Determine the Acceleration due to gravity (g) using Kater's Pendulum.

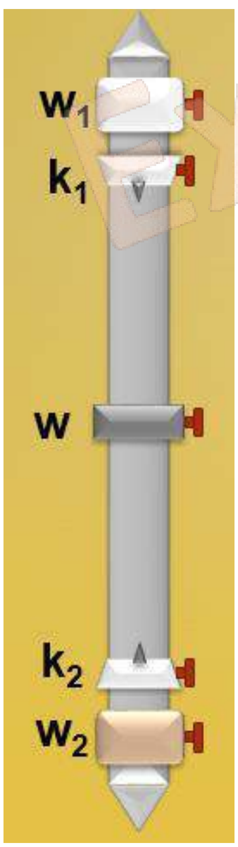
Apparatus - **Kater's Pendulum, Telescope, Stop watch, Meter scale , Sharp wedge, Rigid support.**

Theory **- Kater's pendulum is a compound pendulum based on the principle that the center of suspension and center of oscillation are interchangeable. The movable cylinders, knife edges and the metallic weight are so adjusted such that the time periods of the pendulum about the two knife edges situated asymmetrically with respect to the center of gravity are exactly equal. Then, the distance between the knife edges is equal to the length of equivalent simple pendulum whose time period is given by –**

$$g = \frac{4\pi^2 L}{T^2}$$

Hence, g may be calculated.

We resort to Bessel's approximation where we do not require making the two time periods to be exactly equal because it is quite difficult and time-consuming to set the Kater's pendulum for this configuration.



If T_1 and T_2 represent two nearly equal time periods (in sec) for positions of K_1 and K_2 distant l_1 and l_2 (in cm) from C.G., then we can write

$$T_1 = 2\pi\sqrt{\frac{l_1^2 + k^2}{gl_1}} \quad \text{and} \quad T_2 = 2\pi\sqrt{\frac{l_2^2 + k^2}{gl_2}}$$

Hence, $\frac{gl_1T_1^2}{4\pi^2} = l_1^2 + k^2$ and $\frac{gl_2T_2^2}{4\pi^2} = l_2^2 + k^2$

Subtracting and rearranging we obtain

$$\frac{8\pi^2}{g} = \frac{T_1^2 + T_2^2}{(l_1 + l_2)} + \frac{T_1^2 - T_2^2}{(l_1 - l_2)}$$

Since $T_1 \sim T_2$ and positions of K_1 and K_2 are asymmetrical about C.G, l_1-l_2 is fairly large. Hence, the second term in the denominator is negligibly small and thus, an approximate value of l_1-l_2 is sufficient.

Therefore,

$$g = \frac{8\pi^2}{\frac{T_1^2 + T_2^2}{(l_1 + l_2)} + \frac{T_1^2 - T_2^2}{(l_1 - l_2)}} \qquad (1)$$

where

g = **Acceleration due to gravity** in cm/s^2

T_1 = Time period about K_1 in seconds

T_2 = Time period about K_2 in seconds

l_1 = Distance of K_1 from C.G. in cm

l_2 = Distance of K_2 from C.G. in cm

Procedure –

1. Determine the middle point of the rod and fix the smaller metal weight W there. Fix the brass weight W_1 near one end of the Kater's pendulum (5 cm from end 1) and the knife edge K_1 just below it (at a distance of about 2 cm).
2. Similarly, adjust the wooden weight W_2 and the knife edge K_2 at the other end (end 2) of the pendulum with the same symmetry. The metallic and wooden cylinders are placed at different ends to eliminate viscous drag of air and to make the C.G. asymmetrical about the knife edges .Screw all the five tightly. Knife edges must be sharp, horizontal and parallel to each other so that the **oscillations** are confined to a vertical plane
3. Suspend the pendulum vertically about K_1 and focus the telescope at the tip of its lower end. Set it oscillating with amplitude of about 4-5 degrees for the motion to remain **simple harmonic**. Note the time for 10 oscillations using a stop watch.

4. Now suspend the pendulum vertically about K_2 and repeat step 3.This time will be quite different from that about K_1.
5. Keep moving K_1 and K_2 towards W by small distance (approx. 1 cm) and repeat steps 3 and 4 till the difference in time about K_1 and K_2 is less than one second. If at any stage the time difference increases, then K_1 and K_2 should be moved towards W.
6. Now, move the weight W and repeat step 5 to reduce the time difference to about 0.5 second.
7. The apparatus is ready to record the measurements. Suspend the pendulum about K_1 and K_2 vertically and record the time taken for **50** oscillations. Repeat this 5 times each.
8. Remove the pendulum from support and place it horizontally on a wedge. Balance it and find the C.G. of the system.
9. Measure the distances l_1 and l_2 from C.G. to the knife edges K_1 and K_2.

Observation Table –

Sr. No.	Number of oscillations	Time for oscillations (t_1)	Time for oscillations (t_2)	Time Period (T_1)	Time Period (T_2)	$T_1 - T_2$
Arrangement 1	10			$t_1/10$ = ___	$t_2/10$ = ___	~ 2 sec
Arrangement 2	10			$t_1/10$ = ___	$t_2/10$ = ___	~ 1.5 sec
Arrangement 3	10			$t_1/10$ = ___	$t_2/10$ = ___	~ 1 sec
Arrangement n	10			$t_1/10$ = ___	$t_2/10$ = ___	~ 0.5 sec
Arrangement n	50			$t_1/50$ = ___	$t_2/50$ = ___	~ 0.5 sec
Arrangement n	50			$t_1/50$ = ___	$t_2/50$ = ___	~ 0.5 sec
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Arrangement n	50			$t_1/50$ = ___	$t_2/50$ = ___	~ 0.5 sec
Arrangement n	50			$t_1/50$ = ___	$t_2/50$ = ___	~ 0.5 sec

Calculations –

T_1 = ------ sec
T_2 = ------ sec
l_1 = ------ cm
l_2 = ------ cm

Substitute in the Equation (1) and obtain the value of *g*.

Percentage error

The percentage error can be calculated as

$$\text{Percentage error} = \frac{\text{Standard value} - \text{calculated value}}{\text{standard value}} \times 100$$

where

Standard value = 981 cm/s^2

Calculated value = g

Result

The value of acceleration due to gravity g as calculated in the lab is (---------± max. log error) cm/s^2

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