. To ensure the nut moves linearly, it needs to be constrained in such a way that it cannot rotate.

Combining Gears in Robotics: Achieving Functionality through Synergy

Robots often rely on a combination of different gear types to achieve specific functionalities. Here is an exploration of some common scenarios:

1. **Precise Gripper Control with Powerful Base Movement (Robot Arm):**
    - **Gears Used:**
        - **Worm Gear:** Offers a high reduction ratio for precise control of the gripper's opening and closing.
        - **Spur Gears:** Deliver efficient power transfer for robust arm movement.
    - **Why Combine?**
        - A worm gear provides fine rotational control over the gripper's delicate movements.
        - Spur gears efficiently transfer power from the motor for strong and stable arm movement.
    - **Use Case:** A robot arm picks up a small object with its gripper (controlled by the worm gear) while the base rotates smoothly (powered by spur gears) to position itself for further actions.

2. **Articulated Steering with Power Delivery (Car Robot):**
   - **Gears Used:**
     - **Bevel Gears:** Change the direction of wheel rotation by 90 degrees, allowing the steering wheel rotation to translate to perpendicular causing the wheels to move either left or right.
     - **Spur Gears:** Efficiently transfer power from the motor to the wheels for driving.
   - **Why Combine?**
     - Bevel gears redirect the steering wheel's rotational input for perpendicular wheel control.
     - Spur gears ensure smooth power transfer from the motor to propel the car.
   - **Use Case:** A car robot navigates a course, using the steering wheel to control direction while the motor and spur gears provide the driving force.
3. **Linear Actuator with Efficient Power Transfer (Gripper or Lifting Platform):**
   - **Gears Used:**
     - **Rack and Pinion Gears:** Convert the rotary motion of a motor into linear motion for extending and retracting the gripper or lifting platform.
     - **Spur Gears:** Can be used within the rack and pinion mechanism to connect the motor to the pinion gear for efficient power transfer.
   - **Why Combine?**
     - Rack and pinion gears translate rotary motion into the linear movement needed for the gripper or platform.
     - Spur gears (if used) ensure smooth power transfer from the motor to the rack and pinion mechanism.

   Use Case: A robot arm uses a rack and pinion mechanism in its gripper to extend and retract for grasping objects. Spur gears within the mechanism might ensure efficient power transfer from the motor. (Note: gripper operation not included in this mechanism).

Activity 7.8: Vehicles with Single and Dual Motors

In this activity, you are to build robots with either wheels or tracks for locomotion in a group of 3-5 members. You will explore how to control them using both single and dual motor configurations to achieve different driving capabilities. This practical activity will provide valuable insights into robot mechanics and motor control.

Materials Needed:

- Robot chassis with wheel or tracks depending on the available kits.

- Motors (both single and dual motor configurations)
- Microcontroller type depending on availability.
- Battery pack or power supply

Instructions:

- Step 1: Build the robot with a single motor configuration.
- Step 2: Program it to move forward and backward using the appropriate programming language based on the robotics kit being used.
- Step 3: Experiment with the turning capabilities of the robot by using differential control.
- Step 4: Test the robot on various terrains (smooth surface, carpet, or rough terrain) to observe its performance.
- Step 5: Fine-tune the motor control program to optimise the robot's performance by adjusting the speed and tuning parameters to achieve smoother movements.
- Step 6: Repeat steps 2 – 5 for a robot with a dual motor configuration. Test the robot's turning ability by moving one motor forward and the other in reverse.
- Step 7: Analyse how the robot adapts to different surfaces and how its driving capabilities change for both motor configurations.

Reference Link	QR Code
DIY Arduino Car with 1 DC Motor, Ultrasonic Sensor & VEX Robot Parts https://www.youtube.com/watch?v=Z3FJRHGcyqo	

Walking Machines: A New Way for Robots to Move

Walking machines are robots that move using legs, similar to how animals or humans walk. These robots are designed to handle tough surfaces where wheeled robots would struggle. By copying the way living creatures move, walking machines can be more flexible, stable, and better suited for different environments. Some important features and benefits of walking machines are:

1. **Locomotion Principle**: Walking machines use legs to move, just like animals. Their legs allow them to take steps, lift off the ground, and stay balanced on uneven ground.
2. **Versatility in Terrain**: One big advantage of walking machines is that they can move on many types of surfaces. They can walk over rocks, climb stairs, move through sand or mud, and cross gaps that wheeled robots cannot.

3. **Stability and Balance**: Walking machines are built to stay balanced and stable while they move. They adjust their legs and body to stay upright, even on sloped or bumpy surfaces.
4. **Obstacle Negotiation**: Walking machines can step over or climb objects in their way. This makes them useful in search and rescue missions, especially in disaster areas where the ground is uneven.
5. **Energy Efficiency**: In some cases, walking machines use less energy than wheeled robots. Their legs allow them to move more easily over rough surfaces without using too much power as compared to rolling or sliding on wheels or tracks.
6. **Adaptability to Changing Environments**: Walking machines are very flexible and can adapt to changing environments, like disaster zones or rough outdoor areas.
7. **Biomimicry and Bio-inspired Designs**: Many walking machines are inspired by the way animals and insects move. Depending on their purpose, they can mimic the movement of insects, quadrupeds (four-legged) animals, or even bipeds (two-legged animals).
8. **Research and Exploration**: Walking machines are also used in science, especially for exploring new places like other planets. For example, they can help explore the surface of Mars and provide important information.

While walking machines have many benefits, they also face challenges, like being harder to control due to their many moving parts. Engineers and roboticists continue to work on refining the design and control of walking machines to enhance their performance and enable them to tackle even more challenging terrains and tasks.

Fig. 7.11: Walking Robots (Riccio, *Boston Dynamics' 10 robots that will change the world: Near future* 2022)

Arms, Wings & Other Actuators

Flapping Wing Aerial Robot: Designing a robot with flapping wings mimics the flight of birds and insects. These robots are perfect for exploring challenging terrains and aerial surveillance.

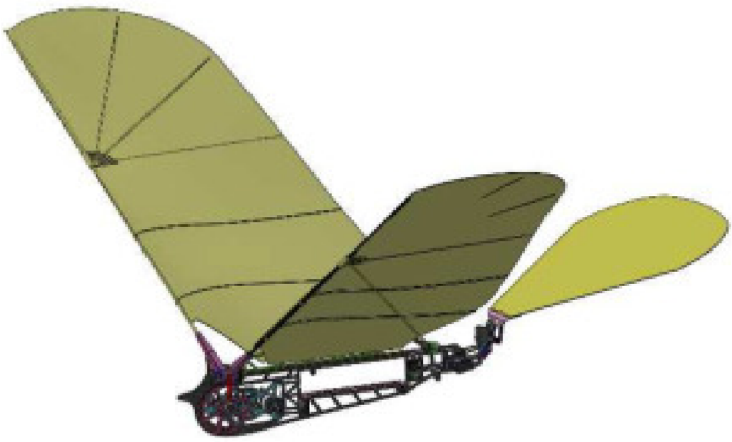


Fig. 7.12: Flapping Wing Aerial Robot (Zhong & Xu, *Power modelling and experiment study of large flapping-wing flying robot during forward flight* 2022)

Gripping Figure Pick-and-Place Robot

The gripping figure robot is designed to pick up objects from one location and place them in another. This robot is valuable in industrial automation and logistics applications.

Fig. 7.13: Gripping Figure Pick-and-Place Robot (*Robotic ARM isolated Images-Adobe Stock*)

Lifting Mechanism Robot

The lifting mechanism robot is designed to carry and transport heavy objects with precision. This robot is useful in scenarios where human strength is insufficient or dangerous.

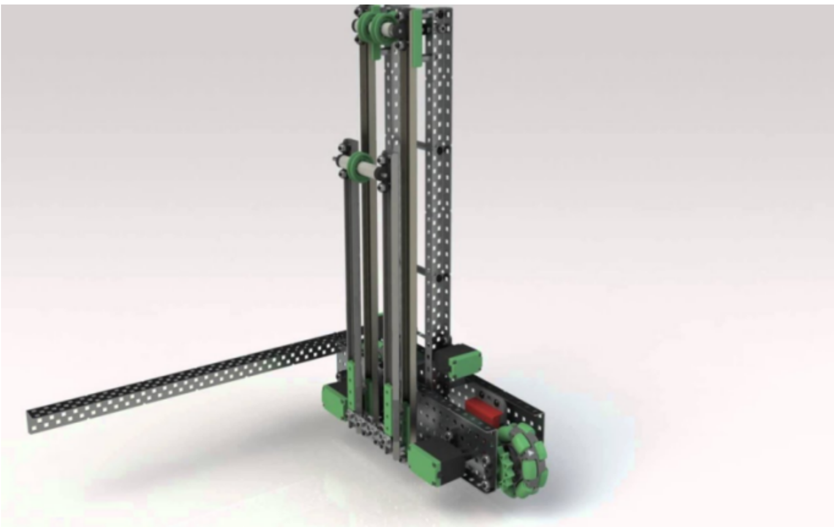


Fig. 7.14: Lifting Mechanism Robot (*254 VEX talk: Episode 3 - an overview of lifts* 2012)

Activity 7.9

You are required to design, build and program an autonomous robot firefighter that can rescue victims (golf balls or table tennis balls) from a burning building (a flat surface with wooden obstacles positioned at strategic positions by your teacher) and send them to a hospital (a box).

In a group of 3-5 members, select one of the three robot types (flapping wing, gripping figure, and/or lifting mechanism) to build.

1. Plan the robot's components and dimensions based on the area provided by your teacher.
2. Build and program the robot with the appropriate materials and actuation mechanisms.
3. Test the robot's functionality, making necessary adjustments for optimal performance.

Review Questions

Review Questions 7.1: Designing Stable Structures And Understanding Mass And Centre Of Gravity

1. Explain why a pyramid is more stable than a narrow, tall tower.
2. Explain how the mass of a robot affects its stability.
3. Compare and contrast the stability of a robot with a high centre of gravity and a robot with a low centre of gravity. What measures can be taken to address centre of gravity issues when building robots?

Review Questions 7.2: Building And Testing Robot Structures

1. Describe three tests that can be used to assess the stability and force resistance of a robot.
2. Identify two methods for creating a strong robot structure.
3. What type of material will you use to design a robot for the following applications:
   a. A lightweight and easy-to-navigate robot for a line following competition
   b. A robot to carry heavy objects in a warehouse
4. Describe three factors that should be considered before any robot is constructed.

Review Questions 7.3

1. Explain how gears can be used to speed up or slow down the actions of robots.
2. What type of gears would you use for a four wheeled robot cart which needs to move both backwards and forwards and the front wheels need to steer around obstacles? Give reasons for your choices.
3. You are designing a robot arm that needs to move slowly with high precision. Explain what type of gear and gear ratio you would choose.
4. Compare the movement of a robot with wheels to one with legs. Explain why one might be better suited to move on rough ground? Give an example of where a robot suited to rough ground might be useful.

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GLOSSARY

Bipedal: Movement on two legs

Chassis: The body or frame of a robot

Manoeuvrability: The quality of being easy to steer while in motion.

Quadpedal: Movement on four legs

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