# -MOMENTS & COUPLES-

## OBJECTIVES:

- Students will be introduced to the basic engineering principles of forces, equilibrium, moments and couples.

## PART 1:

- Students will compare actual physical results to theoretical predictions made with the use of the hands-on **QUT SQUEAK MOMENTS & COUPLES ACTIVITY KIT**.
- Students will then calculate theoretical moments using basic moment formulae.

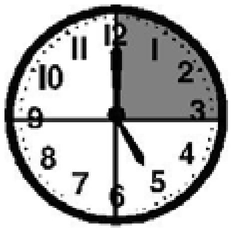
## PART 2:

- Students will experience first hand the MOMENT required to counteract an applied weight.
- Discuss the application of moments and couples in real life.

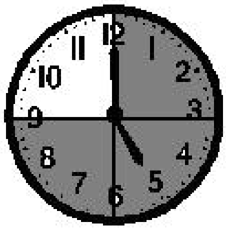
## WORDS TO KNOW:

- Moment
- Couple
- Force
- Equilibrium
- Rotation
- Perpendicular
- Lever Arm
- Clockwise & Anticlockwise
- Positive & Negative
- Newtons (N) & Kilonewtons (kN)
- Magnitude
- Direction
- Parallel
- Noncollinear
- Mass
- Acceleration
- Axis

## PREPARATION TIME:



## LESSON TIME:



## SAFETY NOTES:

Adult supervision is recommended as activity:

- Contains metal components requiring some assembly.
- Requires use of metal weights. In order to prevent accidental toppling of weights during testing – avoid over stacking of weights.

## MATERIALS:

**1 x QUT SQUEAK MOMENTS AND COUPLES ACTIVITY KIT containing:**

- Instruction and Activity Sheets
- 10 Square Hollow Beams
- 5 Balancing Fulcrums
- 10 Weight Rods
- Selection of Brass Weights
- 5 Elbow Connections

# LESSON STEPS – PART 1:

## 1. DEFINITIONS

### Force

A force is defined as the action of one body on another. A force has magnitude, direction and a point of application.

Magnitude of force is expressed in newtons (N). Force units are defined in terms of mass multiplied by the acceleration produced by gravity (9.8m/s$^2$).

For example if m= 1 kg then

Force = mass x acceleration
F= 1 x 9.8
F= 9.8 N

### Moment

A moment is a measure of rotation about a point.

The moment of a force is the product of the force and a perpendicular distance from the point of rotation.

A moment has both magnitude and direction.

### Couple

A couple consists of two equal, noncollinear, parallel forces of opposite sense.

### Equilibrium

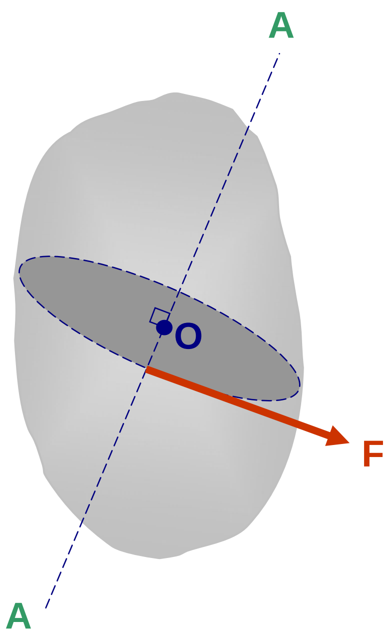
Equilibrium occurs when all the forces acting on a body are balanced.

## 2. MOMENT THEORY

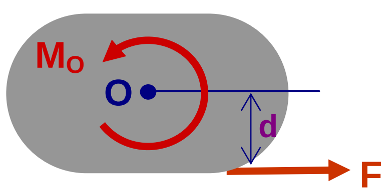
The moment of a force about a point is a measure of the tendancy of that force to rotate about that point.

For example, the moment of force **F** about point "**O**" in Figure 1(a) is a measure of the tendency of the force to rotate the body about line **A-A**. Line **A-A** is perpendicular to the plane containing force **F** and point "**O**".

Figure 1(b) shows the plane containing **F** and "**O**". Point "**O**" is called the ***moment centre***, distance "**d**" is called the ***moment arm*** and line **A-A** is called the ***axis of the moment***.




**(a)**




**(b)**

**Figure 1**

## 3. MOMENT FORMULA

The moment of a force is the product of that force by its perpendicular distance from the point of rotation.

**Moment = Force × ⊥ Distance**

**$M = F \times \perp d$**

**Note:** The sum of moments about a point is equal to zero.

$$\sum M_o = 0$$

## 4. THE UNIT OF A MOMENT

The measurement unit of a moment is the **Newton metre (Nm)**.

**REMEMBER:**

The definition of a moment is a force (measured in Newtons) multiplied by the perpendicular distance (measured in metres).

Therefore all forces & perpendicular distances must be converted to **Newtons** & **metres** respectively.

**IMPORTANT NOTE:**

Due to the scale of this activity, all readings and calculations will be made in grams and millimetres.

## 5. MOMENT SIGN CONVENTION

When dealing with moments it is important to apply a **CONSISTENT** sign convention with the direction of the moment.

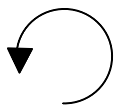
Look at which way the moment is turning. Is it turning **CLOCKWISE** or **ANTICLOCKWISE**?

**REMEMBER:**

It doesn't matter in which direction you apply the sign convention as long as you remain **CONSISTENT**.

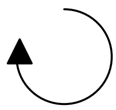
For the purposes of this activity, let us apply a sign convention:

If a moment is moving **ANTICLOCKWISE** it is considered a **POSITIVE** moment.



**= POSITIVE**

If a moment is moving **CLOCKWISE** it is considered a **NEGATIVE** moment.



**= NEGATIVE**

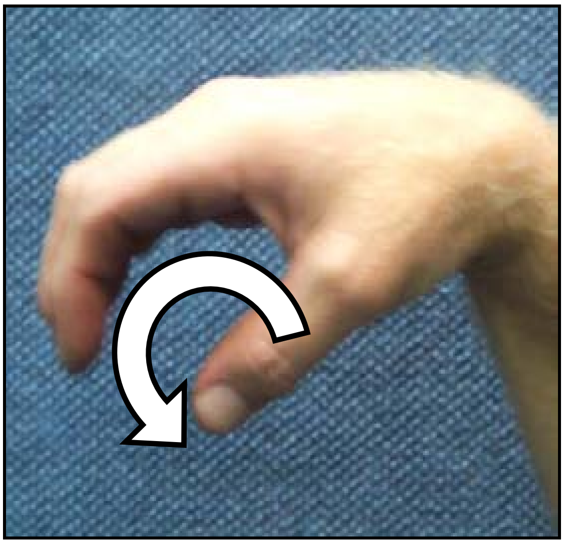
## MOMENT SIGN CONVENTION Cont'd

An easy way to remember this sign convention is by using your **RIGHT HAND** as a guide.

For a **POSITIVE** moment turning in an **ANTICLOCKWISE** direction:

- Position your hand as shown in Picture 1.
- Following the arrow with your fingertips and imagine that you are turning a doorknob in an **ANTICLOCKWISE** direction.
- You will notice that your hand is turning in the direction where you have **MORE** fingers.

**HINT**: A good way to remember this movement and its meaning is by thinking **POSITIVE** means **MORE**.

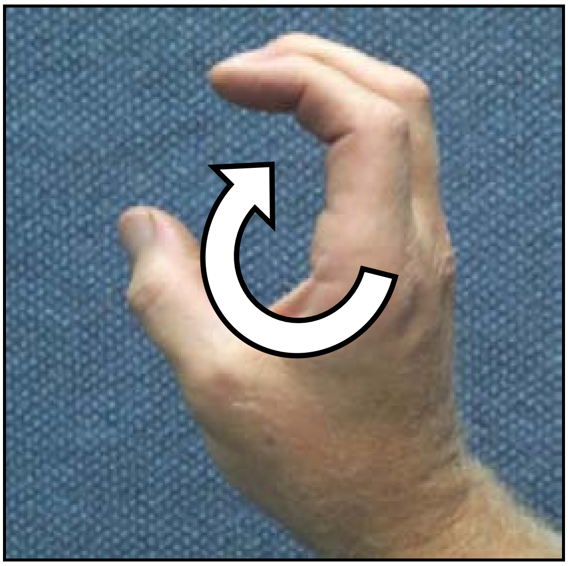


**Picture 1**

For a **NEGATIVE** moment turning in a **CLOCKWISE** direction, the same thinking applies:

- Turn the doorknob in the opposite direction (i.e. the **CLOCKWISE** direction).
- Using your thumb as the guide, turn your hand to follow the arrow as shown in Picture 2.
- Once again you should notice that you are turning your hand in the direction that has **LESS** fingers, that is, the **NEGATIVE** direction.

**HINT**: This movement is exactly opposite to the POSITIVE one therefore by using the same thinking **NEGATIVE** means **LESS.**



**Picture 2**

**NOTE:** QUT students enrolled in ENB101 are to utilise the **"Right Hand Rule"** to include axis references as discussed in lectures & SI sessions.

## 6. ACTIVITY 1.1

Activity 1.1 is aimed at familiarising us with the use of the moment formula:

**Moment = Force x ⊥ Distance**

Complete the calculations in Table 1 below.

| FORCE (N) | ⊥ DISTANCE (m) | MOMENT F x ⊥d (Nm) |
|---|---|---|
| 150 | 8 | 1200 |
| 70 | 35 | 2450 |
| 205 | 14 | 2870 |
| 4 | 18 | 72 |
| 500 | 3 | 1500 |

**Table 1**

## 7. ACTIVITY 1.2

Activity 1.2 aims to physically model moments and couples by the use of a balancing system of beams and weights. This will allow us to compare physical results with those we calculate using the moment formulae.

You will be required to use the Work Sheet for Activity 1.2. (**NOTE:** The Work Sheet can be found on page 8. Copies of the work sheet should be made for each student prior to the lesson).

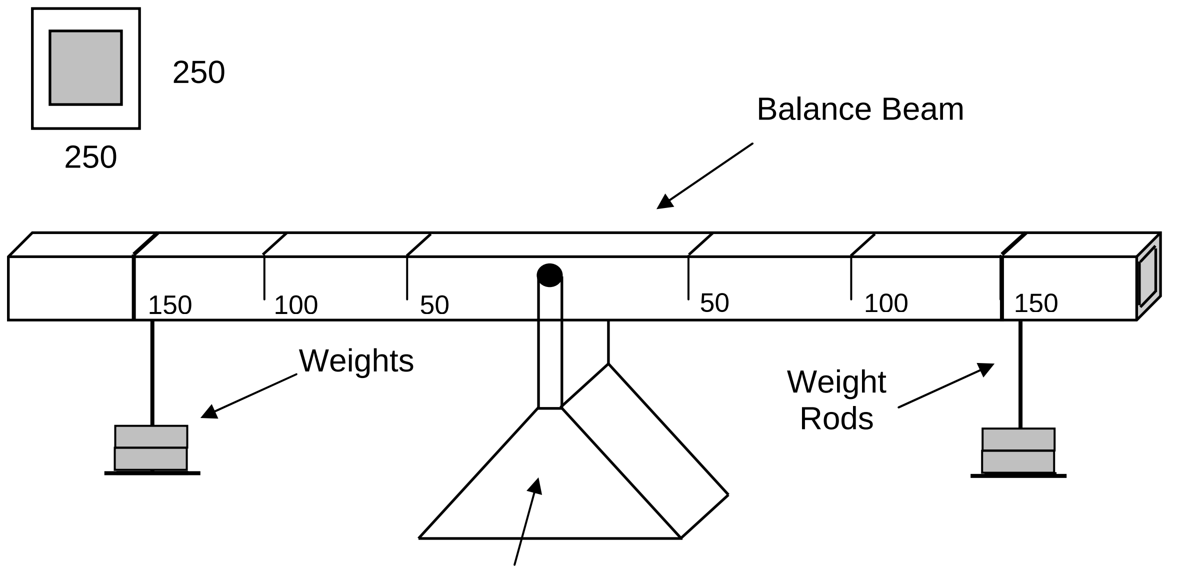



Figure 2

1. Assemble the activity by attaching the balance beam to the cradle of the balancing fulcrum as pictured in Figure 2.

2. Place one weight rod on each side of the fulcrum at equal distances along the balance beam so as to achieve balance or **EQUILIBRIUM** across the beam. Do not add weights at this point of the activity.

3. **For this portion of the activity use only the shaded area of the Work Sheet.** Load the balance beam with the given values in the first row of the Work Sheet.

4. Attempt to solve for the unknown mass or distance by applying different weights to, or moving the weight along, the left weight rod in an attempt to once again achieve balance or **EQUILIBRIUM** in the beam. **NOTE:** Do not

change any of the given values, when solving for an unknown mass only change the value of the mass you are placing on the weight rod.

**IMPORTANT NOTE:** When calculating moments in the balance beam, do not forget to allow for the self weight of the weight rods. Though the rods seem light, they are an additional force at each point of loading and therefore will contribute to the moment produced in the same way as an additional weight would.

5. Continue working through the first 4 rows of the Work Sheet and solve for all the unknown values within the shaded area. Remember to write down your answers on the sheet as you proceed.

The 2nd part of the activity will now use the **Moment Formula (Force x ⊥ Distance)** to calculate the moments from the values that you have just found.

6. Using a calculator, determine the answers for the right & left moments using the values in the first 4 columns. Record your answers in the appropriate boxes.

7. Using the **Moment Sign Convention** that we established at the beginning of the lesson, record the direction that you think the moment is turning. Is the moment moving in the **Positive** or **Negative** direction? That is, is the moment turning **Anticlockwise** or **Clockwise**? If you are unsure, refer back to the notes on Moment Sign Convention on pages 3 & 4.

**CLASS DISCUSSION:** Do you notice a trend occurring in your directional findings? Discuss these trends.

8. Now that you have moment values for the right & left hand sides of the balance beam sum these 2 values using the **2nd Moment Formula ($\Sigma M_o = 0$).**

9. Once you have summed the moments look at your results and calculations. Did the 2 moments cancel each other out and equal zero? That is, did the moments **BALANCE**? Discuss your findings as a group.

**NOTE:** The results of the activity may slightly differ from predicted results this may be due to kit component accuracy during the manufacturing process.

Do not let this interfere with your predictions or deter your understanding of the activity. Nearest approximate values achieved by using the balance beam are sufficient

# Replace page with Master Work Sheet

## LESSON STEPS – PART 2:

### 1. ACTIVITY 2.1

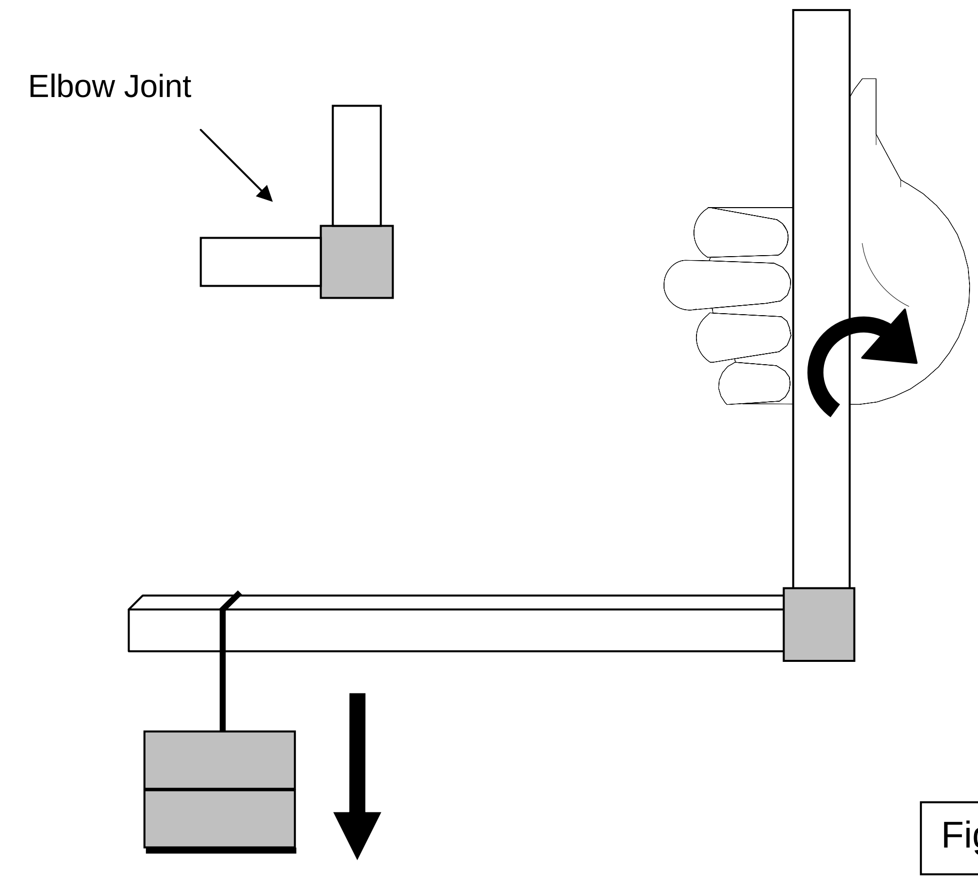



Figure 3

This section of the activity provides the students with the opportunity to experience the **MOMENTS** that would be required to counteract applied weights.

1. For this part of the activity you will need to utilise the 2nd beam from the kit.

2. Connect the 2 beams together with the elbow joint provided as pictured in Figure 3.

3. Firmly hold the new “L” shaped beam structure and slowly apply a load to the opposite end of the beam as pictured.

4. Describe the feeling in your hand as the weight loads and distances are increased. Can you feel the grip in your hand tightening, moving in the direction opposite to the load and increasing with the increase in load? What you are experiencing is a **MOMENT**.

5. Discuss your findings.

## 2. ACTIVITY 2.1

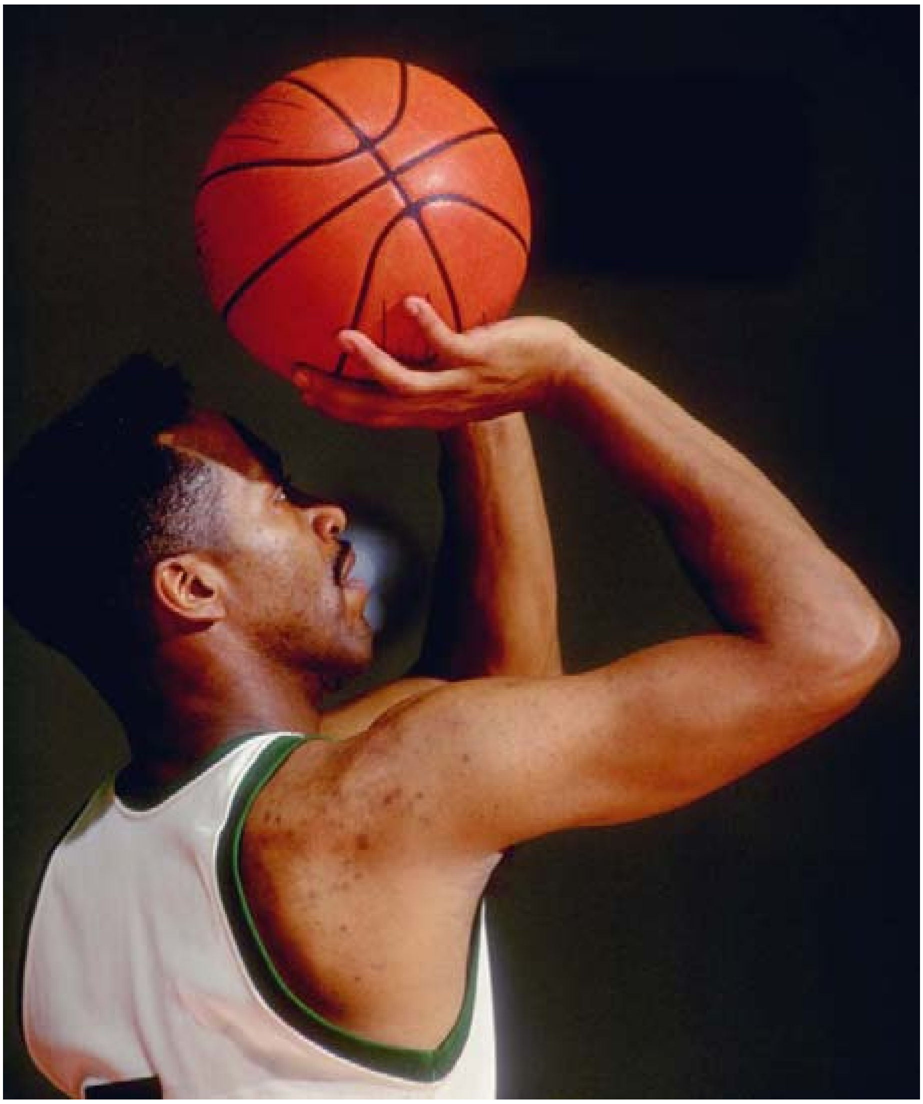
### GROUP ACTIVITY & CLASS DISCUSSION:

Each of the students should break into groups of 2-3 for this activity. Students will discuss some real life applications of moments & couples.

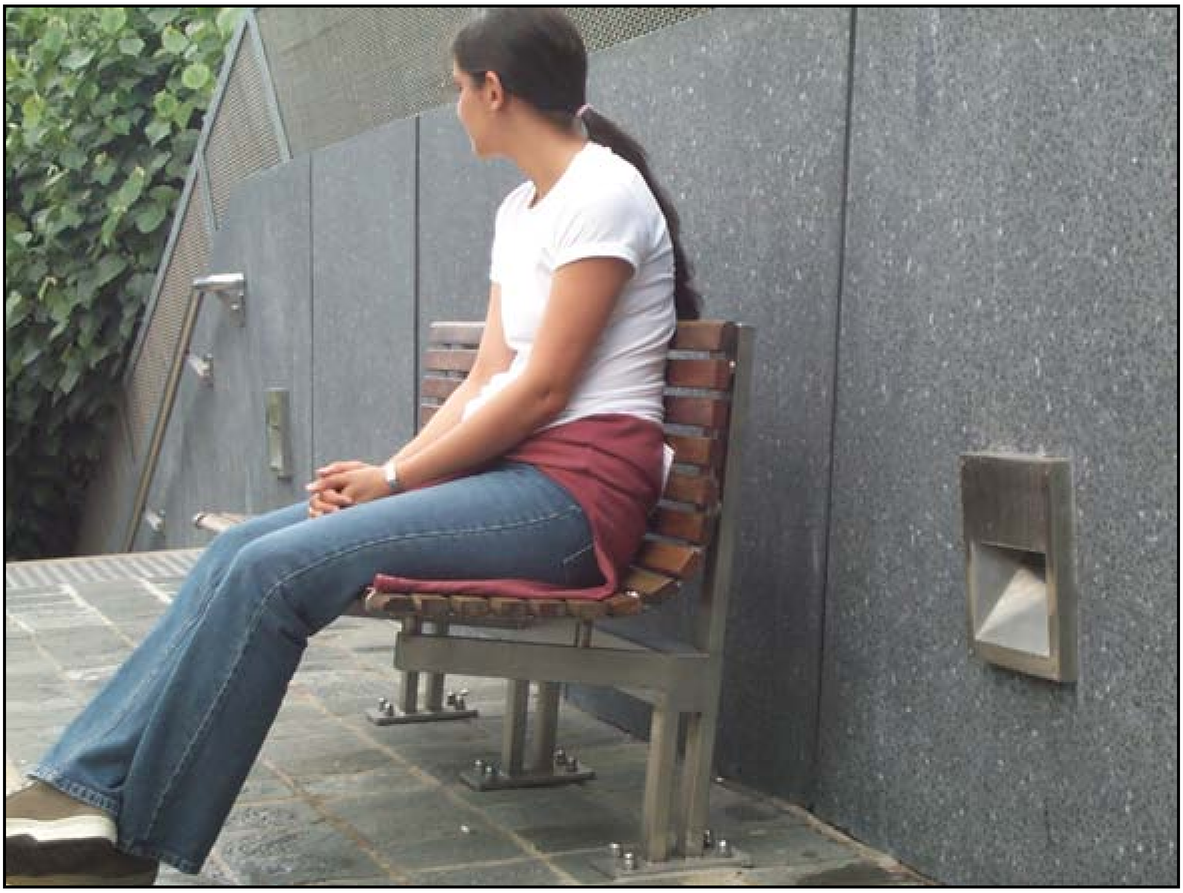
- Where would you see moments/couples occurring in real life? List ideas.
- Discuss cantilever structures on buildings.
- Discuss the moments and couples occurring in each of the following images.

  Each group will also be given a laminated A4 copy of one of images. Using the supplied whiteboard marker, groups are to draw the occurring moments.

  Each group will then present their findings to the class.

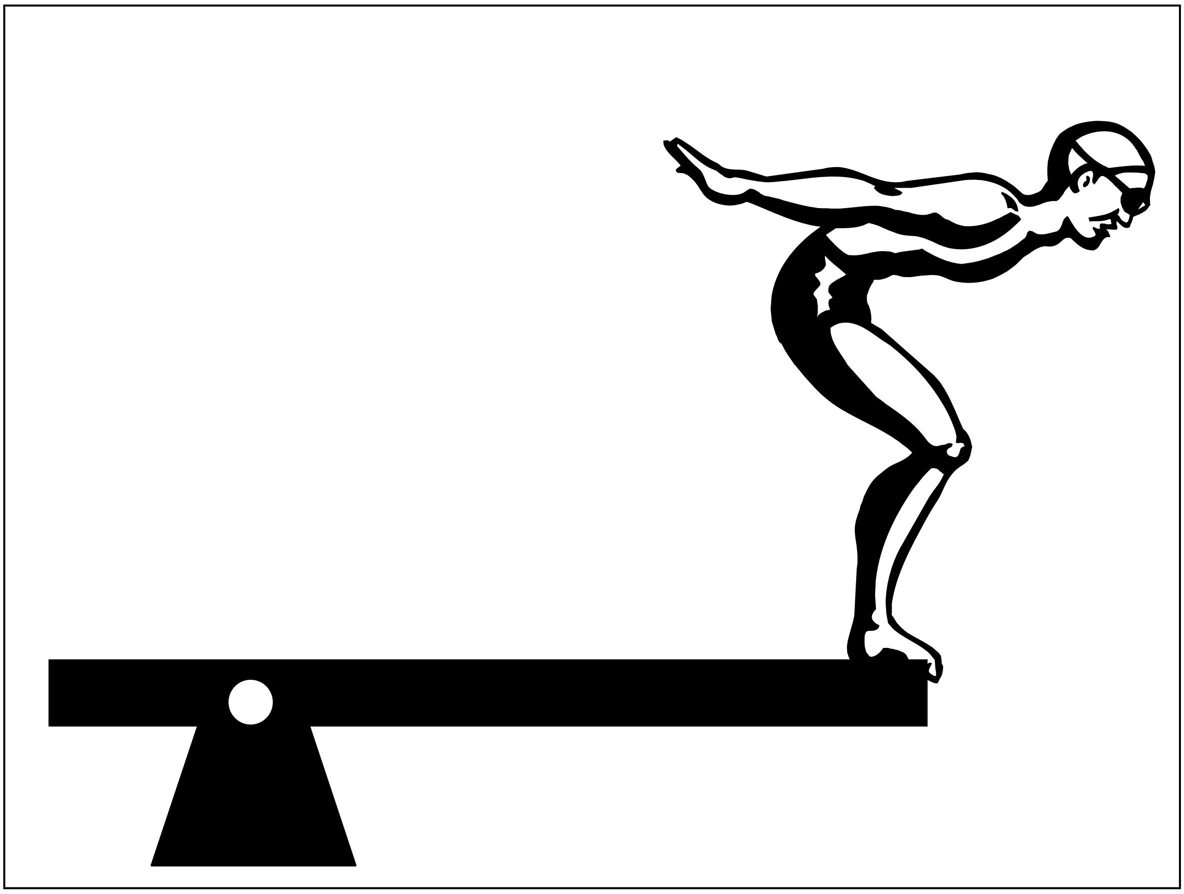


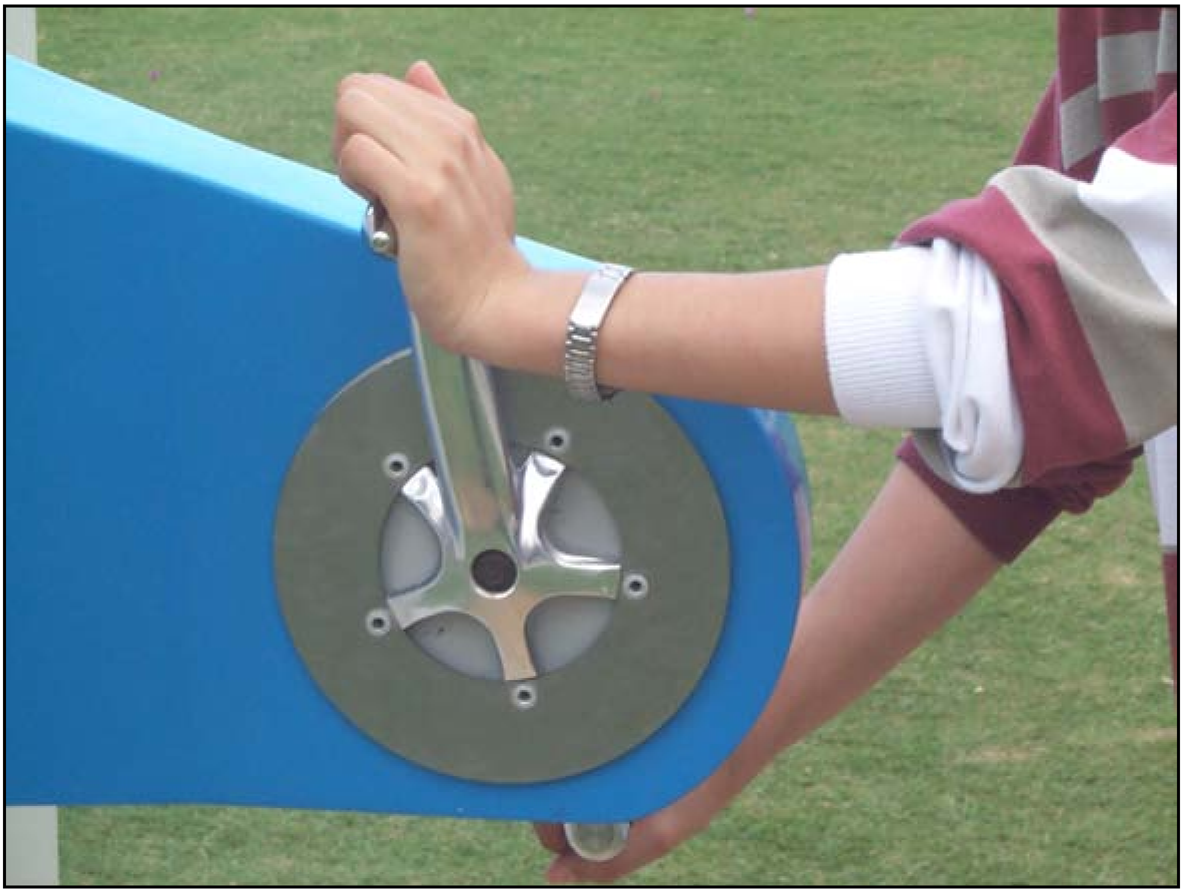

Gardens Point




PLAYGROUND


GEDORE • VANADIUM





## CHALLENGE EXERCISE:

The tower crane is important to civil engineers in the construction of projects. A tower crane has a permanent mass load on the opposite side to the arm of the crane. This load opposes and balances the moment produced when the crane is lifting heavy materials.

Using the knowledge you have gained from the moments and couples activities, answer the following questions.

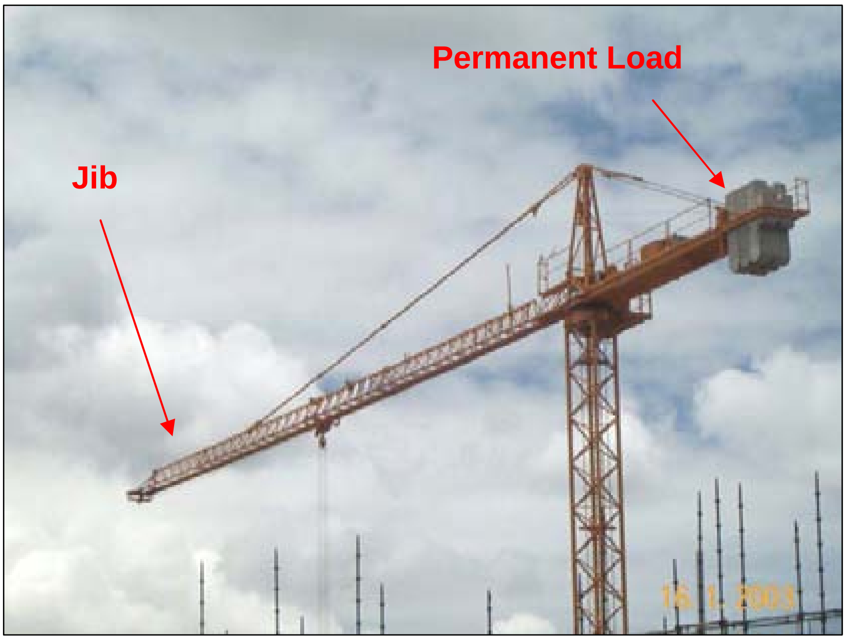
A LC5013 tower crane can lift a maximum mass of 1300kg at the end of its jib. Assume the centre of gravity of the permanent load is 12.5m from the centreline of the tower and the maximum stretch of the crane jib is 50m in length.

1. Draw a diagram that represents the crane and the loads it is supporting.
2. Find the moment at the centre of the crane tower due to:

   a. The maximum mass at the end of the crane jib.
   b. A permanent load of 2000kg.
   c. What is the resultant moment from the 2 loads?

3. A critical component of the engineering structures is the types of joints used when connecting members. What would happen to the structure, given the loads in question 2, if:

   a. A pin joint was used? (An example of a pin joint is centre point of a see-saw)
   b. A fixed joint was used? (An example of a fixed joint is where a table top connects to the table's legs)



## REFERENCES

Riley, W.F., Sturges, L.D. and Morris, D.H. (2002) "Statics and Mechanic of Materials: An Integrated Approach" John Wiley and Sons, Inc. NY.

## ACKNOWLEDGMENTS

SQUEAK Activity Kit #2 – Moments & Couples first created by Tracie Fong for the QUT School of Civil Engineering 2002.

## REVISIONS & MODIFICATIONS

| | |
|---|---|
| Jan 2002 | First Edition – Tracie Fong |
| 2003-2008 | Revised Additions – SQUEAK Coordinators |
| Jan 2009 | Revised Edition – Tracie Fong |
| | |