Crazy Suitcase

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Abstract:

When two wheel's suitcase is pulled along, under certain circumstances it can wobble side to side so strongly to the limit that it may turn over. Study this phenomenon. Can it be suppressed or intensified by changing of the luggage packing? By hypothesis such as balance condition and several experiments, important parameters have been investigated.

Inroduction

Hypothesis1: The suitcase is in balance condition

As illustrated in figure (1) when the suitcase is in balance condition by proper packing, accordingly the center of mass is on on *Z* axis, which leads to torque of the suitcase around *X* axis.

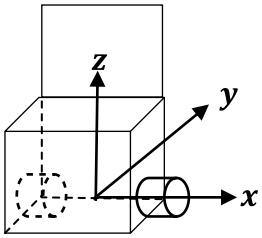


Fig. 1: suitcase is in balance condition

First, we solve a simple problem and then generalize it to the original question.

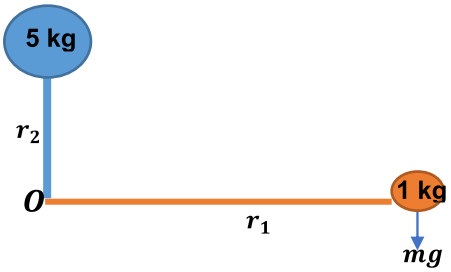
Theory

The physicists have always been using simplification methods and skills to solve complex issues and problems; so a simple question is initially examined which will be extended to the complicated question in next step and we want to do it.

Question Simplification

Step 1:

It is presumed that two spheres like cannonball as shown in figure (2) are interconnected by means of two light rods and whole system is fixed to the wall in the point of O.



$$\tau_t = r\, m_1\, sin\theta$$

Fig. 2: The illustrated system in suitcase

Firstly, we study the illustrated system as shown in figure (2), under this condition, developed torque is on the ball with weight of 2 kg which causes the mentioned ball to turn to the right side; however, when the below illustrated system (Fig. 3) is considered, in that case, the torque is existed on the both weight and consequently there would be probability of load dropping to the both side.

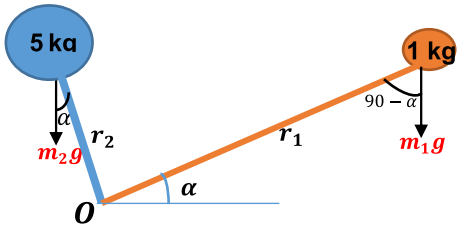


Fig. 3: Connected wheels with different condition in suitcase

5 kg → $\tau_2 = r_2 F_2 sin\theta_2 = r_2 \times m_2 g \times \sin(180-\alpha) = r_2 m_2 g \sin(\alpha)$

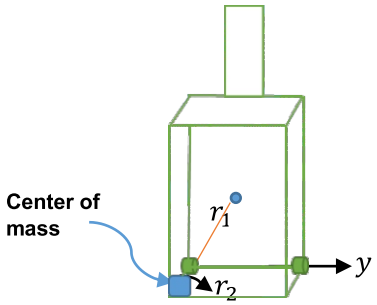
1 kg → $\tau_1 = r_1 F_1 sin\theta_1 = r_1 m_1 g \sin(90-\alpha) = r_1 m_1 g \cos(\alpha)$

$$\tau_1 + \tau_2 = r_2 m_2 \sin\alpha - r_1 m_1 \cos\alpha = 0$$

$$r_2 m_2 \sin\alpha = r_1 m_1 \cos\alpha$$

$$\tan\alpha = \frac{r_1 m_1}{r_2 m_2} \quad (1)$$

Based on the calculation it is concluded that the magnitude of developed torque on the balls depends on two quantities:



1.The forced applied by the weight

2. The Length of the lever arm.

Now, by solving this problem, we get back to the previous question.

Step 2:

In this system, two following parameters are important in torque:

1- The centre of mass of baggage

2- Centre of gravity of the load

And suitcase can have two rotations:

1- Rotation around y (θ)

2- Rotating which is caused by the disruptions (Φ) (orbit the suitcases category)

-Before turning to luggage:

$$\overrightarrow{r_2} = \frac{1}{2}\begin{Bmatrix} a \\ b \\ c \end{Bmatrix} \qquad \overrightarrow{r_1} = \begin{Bmatrix} a \\ 0 \\ 0 \end{Bmatrix}$$

After rotation: matri x r_1 and r_2 must be multiplied as follows:

$$\overrightarrow{r_2'} = \begin{bmatrix} \square & \square \\ \square & \square \end{bmatrix} \vec{r}_2 \qquad \vec{r}_1' = \begin{bmatrix} \square & \square \\ \square & \square \end{bmatrix} \vec{r}_1$$

If this formula is inserted into the formula (1), we have:

α angle between r_2' and g

β angle between r_1' and g

($\vec{g}$ vector to the centre of the Earth)

By putting these two equations :

$$\tau_{r_2'} = r_2'(m_2\vec{g}) \sin\alpha$$

$$\tau_{r_1'} = r_1'(m_1\vec{g}) \sin\beta$$

in the **Mathematica** app for baggage with dimensions of 10, 20 and 30 cm and a mass of one kilogram for baggage (M) and weighs 4 kg for luggage once inside (m) and the carrying angle is θ = 30 , accordingly, the critical angle for staggering baggage in this particular case is 18.4349. If luggage reaches to this critical angle, it will begin to wobble.

Important Parameters in suitcase wobbling

Parameters which are affecting on the wobbling in suitcases are as follows:

-wheel dimensions
- material of wheels
- shape of wheels
- distance of wheels between each other
- concurrent moving of wheels
- speed of suitcase
- angle of person's hand
- category of suitcases
- location of wheels
- ruggedness surface/ obstacle
- surface material (friction)
- handle adjoined body or wheels
- material of load (liquid or solid)
- dimensions of suitcase
- place of center of mass

wheels and baggage is considered as a single object.

Here, we have extended the simplifying assumptions to the original problem. Also assume that the suitcase as a rigid object and cuboid, and it is symmetric (simple premise: 2). (In fact it is not). We had to get the **best** parameters.

-Surface roughness: unevenness of the surface also causes suitcase stumbling.

Type of collision: When a suitcase is pulled over the stony ground, it hits the stones; therefore, it begins to move unsteadily and sways as it is being stricken by stones. Under this condition, the suitcase hits the obstacles continuously and loses part of its energy with each stroke. Partially energy losses in the suitcase is inevitable and therefore, the wobbling period is shortened and consequently it falls down faster as being stricken by more obstacles. With respect to the mentioned conducted experiments, it is observed that the magnitude of developed torque on the suitcase (when it is pulled over uneven surface) is larger and time taking to fall down is less comparing with the time it is pulled over even surface.

-Suitcase's speed: Assume that the suitcase is

moving on a flat surface, but suddenly bops to an obstacle and wobbles and finally falls. If the movement's speed is increases, the suitcase wobbles more. Because in this case, suitcase has traveled the same distance of the obstacle at the less period, so the impact intensity of the obstacle will increase and this force will be transferred to suitcase that was causing more torque (Fig.4) .

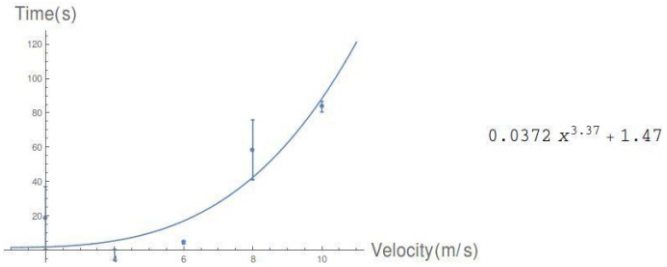


Fig. 4: velocity versus time

-Material of load: We presume that the baggage is liquid. So, when the suitcase moves, the centre of mass will change and then, the torque will increase. But if the load is solid, the centre of mass remains constantly and does not change the location.

-The length of handle: If the length of handle increases, the torque lever around X axis. increases. As a result, the torque around the X axis will increase and wobble of suitcase occurs in less time and the baggage falls sooner. (if it is short-the angle changes)

-The distance of wheels: if the wheels become closer to the Z axis the torque lever of COM around Z axis becomes less and the existing torque will lessen. But in this case the centre of mass of the object B will be farther from the wheel. The wobble of suitcase will increase by approaching two wheels to each other around Z axis ; (symmetrically) the torque will increase.

-simultaneously movement of the wheels: When the suitcase moves on a straight path, the wheels mete the equal distance. But when the suitcase rounds, one of the wheels will stay constant on the ground and the other one will traverse the distance. When the wheels are connected to each other, the existing torque becomes less but in this case the suitcase can't rotate and will be in trouble.

-Mass of load: Sometimes, the suitcase isn't in balanced condition by improper packing thus the center of mass of the suitcase is placed asymmetrically with three axes and if the weight of load increases, the torque force increases more and finally suitcase rampages more. .

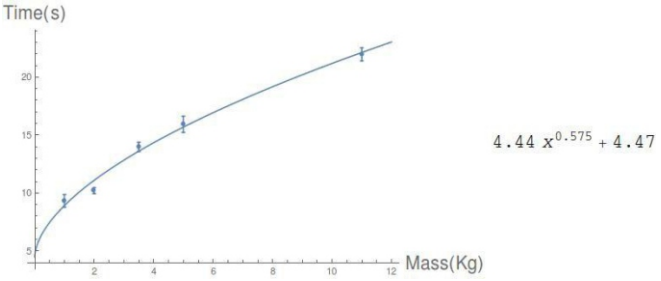


Fig. 5: Mass versus time

Results

-Obstacle: sometimes, when we are carrying the suitcase, suddenly it hits an obstacle and the obstacle enters the angular momentum to the luggage in opposite direction. If the force can overcome the resistant force, the suitcase will wobble.

-The effects of butterflies: The butterfly effect is one of the reasons of wobbling the suitcase. These chaotic dynamical systems study the chaos theory. Chaotic systems are nonlinear dynamic systems and very sensitive to their original condition. Small changes in initial conditions will become the big changes in the future. This phenomenon is well known in chaos theory butterfly effect. The behaviour of chaotic systems is seemingly accidental. Sometimes, the cause of wobbling of the suitcase is a tiny rock. In this state if conditions are favourable, suitcase may start to severe wobble and a very small force in the opposite direction enter the suitcase and in good condition, has become a cause for its craziness.

Centre of Mass: at most times the centre of mass is placed outside the centre of suitcase, therefor the force of the centre of mass of the luggage for torque will reach to its lowest level. Also, if place of the centre of mass be closer to the bottom of the suitcase (on axis Z)), it will wobble less.

Because in this case, if the bags do start to wobble, the center of mass to the opposite side and the luggage back to the original state is balance. Because when suitcase starts to wobble, the force of the centre of mass enters into the opposite direction, then it will return to balance condition. In fact, the place of the center of mass led to the centre of mass as a function resistant. But if load packing is unbalanced and the centre of mass be placed at a minimum distance of three axis coordinates and a fixed distance from the axis, the torque force becomes less. because the torque arm around three axes become shorter.

Conclusion

- The first part, proved staggering suitcases and bags in certain circumstances, have gained critical mass angle equal to 18.4349
- Factors affecting the intensity of the wobble baggage and then went to check some of them.

So if the ground is rocky, Increases movement speed, its mass is very high and if is picking unbalanced load, Wheel distance is less and length increases in these cases is staggering possibility of increasing luggage.

Recommendations

1. We can make this phenomenon optimized by changing the load packaging. If the centre of mass of load be placed at a minimum distance of three axis coordinates and a fixed distance from the axis, the torque force becomes less. it can reduce the effects of insanity. Also, if the objects within the suitcase are placed on both two sides of it, a relative balance created that prevent from wobbling.

2. Also, due to the great influence of the centre of mass in the torque of suitcase, we can use a variable mass centre.

3.We can also use an intelligent system to calculate the Critical Angle. In this system, a special program is used to calculate the critical angle in different situations.

-Description: In this method, an electronic system be installed on the bottom of the suitcase. This electronic system measures the critical angle in current conditions. If when moving suitcase is reached the specific angle, the system warns and this causes the variable centre of mass becomes activated and prevents the wobbling suitcase then suitcase will balance. In this method, we use a fluid for the variable center of mass to move it sooner.

4. We can build the bottom of suitcase like an arc and half of the wheels are inside of it. by this method, we can reduce the torque of wheels.

*** After extensive review, we decided to instal a gyroscopic on the axis of rotation of suitcase to equipoise it. The force of the spinning gyroscope's rings acted as resistance force that is making it harder to move the suitcase around the rotation axis, thus suitcase becomes balance. With increase in mass of rings and the rotation speed of them, more resistant force is created. In this case, using a digital sensor can control output force of gyroscope to give the needed force (at any circumstances) to suitcase for balance.

- In this way we can use electronic gyroscope because it is accurately and more efficiently.

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