ME 3010

Mini-Project
Measurements, Instrumentation and Control

Hydrostatic Weight Measurement Device

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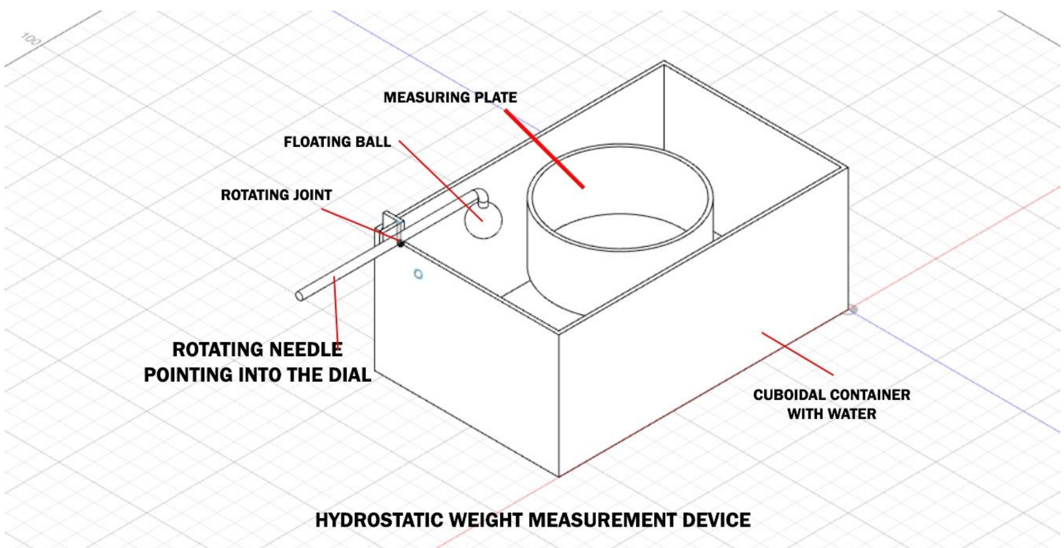
Videos of the device are in the below mentioned drive.

https://drive.google.com/drive/folders/1FBTMMLlLblU4riKx6hjOzg75eGUcIbAg

INTRODUCTION

This is a simple instrument which can be used to measure the weight(mass) of small scale bodies, using the concept of buoyant force acting on that body, when immersed in water.
A Cuboidal box of known dimensions, with an opening at the top is filled with water. A measuring plate is placed on top of the water, on which the object, who's weight is to be measured will be placed. Another plastic ball fixed at the end of a slender rod is kept attached to the wall of the cuboidal container, through a rotating joint. The other end of the rod keeps pointing outwards. This end rotates around a dial, which shows the weight of the body in the plate.
Any weight added onto the measuring plate, will increase the water level, which in turn displaces the floating ball, and hence the needle rotates around the dial showing the appropriate weight of the body.



STRUCTURE

The container with water is considered as a cuboid with

length=17.5 cm
breadth=11.5 cm
Therefore area of the surface of water(A1)=201.25 cm sq

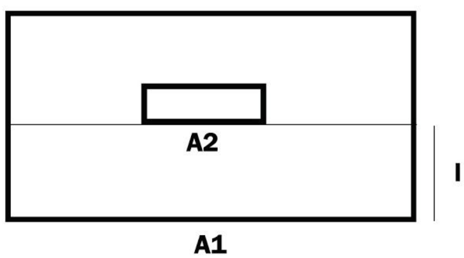
The measuring plate(plastic) is considered as a body with cylindrical cross section.

radius=3 cm
Area of cross section(A2)=28.26 cm sq

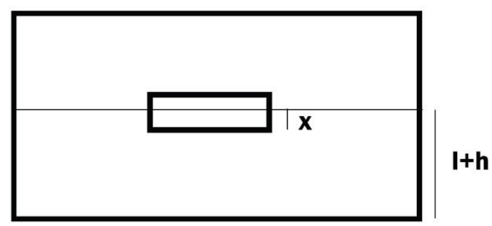
(There is only a marginal rise in level when the measuring plate is put in the water, therefore the mass of plate is neglected)

When putting a weight on the measuring plate, the plate moves a depth “x” into the water, and the water level in the container rises by “h”. Let the initial water level be “l”.

(Here we are considering uniform downward motion of the plate, without any moments and angular velocities. To achieve this, guider structures are placed inside the container.)



Before putting weight



After putting weight

By the conservation of mass of water,

$$A1l=A1(l+h) - A2x$$
$$\mathbf{h=(A2/A1)*x} \text{ --(1)}$$

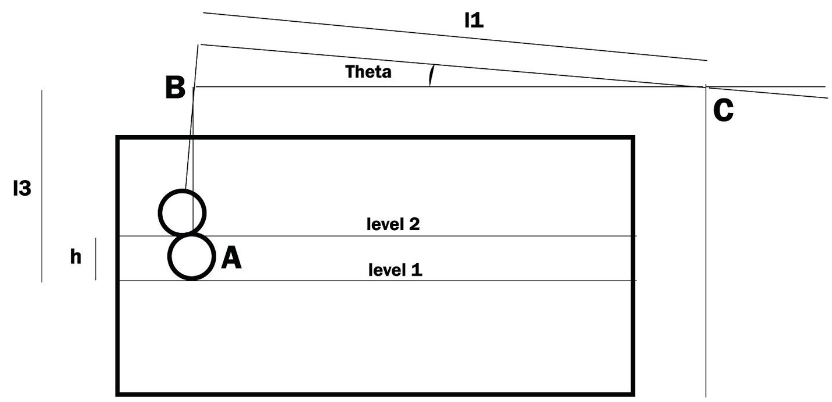
We need to fix the initial water level to some value. Hence we are taking l=2cm.

ROTATING ROD

A rod as shown in the figure is used.

Here ABC forms the rod(single link), with point C, forming the rotating point about a fixed point outside the container. Points A and B are points on the link.

Here, the plastic ball immersion in water is negligible. The weight of the rod is also very less. Hence they are considered as massless. The lowest point of the ball is in contact with the water surface(This point is considered as point A). This is done so that we can get a direct idea of the water level.



Initial water level in the container= level 1

Water level in the container after putting mass on the measuring plate= level 2

Change in water level= h

Length of AB=l3 (AB is taken as l3=length or rod+diameter of plastic ball)

Length of BC=l1

We take l1=16.2cm and l3=8.7cm.

Angle change between 2 positions of rod= Theta

From Geometry, we can get the relation,

h=l1*sin(Theta) + l3*(1-cos(Theta)) --(2)

BUOYANCY

Force balance between weight of object in the measuring plate and the Buoyant force.

Assume, Mass of body=m

Volume of water displaced=V=A2*x

Density of water at 22 degree celsius=k= 997.77 kg/meter cube

mg=B(Buoyant force)

mg=k*V=k*A2*x

x=m/(k*A2) --(3)

RELATION BETWEEN MASS OF OBJECT AND ANGLE OF DEVIATION

From (1), (2), and (3), we can get,

m=k*A1*[l1*sin(Theta) + l3*(1 - cos(Theta))] --(4)

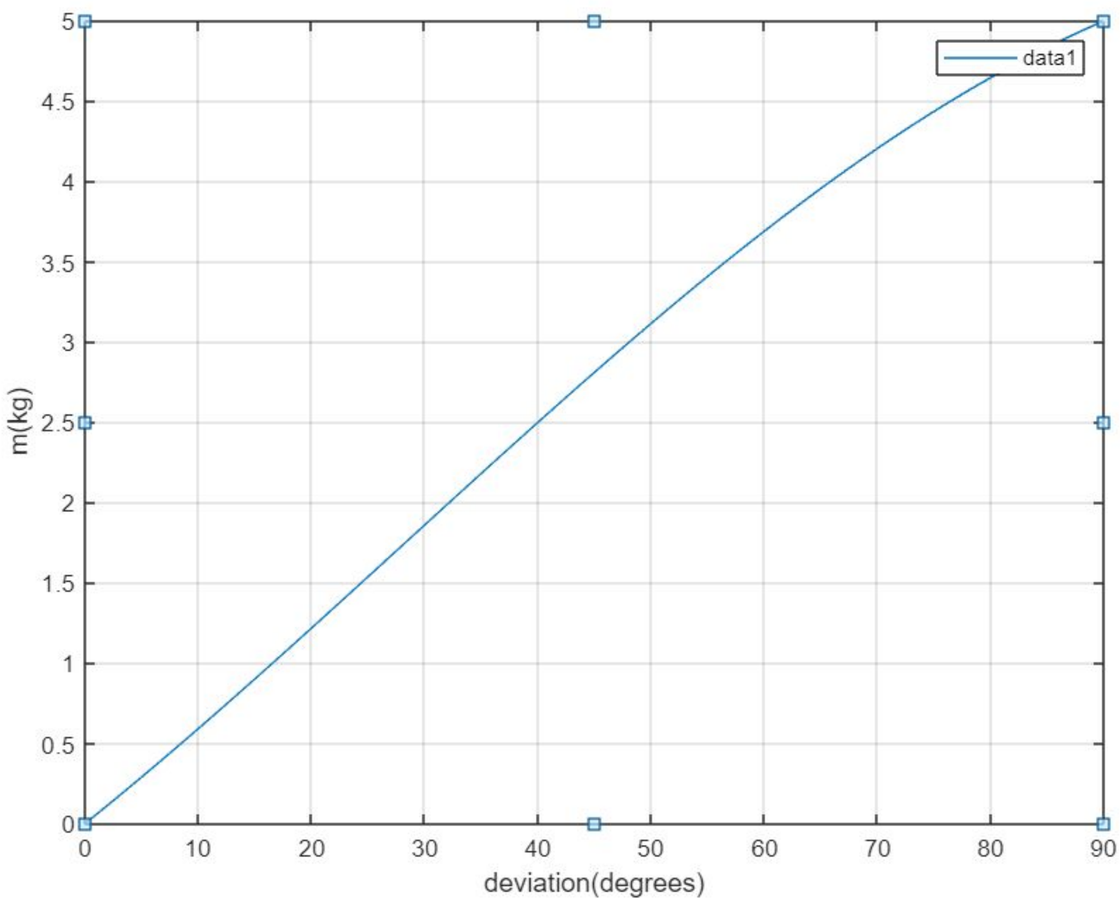
After putting all the fixed values in the equation,

m=(997.77*17.5*11.5*0.0001)*((16.2*0.01)*sin(t*3.14/180)+(8.7*0.01)*(1-cos(t*3.14/180)))

(m in kg, t in degrees) This equation is used to plot the graph.

PLOTTING MASS AND THETA

Plotting eqn(4), for different values of Theta(from 0-90 degrees) (Considering 90 degrees downwards as the maximum possible deflection for the rod.), We get the following curve.



We can infer from the graph that, upto a mass of 4kg, the variation of Theta with mass is almost linear. Hence, we will try to fix the range of the device as mass=[0,4]

We can get the value of Theta, which is caused by a specific amount of mass.
https://docs.google.com/spreadsheets/d/1Z-2twXC6UoXGnufNa-1Ii40sTYycamCBo7PU4AybpMA/edit?usp=sharing

Hence, we find that, for a mass of 4kg, the deflection is around **65.5 degrees**. Therefore, deviation ranges from 0 degrees to 65.5 degrees, downwards of the horizontal.

DIAL

The pointer, which is fixed to the rotating rod, is calibrated to 0N on the dial at Theta=0 degree. As we consider linear variation till 4kg, the dial is provided divisions corresponding to linear increment in mass. 10 degrees corresponds to .591 kg, 20 degrees corresponds to 1.217 kg and so on. Divisions are present till 4 kg. The first .591 is further divided into 4 divisions.

WORKING

The object whose weight is to be measured is kept on the measuring plate and the corresponding deviation in mass is read from the dial. Measurement of mass of an object is shown in the video. The device has good sensitivity, but viable readings can be taken only if we try with larger mass.

DISADVANTAGES

- Larger container is required to accommodate masses, which can show effective readings.
- Lots of assumptions used, which may affect the real reading.
- Lots of errors due to mechanical arrangement. Eg ripples in water, disorientation of rotating joints, error in pointer, exclusion of mass of the ball, plate etc.
- Variation of density of water with temperature.