

An example lab

What follows is a good example of a lab report for 191. It is on an experiment we aren't doing. It is not claimed to be perfect (or even a good reference!) for any particular detail, but is meant to give you a feeling for what a good lab report might look like.

I don't regard the "Objectives" section as critical, since you normally have been given those in the lab manual already. Here it's mainly to stand in for the non-existent lab manual for this lab, to help you read it.

Some things to notice:

Equations and sample calculations

Lab book pages, tables, and graphs inserted as needed in the text

Good labeling and referencing of tables and figures

I would have liked, for example, a clearer comparison of the measured values and expectations, along the lines of:

Page 7 or 9

We expect $g = 9.804$, and measure $9.780 \pm .019 \text{ cm/s}^2$. Our measurement of g is consistent with expectations since the t value of the discrepancy is $t = -.024/.019 = -1.3$ standard deviations, less than 2 standard deviations from the expected result.

Page 13 *as the text says, it's compatible with 0; better would have been:*

Then the coefficient is $-.021 \pm .017 \text{ J/kg s}$, which, though it is nonzero, is also statistically consistent with zero ($t = -1.2$)

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Ideally the student would have had time to perform the fits with a custom function, in which case the uncertainty in the parameter would have been available. So I will imagine that had happened.

Here is a table with the various parameters of the quadratic fits, and their sums. The sum of each is expected to be zero. The uncertainties on the sum of the terms come from:

$$\delta(a + b) = \sqrt{\{(\delta a)^2 + (\delta b)^2\}} \text{ and } t = (a + b - 0) / \delta(a + b)$$

Term	PE/m	KE/m	sum	error(sum)	t
constant	0	0.015	0.015	0.02	0.7
Linear	-2.06	2.18	0.12	0.07	1.7
quadratic	-47.86	47.52	-0.34	0.13	-2.6

We can see that the constant and linear terms are consistent with zero, but the quadratic term is not, because $|t| > 2$.

Energy of a Free-Falling Body

Objectives:

- 1) To observe the changes of the potential energy (PE), the kinetic energy (KE), and the total energy (TE), of a free-falling body.
- 2) To verify, graphically, that the TE remains constant in time.
- 3) To compare the theoretical predictions for the time dependence of the potential energy and the kinetic energy, with the experimental results.

PART 1

In this part we want to test the conservation of the TE of a free-falling object. In the Behr apparatus, an object is released from a given height. Falling down, it marks periodically a tape, with period $\tau=1/60$ s. The latter quantity is given with negligible error. We ignore the first and the last marks on the tape, because they are affected by the systematic errors connected to the motion beginning and the motion end. Therefore, the second mark on the tape corresponds to the 0th point in Tab.1. We assign the instant $t=0$ s to the 0th point, so that the nth point corresponds to $t=n/60$ s. We measure the distance of the nth point from the zero-tick of a meter stick, and denote it by y_n . The error on y_n is $\delta y=0.0008$ m, as explained in the lab book.

Equations Used

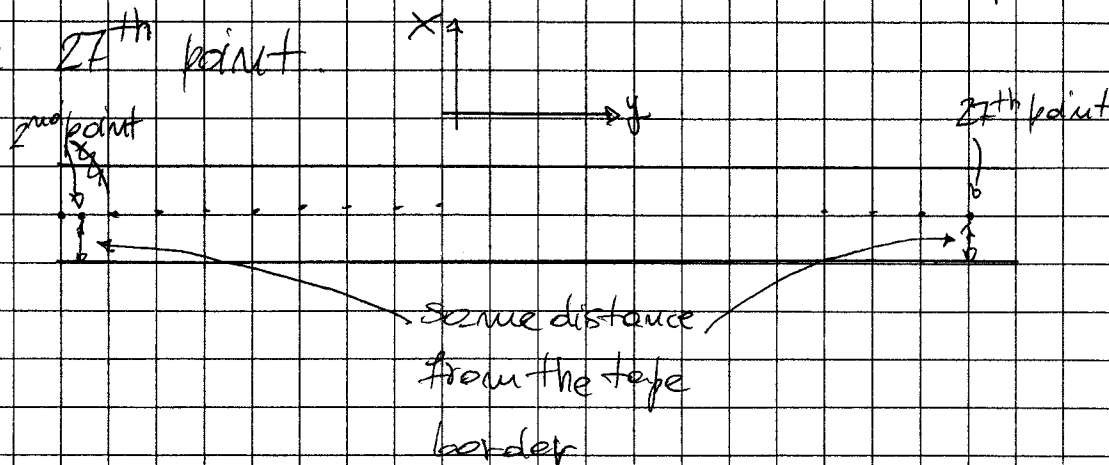
The instantaneous velocity at the nth mark is

$$V_m = \frac{y_{m+1} - y_m}{2\tau} \quad \left(\text{ex: } V_1 = \frac{1.29 \cdot 10^{-2} - 10^{-4}}{2 \cdot \frac{1}{60}} \frac{\text{m}}{\text{s}} = 3.84 \cdot 10^{-1} \frac{\text{m}}{\text{s}} \right)$$

The corresponding error is

$$\delta V_m = \frac{2\delta y}{2\tau} = \frac{\delta y}{\tau} = \frac{8.0 \cdot 10^{-4} \text{ m}}{\frac{1}{60} \text{ s}} = 4.80 \cdot 10^{-2} \frac{\text{m}}{\text{s}}$$

- After we run the Behr free fall apparatus, following the directions given in the "Experimental Procedure" section, we measure the position of each point, taking the second point to be $y=0$, and ~~we~~ ignoring the last point. We ignore the first and last points because they are affected by systematic errors. We find that the points do not fall on a straight line, probably due to the tape oscillation. In order to solve this inconvenient, we measure the distance of the second point from the tape border, and look for a far away point which is at the same distance from the border: this happens for the 27^{th} point.



Then we place a meter stick (which we suppose to be reason-

nably straight) on the tape, in such a way that it is tangent to the 2nd and the 27th point. We assume that the oscillations are purely transversal, that is, along the x -direction, in such a way that they do not affect our measurements in a sensible way. Measuring the thickness of the tics with a caliper, we find that they are $\approx 0.54 \div 0.60$ mm thick. Therefore we assign an error, in the y -measurement, of ~~1.6~~ 1.6 mm, that is, $\Delta y = 0.8$ mm (in $y \pm \Delta y$). The values are reported below.

#	y (mm)	#	y (mm)	#	y (mm)
2	0.1	15	275.8	28	72.4
3	5.3	16	315.9	29	148.2
4	11.9 12.9	17	358.5	30	226.3
5	22.6	18	404.5	31	307.0
6	36.3	19	452.9	32	391.6
7	51.4	20	504.0	33	477.0
8	70.1	21	557.8		
9	91.5	22	614.0		
10	115.4	23	673.4		
11	141.9	24	735.4		
12	171.1	25	799.8		
13	203.4	26	867.3		
14	237.9	27	937.9		

The points after the 27th ~~have been measured~~ are measured by repositioning the meter stick, with the zero at the 27th point.

- We create a table with Colidea Graph. The table is shown in the lab report, where we also include the details of how the various quantities have been calculated.

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Table 1

	t(s)	y(m)	v(m/s)	PE/m(J/kg)	KE/m(J/kg)	TE/m(J/kg)	TE/m(J/kg)	TE/m Res.(J/kg)	TE/m Chauvenet
0	0.0000	0.00010000		0.050884					
1	0.016667	0.0053000	0.38400	0.0000	0.073728	0.073728	0.073728	-0.0027846	-0.092662
2	0.033333	0.012900	0.51900	-0.074369	0.13468	0.060311	0.060311	0.010778	0.35867
3	0.050000	0.022600	0.70200	-0.16929	0.24640	0.077115	0.077115	-0.0058784	-0.19561
4	0.066667	0.036300	0.86400	-0.30335	0.37325	0.069901	0.069901	0.0014820	0.049315
5	0.083333	0.051400	1.0140	-0.45111	0.51410	0.062991	0.062991	0.0085378	0.28411
6	0.100000	0.070100	1.2030	-0.63409	0.72360	0.089511	0.089511	-0.017835	-0.59350
7	0.116667	0.091500	1.3590	-0.84350	0.92344	0.079939	0.079939	-0.0081173	-0.27012
8	0.133333	0.11540	1.5120	-1.0774	1.1431	0.065699	0.065699	0.0062687	0.20860
9	0.150000	0.14190	1.6710	-1.3367	1.3961	0.059435	0.059435	0.012679	0.42193
10	0.166667	0.17110	1.8450	-1.6224	1.7020	0.079593	0.079593	-0.0073324	-0.24400
11	0.183333	0.20340	2.0040	-1.9385	2.0080	0.069520	0.069520	0.0028869	0.096068
12	0.200000	0.23790	2.1720	-2.2761	2.3588	0.082708	0.082708	-0.010154	-0.33790
13	0.216667	0.27580	2.3400	-2.6470	2.7378	0.090849	0.090849	-0.018149	-0.60396
14	0.233333	0.31590	2.4810	-3.0393	3.0777	0.038335	0.038335	0.034511	1.1484
15	0.250000	0.35850	2.6580	-3.4562	3.5325	0.076279	0.076279	-0.0032860	-0.10935
16	0.266667	0.40450	2.8320	-3.9063	4.0101	0.10378	0.10378	-0.030641	-1.0196
17	0.283333	0.45290	2.9850	-4.3799	4.4551	0.075167	0.075167	-0.0018818	-0.062619
18	0.300000	0.50400	3.1470	-4.8800	4.9518	0.071826	0.071826	0.0016063	0.053452
19	0.316667	0.55780	3.3000	-5.4064	5.4450	0.038566	0.038566	0.035012	1.1651
20	0.333333	0.61400	3.4680	-5.9564	6.0135	0.057138	0.057138	0.016586	0.55193
21	0.350000	0.67340	3.6420	-6.5376	6.6321	0.094456	0.094456	-0.020585	-0.68500
22	0.366667	0.73540	3.7920	-7.1443	7.1896	0.045311	0.045311	0.028706	0.95524
23	0.383333	0.79980	3.9570	-7.7745	7.8289	0.054425	0.054425	0.019739	0.65685
24	0.400000	0.86730	4.1430	-8.4350	8.5822	0.14721	0.14721	-0.072900	-2.4259
25	0.416667	0.93790	4.2900	-9.1259	9.2021	0.076186	0.076186	-0.0017298	-0.057561
26	0.433333	1.0103	4.4460	-9.8343	9.8835	0.049130	0.049130	0.025472	0.84764
27	0.450000	1.0861	4.6170	-10.576	10.658	0.082285	0.082285	-0.0075358	-0.25077
28	0.466667	1.1642	4.7640	-11.340	11.348	0.0075483	0.0075483	0.067347	2.2411
29	0.483333	1.2449	4.9590	-12.130	12.296	0.16586	0.16586	-0.090817	-3.0221
30	0.500000	1.3295	5.1000	-12.958	13.005	0.047173	0.047173	0.028016	0.93227
31	0.516667	1.4149		-13.794					
32									
33								-0.090817	-3.0221
34								0.067347	2.2411

t(s)	y(m)	v(m/s)	PE/m(J/kg)	KE/m(J/kg)	TE/m(J/kg)	TE/m Res.(J/kg)	TE/m Chau enet
35						-1.4901e-08	-4.9586e-07
36						30.000	998.30
37						-4.9671e-10	-1.6529e-08
38						-0.00012391	-0.0041235
39						0.029546	0.98319
40						0.030051	1.00000
41						0.00090306	0.030051
42						0.0054865	0.18257
43						-0.93075	-30.972
44						2.3822	79.271

Table 1
(cont.)

The relationship between position and time, and between velocity and time, in a free falling object, are

$$y(t) = y_0 + v_0 t + \frac{1}{2} g t^2$$

$$v(t) = v_0 + g t$$

where, v_0 is the velocity at the instant $t=0$, and g is the gravitational acceleration. In Fig.1 we plot velocity vs. time. A linear fit gives the value of g . The error is given by the formulas reported in Taylor, Chapt.8:

$$\delta v_0 = \sqrt{\frac{N-1}{N-2}} \sigma \left(\sum_{m=1}^N t_m^2 \right) / \Delta, \quad \delta g = \sqrt{\frac{N(N-1)}{N-2}} \frac{\sigma}{\Delta}$$

$$\sigma = \text{standard deviation of the residuals} = 8.295 \cdot 10^{-3} \frac{\text{m}}{\text{s}}$$

$$N = \# \text{ of measurement} = 23$$

$$\Delta = N \left(\sum_{m=1}^N t_m^2 \right) - \left(\sum_{m=1}^N t_m \right)^2 = 4.644$$

We obtain:

$$g = (9.780 \pm 0.019) \text{ m/s}^2$$

We calculate the potential energy per unit mass, PE_n/m , at each point n . The formula is

$$PE_m/m = -g \left(y_m - y_0 \right) \quad \left(\text{ex: } PE_{20}/m = -9.78 \frac{\text{m}}{\text{s}^2} (0.614 - 10^{-4})_{\text{mass}} \right)$$

$$= -5.956 \frac{\text{J}}{\text{kg}}$$

The error associated to, PE_n/m is

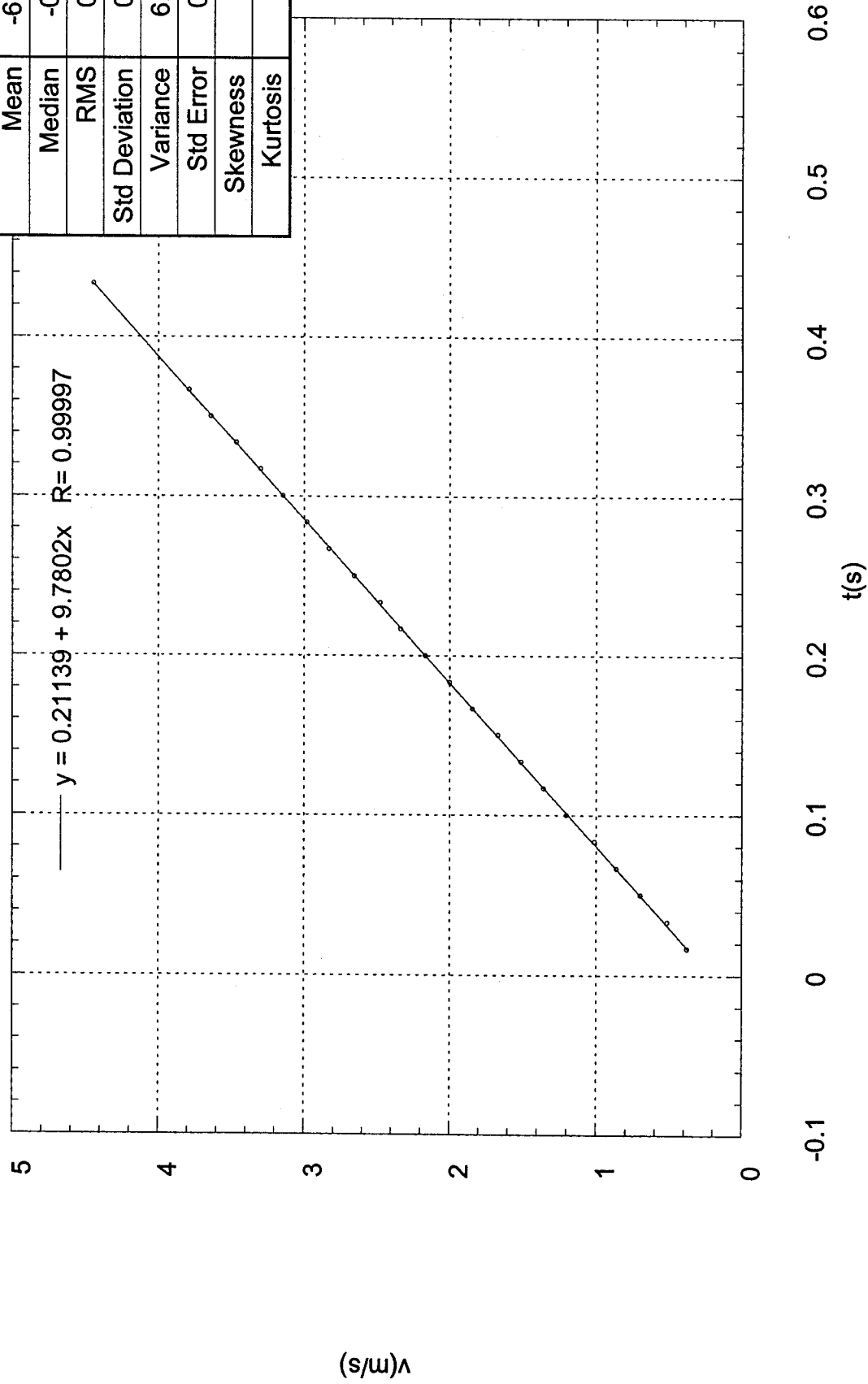
$$\delta \frac{PE_m}{m} = \delta g (y_m - y_0) + g \cdot 2 \delta y \quad \left(\text{ex: } \delta \frac{PE_{20}}{m} = \dots \right)$$

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Figure 1

Velocity vs. Time



Minimum	v Res. (m/s)
Maximum	-0.013586044
Sum	0.018400311
Points	-1.4901161e-07
Mean	23
Median	-6.4787657e-09
RMS	-0.0015451908
Std Deviation	0.0081123583
Variance	0.0082946812
Std Error	6.8801737e-05
Skewness	0.0017295606
Kurtosis	0.34539494
	-0.45711055

Then we calculate the kinetic energy per unit mass, KE_n/m at each point n :

$$\frac{KE_m}{m} = \frac{1}{2} v_m^2 \quad \left(\text{ex. } \frac{KE_{10}}{m} = \frac{1}{2} \cdot (1.711 \cdot 10^{-12})^2 \frac{m^2}{s^2} = -1.622 \text{ J} \right)$$

The error is

$$\delta \frac{KE_m}{m} = \frac{1}{2} \cdot 2v_m \delta v_m = v_m \delta v_m = \frac{v_m}{g} \delta g \quad \left(\text{ex. } \frac{\delta KE_{10}}{m} = \dots \right)$$

Finally, we calculate the total energy per unit mass, TE_n/m at each point n , which is given by

$$TE_m/m = PE_m/m + KE_m/m \quad \left(\text{ex. } \frac{TE_{30}}{m} = -12.130 \text{ J} + 12.296 \text{ J} \right)$$

$$= 1.659 \cdot 10^{-1} \text{ J}$$

with the experimental error

$$\delta \frac{TE_m}{m} = \delta \frac{PE_m}{m} + \delta \frac{KE_m}{m} \quad \left(\text{ex. } \delta \frac{TE_{30}}{m} = \dots \right)$$

Results

All of these quantities are reported in Tab.1. In Fig. ² we show the plot of TE/m vs. time. Based on the Chauvenet criterion, we reject the 24th, the 28th and the 29th points, which are sensibly different from the other ones. We also discard the 0th point, since its velocity is unknown: it cannot be zero, because we ignored the first mark on the tape. As a consequence, also the total energy is not zero, as it is clear from Fig. ². The new data, after the wrong numbers have been rejected, are shown in Tab.2. Note that we can assign a velocity to an even lower number of points. The value we get for g is smaller than what we expect ($g=9.804 \text{ m/s}^2$). A possible explanation for this discrepancy lies in the apparatus oscillations during the free fall. All the quantities in Tab.2 have been calculated based on the obtained value of g . In Fig.2 we show the new TE/m vs. time plot, with the statistic of the residuals. The constant term, in the linear fit, gives the initial TE/m . Its error is

	t(s)	y(m)	v(m/s)	v Res.(m/s)	PE/m(J/kg)	PE/m Res.(J/kg)	PE/m Err.(J/kg)	KE/m(J/kg)	KE/m Res.(J/kg)	KE/m Err.(J/kg)
0	0.0000	0.00010000			0.0000	-0.00093944	0.0078260			
1	0.016667	0.0053000	0.38400	-0.0096031	-0.050857	0.0020530	0.0079243	0.073728	-0.0083408	0.018432
2	0.033333	0.012900	0.51900	0.018400	-0.12519	0.0020272	0.0080679	0.13468	0.0066895	0.024912
3	0.050000	0.022600	0.70200	-0.0015963	-0.22005	-0.0039509	0.0082511	0.24640	-0.0026504	0.033696
4	0.066667	0.036300	0.86400	-0.00059289	-0.35404	0.0027009	0.0085100	0.37325	-0.00071609	0.041472
5	0.083333	0.051400	1.0140	0.012410	-0.50172	-0.0034456	0.0087953	0.51410	0.013613	0.048672
6	0.100000	0.070100	1.2030	-0.013586	-0.68461	-0.0012947	0.0091486	0.72360	-0.014316	0.057744
7	0.116667	0.091500	1.3590	-0.0065826	-0.89391	0.00068784	0.0095529	0.92344	-0.0061752	0.065232
8	0.133333	0.11540	1.5120	0.0034208	-1.1277	0.00063002	0.010004	1.1431	0.0085688	0.072576
9	0.150000	0.14190	1.6710	0.0074241	-1.3868	-0.00048995	0.010505	1.3961	0.016294	0.080208
10	0.166667	0.17110	1.8450	-0.0035725	-1.6724	-0.0016938	0.011057	1.7020	-0.0024251	0.088560
11	0.183333	0.20340	2.0040	0.00043106	-1.9883	0.00059342	0.011667	2.0080	0.0051510	0.096192
12	0.200000	0.23790	2.1720	-0.0045657	-2.3257	-0.0022616	0.012319	2.3588	-0.0056627	0.10426
13	0.216667	0.27580	2.3400	-0.0095623	-2.6964	0.0016451	0.013035	2.7378	-0.018302	0.11232
14	0.233333	0.31590	2.4810	0.012441	-3.0886	0.00057745	0.013792	3.0777	0.034586	0.11909
15	0.250000	0.35850	2.6580	-0.0015554	-3.5052	-0.0025301	0.014597	3.5325	-0.0010495	0.12758
16	0.266667	0.40450	2.8320	-0.012552	-3.9551	0.00087118	0.015466	4.0101	-0.033114	0.13594
17	0.283333	0.45290	2.9850	-0.0025487	-4.4285	0.0010028	0.016381	4.4551	-0.0061502	0.14328
18	0.300000	0.50400	3.1470	-0.0015452	-4.9282	0.0010495	0.017346	4.9518	-0.0044799	0.15106
19	0.316667	0.55780	3.3000	0.0084581	-5.4544	0.0010133	0.018363	5.4450	0.027086	0.15840
20	0.333333	0.61400	3.4680	0.0034616	-6.0041	-0.0020428	0.019424	6.0135	0.0097346	0.16646
21	0.350000	0.67340	3.6420	-0.0075352	-6.5850	-0.00045967	0.020547	6.6321	-0.031277	0.17482
22	0.366667	0.73540	3.7920	0.0054684	-7.1914	-0.00027657	0.021718	7.1896	0.015131	0.18202
23	0.383333	0.79980			-7.8212	-0.0031114	0.022935			
24										
25	0.416667	0.93790			-9.1719	0.0027027	0.025544			
26	0.433333	1.0103	4.4460	0.0034819	-9.8800	-0.0014467	0.026912	9.8835	0.0011234	0.21341
27	0.450000	1.0861			-10.621	0.00074577	0.028344			
28										
29										
30	0.500000	1.3295			-13.002	0.0048599	0.032942			
31	0.516667	1.4149			-13.837	-0.0050192	0.034556			

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Table 2

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Table 2
(cont.)

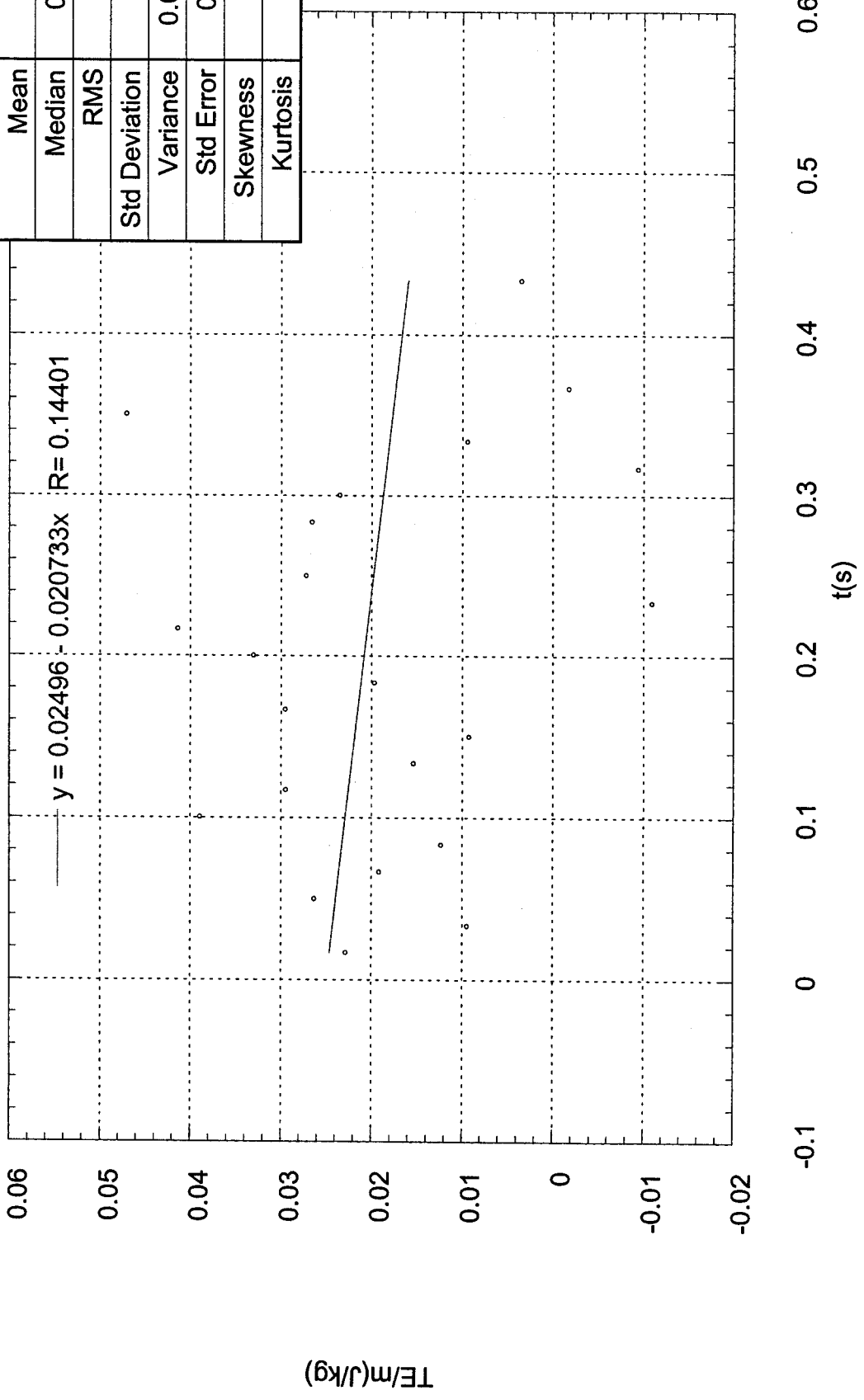
	TE/m(J/kg)	TE/m Res.(J/kg)
0		
1	0.022871	0.0017434
2	0.0094939	0.014775
3	0.026348	-0.0024242
4	0.019205	0.0043729
5	0.012374	0.010858
6	0.038990	-0.016104
7	0.029530	-0.0069891
8	0.015415	0.0067806
9	0.0092883	0.012562
10	0.029598	-0.0080939
11	0.019693	0.0014654
12	0.033060	-0.012247
13	0.041399	-0.020931
14	-0.010907	0.031029
15	0.027258	-0.0074816
16	0.054999	-0.035568
17	0.026638	-0.0075521
18	0.023562	-0.0048220
19	-0.0094180	0.027812
20	0.0094466	0.0086022
21	0.047073	-0.029370
22	-0.0017490	0.019107
23		
24		
25		
26	0.0035000	0.012475
27		
28		
29		
30		
31		

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Figure 2

TE per Unit Mass vs. Time



Minimum	TE/m Res.(J/kg)
Maximum	-0.035568327
Sum	0.031028835
Points	0
Mean	23
Median	0
RMS	0.0014654323
Std Deviation	0.016321382
Variance	0.0166882
Std Error	0.00027849603
Skewness	0.0034797303
Kurtosis	-0.19529332
	-0.29367177

The linear coefficient gives the TE average rate of change. Its error is

$$\delta_{rate} = \sqrt{\frac{N(N-1)}{N-2} \frac{\sigma^2}{\Delta}}, \quad \sigma = 1.669 \cdot 10^{-2} \frac{J}{kg \cdot s}$$

We summarize the results for this part in the table below. We observe that the rate of change is compatible with zero, but a negative value is more likely. This energy loss is probably due to the friction acting on the falling body. We also observe a clear oscillatory pattern. These oscillations are mainly along the tape x-axis, as we assumed in the lab book. They affect the speed measurement, because one has to take into account the total distance between the two points, not only their vertical displacement. Therefore, a more accurate measure would require one column for the x-position, in addition to the column for the y-position of Tab.2.

$g(m/s^2)$	Err.(m/s^2)	TE/ $m(t=0)(10^{-2} J/kg)$	Err.($10^{-2} J/kg$)	Rate ($10^{-2} J/kg \cdot s$)	Err.($10^{-2} J/kg \cdot s$)
9.78	0.019	2.5	1.2	-2.1	4

PART II

In this part we compare the theoretical prediction for the PE and the KE as functions of time, with the experimental curves.

Equations Used

Inserting the equations for $y(t)$ and $v(t)$ in the formulas for the PE and the KE, we obtain

$$\frac{PE}{m} = -g(y(t) - y_0) = -g(v_0 t + \frac{1}{2} g t^2) = -g v_0 t - \frac{1}{2} g^2 t^2$$

$$\frac{KE}{m} = \frac{1}{2} v^2 = \frac{1}{2} (v_0 + g t)^2 = \frac{1}{2} v_0^2 + g v_0 t + \frac{1}{2} g^2 t^2$$

NOTE: THE ABS. VALUE OF THE LINEAR AND QUADRATIC COEFFICIENTS ARE IDENTICAL

Results

The PE/m vs. time, and the KE/m vs. time plots are in Fig.3 and Fig.4, respectively, with the statistic of the residuals. The absolute values of the linear and quadratic terms, from the PE and the KE fits, do not coincide. The main reason for this, once again, is the oscillations of the apparatus, which affect the speed measurements, mainly because we ignored the x-displacements. They also affect the y-position measurements, since an oscillation is never purely transverse. However, the single fits for PE/m and KE/m are excellent, as the correlation coefficients show.

Questions for Preliminary Discussion

- 1) Discuss the time $PE=TE$ and the time $KE=TE$ for an object in free fall. What happens at these points? That is, what are the position, speed, and acceleration of the object at these points?

The condition $PE=TE$ corresponds to $KE=0$: this happens at the beginning of the motion, right after the object is released. At that instant the speed is zero, and the acceleration is g . The condition $KE=TE$ corresponds to $PE=0$: this happens at the end of the motion, right before the object touches the ground. At that instant the speed has its maximum value, $v_{max}=2TE/m$, and the acceleration is of course still g .

- 2) A student says that the TE of a body is 2.3 J. A different student says that the TE of the same object is 532.2 J. What do you think is the reason of this discrepancy?

The TE of an object is defined only up to a constant, which is arbitrary. For example, if we decide that the PE at the top of the free-fall motion is zero, then $TE=0$. In the same way, if we decide that the PE at the bottom of the free-fall motion is zero, then $TE=(1/2)m v_{max}^2$.

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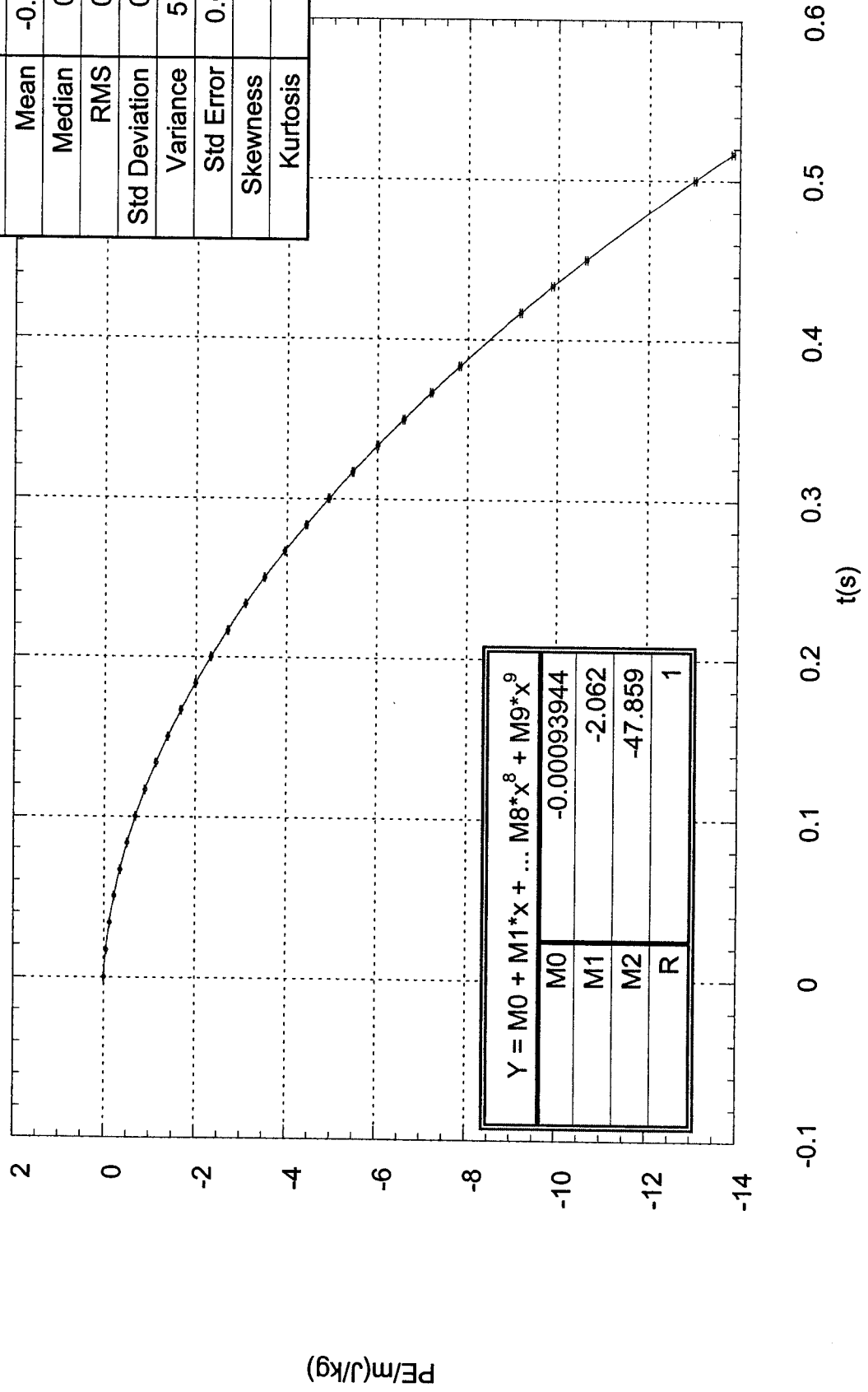
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Figure 3

PE per Unit Mass vs. Time

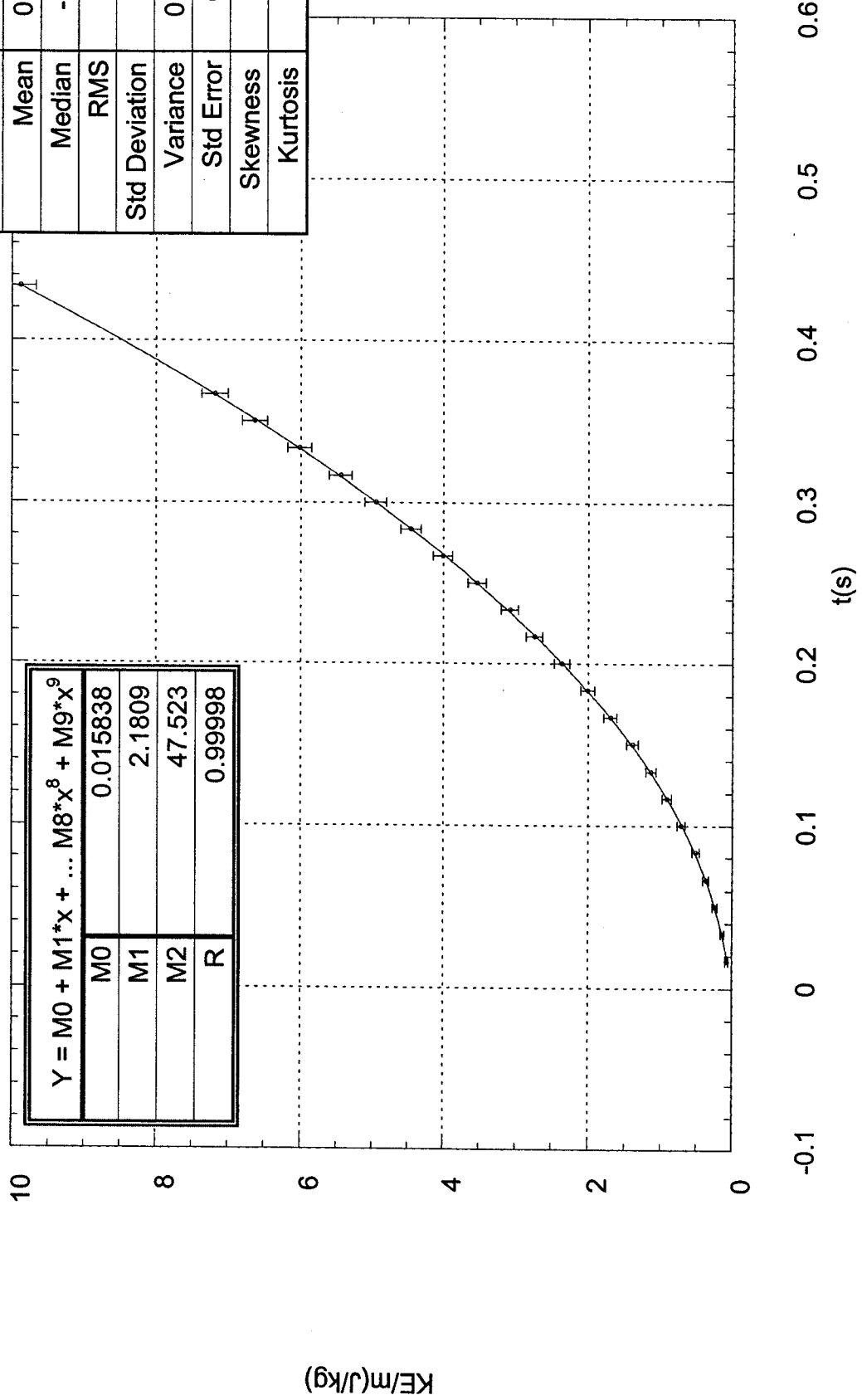


Minimum	PE/m Res.(J/kg)
Maximum	-0.0050191879
Sum	0.0048599243
Points	-0.0058024026
Mean	29
Median	-0.00020008285
RMS	0.0005774498
Std Deviation	0.0022077222
Variance	0.0022375538
Std Error	5.0066471e-06
Skewness	0.00041550331
Kurtosis	-0.13384489
	-0.2577745

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Figure 4

KE per Unit Mass vs. Time



Y = M0 + M1*X + ... M8*X ⁸ + M9*X ⁹	
M0	0.015838
M1	2.1809
M2	47.523
R	0.99998

Minimum	-0.033114195	KE/m Res.(J/kg)
Maximum	0.034585714	
Sum	0.0033183321	
Points	23	
Mean	0.00014427531	
Median	-0.0010495186	
RMS	0.015710973	
Std Deviation	0.016063395	
Variance	0.00025803265	
Std Error	0.0033494494	
Skewness	-0.069965118	
Kurtosis	0.18976413	

KE/m(J/kg)

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Questions to be Discussed

- 1) Does $TE/mass$ depend linearly on t ? If not, what kind of time dependence does it show?

The plot $TE/mass$ vs. t is shown in Fig.2. We observe that the dots form, approximately, a sinusoid whose middle point falls down roughly linearly. The reason for this behavior is in the systematic error due to the apparatus oscillation, which we (mistakenly) neglected.

- 2) Does the fit curves for $PE/mass$ and $KE/mass$ fall within the experimental uncertainties?

The curves, for $KE/mass$, and, especially, for $PE/mass$ are very accurate: there is no point, in each plot, that does not contain the curve. We were careful not to overestimate the error, and tried to be as accurate and precise as possible in determining the mark positions on the tape. In this way we reduced the only source of casual error to the minimum, since the time intervals are extremely accurate.

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QUESTION

ANSWER

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Conclusions

In the first part of this experiment we tested the conservation of the TE for a free-falling body. First, we found the gravitational acceleration, by linearly fitting the velocity vs. time plot. The obtained value of g , $g=9.78 \text{ m/s}^2$, was slightly below its known value,

$g=9.80 \text{ m/s}^2$. (The reasons for this discrepancy have been discussed in the Exp.2 Lab Report.) Then, we calculated the TE, and plotted it vs. time. Our results show that some energy is lost during the motion, most likely because of frictional forces acting in the Behr apparatus. Also, we found that the motion was affected by oscillations, which propagated up to the measured values of the PE, the KE, and the TE. Based on these observations, we believe that the experiment can be improved by: (1) Trying to keep the apparatus stable. (2) Measuring also the x-component of the motion, and including it in the formulas for the KE and the TE. (3) Reducing the apparatus friction, by using a specific lubricant.

In the second part of the experiment, we compared the theoretical predictions for the PE and the KE of the falling body (per unit mass), with the data fits. The absolute values of the coefficients, in the quadratic fits, should be the same, for both PE/m and KE/m . Our results show some discrepancy (we did not calculate the error), which are probably due to the systematic sources of error discussed above: oscillation of the apparatus, and frictional forces. Our suggestions, summarized in the points (1)-(3) of the last paragraph, should improve also this part of the experiment. However, the quadratic fits are excellent, for both PE/m and KE/m , with coefficients of correlation very close to unity: this means that casual errors have been reduced to a very high level of accuracy. Thus the systematic errors are mainly responsible for the large uncertainties in the TE and its rate of change, (as the oscillatory pattern of Fig.2 clearly shows) , and the discrepancies between the coefficients of the PE/m and KE/m fits.