**Robot Arm Challenge Answer Key**

**Fluid Power Worksheet**

These are some of the words and ideas that engineers use when working with fluid power. They are also used by mechanics and equipment operators when controlling and repairing heavy equipment. Can you think of any other careers where people need to know about fluid power?

### Terms:

Hydraulics use a **fluid** such as **oil** or **water** to make things move. Pneumatics use a **gas** such as **air** to make things move.

A liquid is an **incompressible** fluid. That means that it doesn’t “shrink” when you push on it.

A gas is a **compressible** fluid. That means that it acts kind of like a spring when you push on it. Pressure is a measure of **force** divided by **area**.

Air pressure acts on us all the time. One “atmosphere” of air pressure is the pressure we feel on

Earth at sea level. In metric measure, one atmosphere is measured as **about 100 (101.3)** kPa. In imperial measure it is measured as **15** psi.

Our robot will use syringes to make things move. In the photo below, label the part of the syringe that is the “piston.” Label the part that is the “cylinder.” Label the piston rings that keep the fluid

in the syringe.



The fluid can push on the piston to make it move. How hard the piston pushes is called the

**force** It is calculated by multiplying the **pressure** of the fluid by the **area** of the piston.

When filling a hydraulic system with fluid, it is important to get all the **air** out of the system. This is called **bleeding** the system.



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#### Calculations

When engineers, mechanics and equipment operators use fluid power, they need to know how much force their system can apply. These are some of the calculations that they use. Fill in the spaces.

|  |  |  |
| --- | --- | --- |
|  | **10 cc syringe** | **5 cc syringe** |
| Diameter of piston | 14.5 mm | 12 mm |
| Diameter of piston in metres (divide mm by 1000) | **0.0145 m** | **0.012 m** |
| Radius of piston (divide diameter by 2) | **0.00725 m** | **0.006 m** |
| Area of piston (3.14 × radius squared) | **0.000165 m2** | **0.000113 m2** |
| Force on piston at 100,000 Pa (multiply  area by 100,000) | **16.5 N** | **11.3 N** |

Which piston exerts the larger force at 100 kPa? **10 cc syringe**

Why does the larger piston exert the larger force?

#### greater surface area on piston (bigger diameter)



**10 cc syringe**

**5 cc syringe**

In the photo above, a 10 cc syringe is connected to a 5 cc syringe so that the fluid can flow from one to the other. If you push on the piston in the 10 cc syringe, the 5 cc syringe’s piston will move outward. It will move with **less** force than is pushing on the 10 cc syringe piston, but will move a **greater** distance.

If you push on the piston in the 5 cc syringe, the 10 cc syringe’s piston will move outwards. It will move with **more** force than is pushing on the 5 cc syringe piston but will move a **shorter** distance.

Fluid power works best when pushing. When you “pull” on one syringe you are relying on ambient **air** pressure to push the other piston inward. If you pull too hard, then **bubbles** will form in the hydraulic fluid.

**Moments and Counterbalances Worksheet**

Your robot arm will rotate about joints, or pivot points. The amount of force acting on the arm and the distance of that force from the pivot point will be important in making sure that your arm can lift its load. Learning about moments and counterbalances will help you design and build a better robot arm.

A **moment** is a twisting force, also known as **torque** It is the result of a **force** pushing at a distance from a **pivot** point.

In metric measure the standard unit for a moment is the **newton metre** or Nm. In imperial measure people use the **foot pound** or ft. lb.

The equation to calculate a moment is **force** × **distance**

In this diagram the live load is 100 g and acts at a distance of 10 cm from the pivot.

10 cm

5 cm

100 g

100 g of mass in Earth’s gravitation gives a force of **1** N. A distance of 10 cm expressed in metres is **0.1** m.

The moment is: **1** N × **0.1** m = **0.1** Nm.

The syringe must counteract the moment of the live load. The syringe is at a distance of **0.05** m, so we can calculate the force on the syringe as **0.1** Nm / **0.05 m** = **2** N.

This force is roughly the same as that exerted by a mass of **200** g. This makes sense because the syringe pushes **twice** as hard, but at **half** the distance as the load.

The moment can change as the arm rotates. In this diagram the arm is still 10 cm long, but now the load is closer to the pivot point. The moment is now: **1** N × **0.07** m = **0.07** Nm.

To help balance an arm and make it easier to lift, we sometimes add a weight on the opposite side of the pivot point from the main load. We call this a **counterweight (or counterbalance)**. In this arm it creates a counter-clockwise moment of **1** N × **0.05** m = **0.05** Nm.

100 g

7 cm

10 cm

5 cm

5 cm

100 g

100 g

This means the syringe only has to create a moment of **0.05** Nm to balance the arm.

One problem with counterbalances (also called counterweights) is that they make an arm

#### heavy (or slow).

Robot arm designers can help support the load by adding **springs** or **elastics** to help pull the arm up.

There are two main types of load on the arm. The **live** load is the weight of the object the arm is lifting, while the **dead** load is the weight of the arm itself. The weight of the object might change, but the weight of the arm usually remains constant. For this reason robot designers will usually use the counterbalance to support the moment caused by the dead load, and let the piston or

motor support the weight of the live load.

# Robot Arm Quiz

Name: Date: Block: Score: /16

1. Matching—Place the letter that best represents the term in the column indicated. (0.5 mark each–6 marks)

**Place Letter Here**

**Term**

**E**

Hydraulic power

A

Force / Area

B

About 100 kPa in metric, about 15 psi in imperial

C

A metric unit of force, about equal to a mass of 100 g

**H**

Pneumatic power

**A**

Pressure

**B**

Air pressure at sea level

D

10 cm

**C**

Newton

G

A weight or spring added to the back of your robot arm to assist with lifting the load

H

Fluid power using a gas such as air as the fluid

I

The imperial unit of torque, the foot pound

**F**

Nm

**I**

Ft. lb.

**L**

Live load

J

The weight of the structure; in this case, the weight of the arm

K

Removing air bubbles from a hydraulic system

L

The weight of the object you are moving

**J**

Dead load

**G**

Counterbalance

**K**

Bleeding

**D**

Moment

E F

Fluid power The metric unit using a liquid of torque, the such as oil or newton metre water as the

fluid

100 g

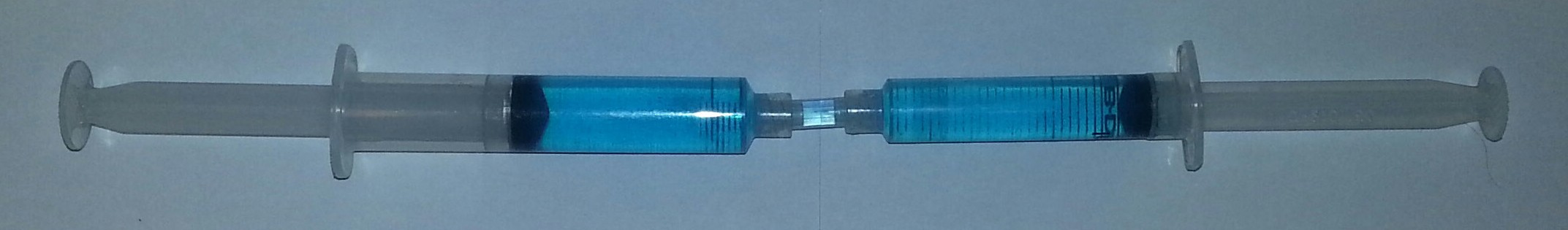
1. Our syringes work best when pushing. Why? (1 mark)

#### They are single-acting syringes that rely upon air pressure to “pull”

1. What do we call a cylinder that can both PUSH and PULL? (1 mark)

#### Double acting

1. In this photo there are two syringes of different diameters. (3 marks)



#### 15 mm diameter

**10 mm diameter**

1. If the syringe on the right (10 mm) is pushed with a force of 8 N, how much force will the larger syringe exert?

#### Area of 10 mm syringe = 0.0000785 m2 Area of 15 mm syringe = 0.000176 m2

**Water pressure = 8 N / 0.0000785 m2 = 101,910 Pa**

**Force on 15 mm syringe = 0.000176 m2 × 101,910 Pa = 17.9 N**

**(The area of the larger syringe is just over twice that of the smaller one, so the force is just over twice as much, too.)**

1. Which piston will move the greatest distance?

#### the smaller piston (10 mm dia.)

1. In the diagram an arm has a counterweight that exerts 5 N at a distance of 0.15 m from the pivot point and a syringe that exerts 6 N at a distance of 0.1 m. (5 marks)

.3 m

.15 m

.1 m

6N

5N

F

* 1. How much torque does the counterweight create?

#### 5 N × 0.15 m = 0.75 Nm rotating counter-clockwise

* 1. With the counterweight and syringe working together, how much force can be exerted to lift the load labelled “F”?

#### Counterweight torque = 0.75 Nm rotating counter-clockwise Syringe torque = 6 N × 0.1 m = 0.6 Nm rotating counter-clockwise. Total “lifting” torque = 1.35 Nm

**1.35 Nm / 0.3 m = 4.5 N of force that can be exerted to lift the load**

**Assessment**

**Student name:**

“Cardboard Aided Design” Score: /5

Team demonstrates shoulder and elbow joint movement. Team demonstrates suitable range of motion for end effector. Team demonstrates suitable locations for piston mount points.

Mount points do not exceed syringe extension/retraction limits. Mount points allow for syringe to rotate arm.

Scale Model Drawing Score: /5

Scale model matches “CAD” model.

Drawing completed with care and attention to detail.

Student uses straightedge, pencil and eraser.

Drawing shows key measurements.

Pivot points

Syringe mount points

Robot Arm Quiz Score: /16

Robot Arm Construction Score: /10

Parts fit snugly

Appropriate use of fasteners and adhesives Tubing secured and tidy

Overall appearance of final product

Robot Arm Performance Score: /10

Arm can pick up playing piece.

Arm has sufficient range of movement to pick up pieces anywhere on playing field. Arm can successfully deposit playing pieces in receptacle or goal location.

Arm has reasonable degree of control.

Arm demonstrates reliability and robustness.

Robot Arm Competition Score: /10

Criteria based upon the challenge as set by the teacher

#### Total score: /56