1. DETERMINATION OF GRAVITATIONAL ACCELERATION USING A RUBBER BALL

AIM

Determination of gravitational acceleration and coefficient of restitution using a rubber ball.

APPARATUS

1) Measuring scale
2) Rubber ball
3) Smartphone with 'phyphox' app

Formulae

Consider a ball is freely falling from a height h_0 from the ground. It takes time t to reach the ground. We can use the relation (1) , to find the value of acceleration due to gravity(g).

$$h_0 = \frac{1}{2} g t^2 \qquad (1)$$

$$e = \frac{h_1}{h_0} \qquad (2)$$

h_1 is the height of the first bounce of the ball.

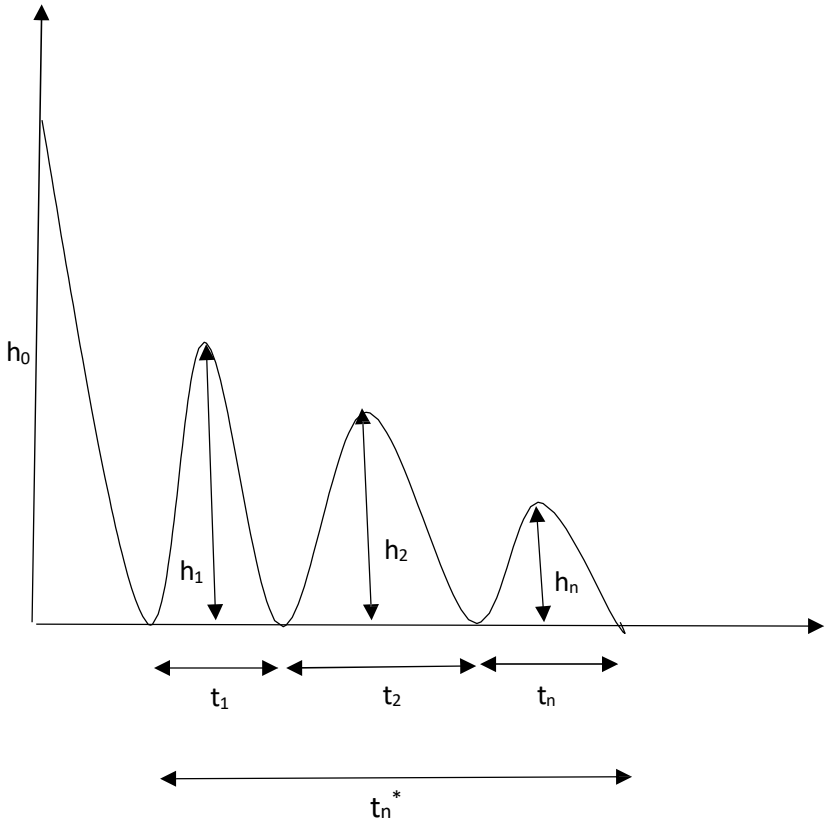
Suppose one measures the time t_1 elapsed between the first and the second bounce

$$g = \frac{2h_1}{\left(\frac{t_1}{2}\right)^2} = \frac{8h_1}{t_1^2} = \frac{8\,e\,h_0}{t_1^2} \qquad (3)$$

$$t_n^* = t_1 + t_2 + \ldots\ldots + t_n \qquad (4)$$

using the value of time t in eqn (3), eqn (4) changes to

$$t_n^* = 1 + \sqrt{e} + \ldots\ldots\ldots + (\sqrt{e})^{n-1} \qquad (5)$$



$$t_1 = t_n^* \left[\frac{\sqrt{e}-1}{(\sqrt{e})^2-1} \right] \quad (6)$$

$$g = \frac{8h_0}{(t_n^*)^2} \left[\frac{(\sqrt{e})^n-1}{\sqrt{e}-1} \right] \quad (7)$$

PROCEDURE

1) Find the coefficient of restitution(e).
    1) Drop the ball height h_0 from the ground. Measure h_0 using a measuring tape.
    2) Observe the height of the first bounce and measure it.

2) Find acceleration due to gravity (g).
    1) Drop the ball height h_0 from the ground. Measure h_0 using a measuring tape.
    2) observe time(t_n^*) taken by ball for n collisions. You can choose n = 3. Measure the time by using stop watch in smartphone. You can use 'Acoustic stopwatch' in 'phyphox' app.
    3) You can use (in)elastic collision option in 'phyphox' app to do this experiment.
        3.1) select the (in)elastic collision option in 'phyphox' app.
        3.2) Keep the mobile on the floor.
        3.3) Drop the ball from a particular height.

3.4) This app sense and measure all values. Just not it and do the calculations.

OBSERVATIONS AND CALCULATIONS

Member	h	ho	h1	h2	h3	e	root(e)	t1	t2	t3	sum(t)	g
IMT2023109	100	100.04	57.39	32.92	19.97	0.573671	0.75741	0.684	0.518	0.404	1.606	9.813276
	100	99.14	57.21	33.02	20.21	0.577063	0.759646	0.683	0.519	0.406	1.608	9.811164
	95	95.02	55.23	32.1	19.72	0.581246	0.762395	0.671	0.512	0.401	1.584	9.813411
	95	94.61	55.01	31.99	19.28	0.58144	0.762522	0.67	0.511	0.397	1.578	9.80352
	90	91.11	52.99	30.82	18.32	0.581605	0.76263	0.657	0.501	0.386	1.544	9.820942
	90	88.54	51.71	30.2	18.31	0.58403	0.764218	0.649	0.496	0.386	1.531	9.821439
IMT2023111	85	84.49	49.31	28.78	17.42	0.583619	0.76395	0.634	0.484	0.377	1.495	9.814009
	85	83.58	48.24	27.84	17.07	0.577172	0.759718	0.627	0.477	0.373	1.477	9.816625
	80	80.93	46.76	27.02	16.57	0.577783	0.760121	0.618	0.469	0.368	1.455	9.794619
	80	80.35	46.55	26.97	16.94	0.57934	0.761144	0.616	0.469	0.372	1.457	9.81405
	75	74.58	44.06	26.03	16	0.590775	0.768619	0.599	0.461	0.361	1.421	9.82383
	75	74.31	43.92	25.96	16.06	0.591038	0.76879	0.598	0.46	0.362	1.42	9.825393
IMT2023112	70	70.47	42.08	25.13	15.34	0.597134	0.772744	0.586	0.453	0.354	1.393	9.803259
	70	70.15	42.02	25.17	15.33	0.599002	0.773952	0.585	0.453	0.354	1.392	9.822777
	65	64.12	39.05	23.78	14.49	0.609014	0.780394	0.564	0.44	0.344	1.348	9.820935
	65	64.06	38.76	23.45	14.24	0.605058	0.777855	0.562	0.437	0.341	1.34	9.817505
	60	60.65	36.41	21.85	13.31	0.60033	0.774809	0.545	0.422	0.329	1.296	9.806582
	60	60.63	36.43	21.89	13.07	0.600858	0.77515	0.545	0.422	0.326	1.293	9.811969
IMT2023113	55	56	33.43	19.96	12.32	0.596964	0.772635	0.522	0.403	0.317	1.242	9.814888
	55	54.33	32.54	19.5	11.82	0.598932	0.773907	0.515	0.399	0.31	1.224	9.815063
	50	51.34	31.18	18.94	11.86	0.607324	0.77931	0.504	0.393	0.311	1.208	9.819854
	50	50.27	30.69	18.74	11.66	0.610503	0.781347	0.5	0.391	0.308	1.199	9.8208
	45	45.88	28.28	17.43	10.8	0.616391	0.785105	0.48	0.377	0.297	1.154	9.819444
	45	44.24	27.23	16.76	10.5	0.615506	0.784542	0.471	0.37	0.293	1.134	9.819646

g_{mean} = 9.815208

e_{mean} = 0.593158

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Error Analysis

For e,

$$\text{mean} = \frac{0.573671 + 0.577063 + 0.581246 + 0.58144 + 0.581605 + 0.58403 + 0.584 + 0.5771 + 0.5778 + 0.5780 + 0.5907 + 0.591 + 0.597 + 0.599 + 0.6090 + 0.6050 + 0.6003 + 0.6008 + 0.5969 + 0.5989 + 0.607 + 0.610 + 0.6163 + 0.6155}{24}$$

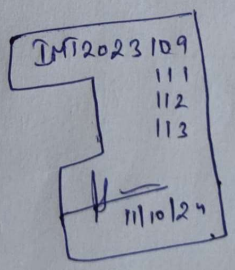
$$= 0.5931$$

Standard dev for e:-

$$= \sqrt{\frac{(0.574 - 0.594)^2 + (0.577 - 0.594)^2 + (0.581 - 0.594)^2 + (0.581 - 0.594)^2 + (0.582 - 0.594)^2 + 2(0.584 - 0.594)^2 + (0.577 - 0.594)^2 + 2(0.578 - 0.594)^2 + 2(0.591 - 0.594)^2 + 2(0.588 - 0.594)^2 + 2(0.601 - 0.594)^2 + 2(0.609 - 0.594)^2 + 2(0.600 - 0.594)^2 + (0.607 - 0.594)^2 + 2(0.616 - 0.594)^2}{24}}$$

$$= 0.013288$$

$$e = 0.5937 \pm 0.013288$$



Calculation for g,

mean for g = $\dfrac{2(9.813) + 9.811 + (9.804)2 + 9.821 + 2(9.814) \; 9.794 + 9.816 + 2(9.824) + 9.823 + (9.821)2 + 2(9.819) + 2(9.820) + 2(9.815) + 9.812 + 9.807 + 9.817}{24}$

$= 9.8152$

Standard deviation for g

$$= \sqrt{\dfrac{2(9.813 - 9.815)^2 + (9.811 - 9.815)^2 + 2(9.804 - 9.815)^2 + (9.821 - 9.815)^2 + 2(9.814 - 9.815)^2 + (9.794 - 9.815)^2 + (9.816 - 9.815)^2 + 2(9.824 - 8.815)^2 + (9.823 - 9.815)^2 + 2(9.821 - 9.815)^2 + 2(9.819 - 9.815)^2 + 2(9.820 - 9.815)^2 + 2(9.815 - 9.815)^2 + (9.812 - 9.815)^2 + (9.807 - 9.815)^2 + (9.817 - 9.815)^2}{24}}$$

$= 0.07378$

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$g = 9.8152 \pm 0.07378$

RESULT

1) coefficient of restitution(e) = 0.5937 ± 0.013288
2) Acceleration due to gravity(g) = 9.8152 ± 0.07378 m/s

Precautions

1. Perform Multiple Trials: Repeat the experiment several times to reduce random errors and ensure consistency in results.
2. Drop the Ball Vertically: Avoid imparting any spin or lateral movement when dropping the ball to ensure consistent vertical motion.
3. Use a Flat Surface: Conduct the experiment on a smooth, level surface to ensure accurate bouncing behaviour.
4. Minimize External Interference: Perform the experiment in a controlled environment, avoiding wind or air currents that could alter the ball's motion.