Rotational equilibrium lab answers

Have you ever tried to remove a stubborn nail from a plate or develop the muscles of the forearm lifting weights? Both activities involve the use of a lever-type action to produce a tipping or torque effect through the application of a force. The same pair can be produced by applying a small force at a greater distance (with more leverage) or by applying a larger force closer to the point at which the object should rotate. These two examples are shown in Figure 1. In the case of the hammer stretching the nail, a small force applied at the end of the handle results in a larger force exerting on the nail at a smaller distance from the point where the nail is fixed to the board. In the second example the weight in the palm of the hand is at a greater distance from the elbow. This requires muscles to apply greater force at a smaller distance, usually less than 5 cm from the elbow. These are two examples of lever action— quite applied at a distance from a fulcrum or pivot point or rotation axis. An applied force as described in the examples above results in a pair in a body. The pair usually produce a rotation of a body. Figure 1: Two pair examples is a measure of the inflection effect of an applied force on an object, and is the rotational analogue to force. In translational motion, a clean force causes an object to accelerate, while in rotational motion, a clean torque causes an object to increase or decrease its rotation rate. The torque is the product of applied strength and perpendicular distance from the turning point to the force line of action and is measured in N·m. units where the lever arm is sometimes called. Note: The pair has the same units as the job, i.a. the force time distance. Torque and work, however, are completely different physical concepts; the fact that they have the same units is a coincidence. Note the irregularly shaped two-dimensional object shown in Fig. 2nd. Figure 2: Illustration of the concept of lever-arm A force F applies to the object in point P, for example, by a string attached there. The object is free to rotate over point O by a nail driven through it at this point, but not free to have translational motion. The steps needed to calculate the pair to the object on point O are described below. 1 Draws a line through force. This dashed line in fig. 2a represents the force action line. 2 Draws a perpendicular line from the rotation axis O to the force action line. This line, marked d in fig. 2, represents the lever arm defined in Eq. (1). Note that when the force line of action moves closer to the center point, the lever arm decreases as shown in fig. 3a and 3b. fig. 3c the force line of action goes through the pivot point. In this case the lever arm is zero and therefore the pair will also be zero. Figure 3: 3: lever arm at the point of application of force Since the lever arm d makes a right angle with the line of action of the force, the three quantities, d, F and r make a right triangle. This triangle has been redrawn in Fig. 2b. From this triangle we see that the lever arm d is given where the angle between r and F. Equation (1) can now be written as If two or more forces are applied to an object, each force produces a pair. The rotation of the wheel shown in fig. 4 is caused by the sum of the two torques. Figure 4: A wheel that experiences two pairs By convention, pairs that cause counterclockwise rotations are considered positive and pairs that cause clockwise rotations are negative. In the example above F1 will produce a positive or counterclockwise pairing, while F2 will produce a negative or clockwise pairing. For rotation over the center the magnitude of the net torque will be the algebraic sum of the two pairs: (4) As mentioned above, the pair is actually a vector. The even vector is perpendicular to the plane formed by vectors r and F. The ruler on the right gives the direction of the torque. Based on this rule of positive torques, such as going off the page, while negative torques such as heading to the page. The torque causes rotational movement with angular (or rotational) acceleration. where I am the time of system inertia and it is angular acceleration. This equation is the angular equivalent of Newton's second law: When the clean pair is zero, the object will not change its rotational motion state — that is, it will not begin to rotate or stop rotating or changing the direction of its rotation. He is said to be on rotational balance. If the sum of the forces acting on the object is also zero, the object is in translational balance and will not change its translational motion state, that is, it will not accelerate or slow down or change its direction of movement. Each time these two conditions are met (7) $\tau = 0$ and $F = 0$, the object is said to be in static balance. The aim of this experiment is to learn how to measure the torque due to a force and adjust the magnitude of one or more forces and their lever arms to produce static balance on a metre pole balanced on a knife edge; Use the conditions for balance to determine the mass of the counter pole and the mass of an unknown object. Meter Stick Edge Known Masses of Different Values Unknown Mass Balance There are three parts to this experiment. In the first part, three forces will be balanced on a metre pole and show that the clean torque is zero when the counter pole is in balance. In the second part the weight of the counter pole will be balanced against a known weight to determine the mass of the meter pole. the principle of rotational equilibrium will be used to determine the mass of an unknown object. The entire lever distances are measured from the edge of the knife, which serves as a support point. You will be using rubber bands to hang the weights on the counter pole. Suppose the masses of the rubber bands are insignificant. Procedure A: Balance torques 1 balance the counter stick on the edge of the knife. The point at which the mast is balanced is the center of gravity of the meter pole. Enter this value in the worksheet. 2 Select two masses of 200 grams and a mass of 100 grams. 3 See Figure 5 and Fig. 6. We place a hanger at the mark of 20 cm, a distance cm to the left of the center of gravity and place too much on it. We put another hanger at the mark of 65 cm, a distance cm to the right of the center of gravity and place a mass. Enter these values in data table 1. Figure 5: Three balanced torchs Figure 6: Photo of experimental configuration 4 Calculate the torchs because and enter these values into the data table 1. Be sure to include the torques sign. 5 Using the right sign for each pair we can write the condition for rotational balance as (8) $\tau = m_1gx_1 - m_2gx_2 - m_3gx_3 = 0$ 6 Use Eq. (8)$\tau = m_1gx_1 - m_2gx_2 - m_3gx_3 = 0$ and peer values due to predicting the torque due to (including its sign) and entering this value in the data table 1. Be sure to include the torques sign. 7 Use the expected value of the torque due to predicting the position of which the third mass should be placed to balance the counter stick. Enter this value in the worksheet. 8 Experimentally determine the position and enter this value into the worksheet. 9 Compare the two position values by looking for the percentage difference between the predicted and experimental values in See Appendix B. Control Point 1: Ask your TA to check the settings and calculations. Procedure B: Finding the mass of a meter pole For this part of the experiment will use a mass of 200 grams, the counter stick and the edge of the knife. 10 Move the edge of the knife to the 25 cm mark. You will notice that the counter pole is no longer in balance. The unbalanced force is the weight of the counter pole that acts in its center of gravity. 11 Experimentally find the position, of the mass of 200 grams, needed to balance the counter stick. Enter the value of the worksheet. 12 In the space provided in the worksheet, sketch and carefully label a diagram of the counter stick and mass of 200 grams. It shows all the producing forces of pairs. Remember that the weight of the counter pole acts in its center of gravity. Indicate in the diagram the indications (clockwise or counterclockwise) of each pair. 13 Calculate the pair due to the mass of 200 grams and enter value in data table 2. 14 Use the torque value due to the mass of 200 grams and conditions for rotational balance to determine the torque due to the mass of the counter stick. Enter this value in data table 2. 15 Using the value of the given pair in step 14, calculate calculate value of the mass of the stick metre m2. Enter this value in the worksheet. 16 Use balance to measure the mass of the meter pole. 17 Compare the measured and calculated values of the counter stick mass by computing the percentage difference. Control Point 2: Ask your TA to check the diagram, settings, and calculations. Procedure C: Determine an unknown mass 18 We place the center of gravity of the counter pole on the support. 19 We place a mass of 50 grams at the mark of 70 cm and a mass of 200 grams at the mark of 20 cm. 20 You will tie the free end of the rope to a shooting bucket around the 1 cm mark and hang it on the pulley as shown in fig. 7 and fig. 8. Figure 7: Settings to determine an unknown mass Figure 8: Configuration photo to determine an unknown mass 21 In the space provided in the worksheet, sketch and carefully label a chart of this configuration. It shows all the producing forces of pairs. Indicate in the diagram the indications (clockwise or counterclockwise) of each pair. 22 Calculate the torques because and enter these values into the data table 3. 23 Use peer values due to both masses and conditions for rotational balance to determine the pair due to Entering this value in data table 3. 24 Now add small masses to the bucket until the mast is balanced. 25 Determine the mass of the shot and the bucket using a balance. 26 Calculate the percentage difference between the experimental and predicted values for the mass of the most bucket shot. Control Point 3: Ask your TA to check your settings, diagram, and calculations. Calculations.