

On the Einstein–Murphy Interaction¹

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Abstract

This paper is a first attempt to reconcile the two great concepts of twentieth century physics: Einstein's theory of general relativity, and Murphy's law.

§(1): *Introduction*

One of the less important (perhaps the least important of all) problems facing physicists today is the challenge of reconciling the laws of physics with Murphy's law. Murphy's law states

Whatever can go wrong, will go wrong.^{3,4}

A well-known folk lemma associated with this Law maintains that

Bread always falls butter side down.

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³There is a corollary which asserts in addition that it will go wrong at the most inconvenient possible moment. Investigation of this corollary is beyond the scope of this paper, but may form the basis for future research (if the authors are still employed after the appearance of this paper).

⁴The authors have been unable to identify the basis of this nomenclature. It seems first to have appeared in print in the 1950s, but all suggestions for the name Murphy are conceded to be apocryphal. A typical example reads [1]: "One day a teacher named Murphy wanted to demonstrate the laws of probability to his mathematics class. He had 30 of his students spread peanut butter on slices of bread, then toss the bread into the air to see if half would fall on the dry side and half on the buttered side. As it turned out, 29 of the slices landed peanut butter side on the floor, while the thirtieth stuck to the ceiling." Copyright © 1971 by William Morris and Mary Morris. Reprinted by permission of Harper and Row, Publishers, Inc.

It is this latter form that gives rise to what we will term “the Einstein–Murphy interaction,” which will be our concern in this paper. On the one hand it is well known that Murphy’s law is true.⁵ On the other hand, the laws of physics are claimed by some physicists to be true. Does this lead to a contradiction?

In order to test this, we have seized upon the problem which goes to the heart of the matter—namely, a slice of buttered bread with zero support in an Einstein field—and subjected it to rigorous theoretical analysis.⁶ In order to bring out the essentials of the problem we have added to the butter a further layer consisting of jam. Actually our analysis is not entirely rigorous, as our calculation will be done in the Newtonian approximation. (We justify this on the grounds that the probability of anyone actually eating their breakfast in the vicinity of nontrivial curvature is negligible.)

§(2): *Statement of the Problem*

We begin by considering a loaf of bread which, for our purposes, will be considered to be a compact manifold admitting a well-behaved foliation. Each folium may be thickened and approximated by a rectangular parallelepiped of homogeneous density.^{7,8} Each folium (hereafter referred to as “slice”) can be represented as in Figure 1 in the limit $\epsilon \rightarrow 0$. Note that it would be invalid to apply such a limiting process to the jam layer, as the amount of jam generally spread (or as is often the case, spooned) tends to be appreciable.

With these reasonable assumptions, we find the center of gravity of the slice to lie at its geometric center, at a height

$$d = \frac{1}{2} \frac{\rho_b b^2 + \rho_j [(b + j)^2 - b^2]}{\rho_b b + \rho_j j}$$

where ρ_b and ρ_j are the densities of the bread and jam sections, respectively.

Also essential to the calculation will be the moment of inertia of the slice. For this calculation we will assume the slice to be a thin plate; the moment of inertia I is calculated for an axis perpendicular to an edge of length l and passing through the center of gravity of the slice. The expression thus arrived at is

⁵ The reader is asked to supply a verification from his/her own personal experience.

⁶ Pioneering experimental work has been reported by Jennings. Since his article is inaccessible, we have quoted the relevant passage in the Appendix.

⁷ This homogeneity assumption is equivalent to neglecting the inhomogeneity inherent in the boundary (also known as crust) of the manifold.

⁸ We will require for our slicing that the resultant folia be topologically simple. This precludes the consideration of falling bagels, whose aerodynamic properties can be expected to differ radically from those of topologically simple slices. The authors are grateful to Professor P. G. Bergmann for pointing out this hole in their argument.

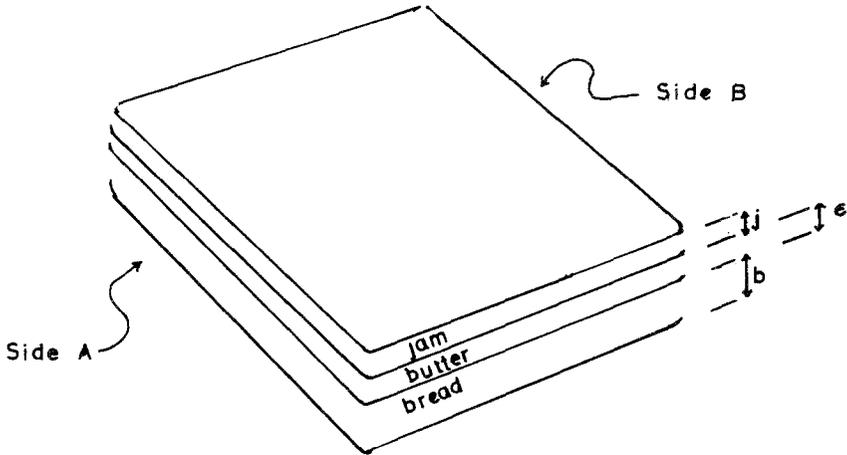


Fig. 1. Folium before limiting process.

$$I = \frac{ml^2}{12}$$

where m is the total mass of the slice,
 l is the length of the slice,
 12 is the number in a dozen.⁹

Finally in our choice of numerical values for the slice parameters, eschewing a standard density, we have performed the analysis using the following four examples which may legitimately be considered to cover the extreme cases:

1. North German pumpernickel, no jam.
2. North German pumpernickel, with thick jam.
3. Toasted presliced American bread, no jam.¹⁰
4. Toasted presliced American bread, with thick jam.

As the density of the jam plays an essential role, the authors researched the problem thoroughly.¹¹ The average densities were found to range from 1.115 g/cm³ (Migros Cranberry Preserve) to 1.400 g/cm³ (Robertson Scotch Orange Marmalade). For purposes of computation, the average value is used throughout. Numerical values are summarized in Table I.

⁹J. Croxall has argued that as defined, because of our subject nature, 12 should be regarded as 13. In defence of 12, the authors point out that a baker's dozen is a geographically local concept while science is global.

¹⁰As this experiment was carried out in Europe, presliced American bread was not available to us. The actual measurements were carried out using English toasting bread, which may be considered a reasonable approximation.

¹¹It is for supplying funds to enable the purchase of 36 varieties of jam that we are grateful to the Office of Aerospace Research.

TABLE I. Slice Parameters

Case	ρ_b (g/cm ³)	b (cm)	l (cm)	ρ_j (g/cm ³)	j (cm)
1	0.80	0.6	4.0	—	0.0
2	0.80	0.6	4.0	1.347	0.7
3	0.27	1.2	7.5	—	0.0
4	0.27	1.2	7.5	1.347	0.7

§(3): *Initial Conditions*

All discussions of this problem that the authors have been able to locate have paid insufficient attention to the initial conditions. In the simple case of the slice being knocked off of a table, no one seems to have taken into account that very few people place their slice upon the table jam side down (JSD). (This statement applies *a fortiori* to the experiment cited in footnote 4, where even fewer of the students will have placed their slice JSD on their hand.)

The following realistic initial conditions will be imposed on the dynamics. At time $t = 0$, the slice will be presumed to lie at rest with the jammed side in the direction of increasing potential of the gravitational field. A further assumption will be that the slice is so positioned as to have side A (see Figure 1) parallel to the edge off of which it is to be brushed.

At time δ , the slice is (inadvertently) brushed by a hand (elbow?) and moves along the table with constant velocity v_0 in a direction perpendicular to the table edge so that side A remains parallel to the aforementioned edge. To obtain a reasonable upper limit for the value of v_0 , measurements were carried out by B. Wälti of the Physics Department of the University of Bern. It was found that the maximum velocity attainable by the human hand when propelled by and remaining attached to its natural owner is of the order of 1500 cm/sec. We have, taking into account such factors as the unintentional nature of the act, the possibility that it is brushed with a forearm or elbow, and early morning torpor, adopted an upper limit of 300 cm/sec.

§(4): *Theory*

Since our calculations are quite elementary, we present only the end results.¹²

(1) Equation of motion of slice while still in contact with (but over edge of) table (phase I):

¹²The authors are grateful to the longhaired graduate student with the blue turtleneck sweater who straightened them out on a point of elementary mechanics which arose in connection with this work.

$$\frac{d\psi}{dt} = \frac{rd\psi^2 - 2rs\psi - gr \cos \theta}{r^2 + I/m}$$

$$\frac{ds}{dt} = [r(r^2 + d^2 + I/m)\psi^2 - 2drs\psi - gdr \cos \theta - g(r^2 + I/m) \sin \theta]$$

where the coordinates r and θ are defined as in Figure 2 and

$$\frac{d\theta}{dt} = \psi$$

$$\frac{dr}{dt} = s$$

(2) Equation of motion (integrated form) of slice in time interval $t_1 < t < t_2$ (phase II), where bread severs contact with table at time t_1 and establishes contact with floor (carpet) at time t_2 :

$$x(t) = x(t_1) + \frac{dx}{dt}(t_1) \cdot (t - t_1)$$

$$y(t) = y(t_1) + \frac{dy}{dt}(t_1) \cdot (t - t_1) - \frac{1}{2}g(t - t_1)^2$$

$$\phi(t) = \phi(t_1) + \frac{d\phi}{dt}(t_1) \cdot (t - t_1)$$

where

$$x = r \cos \theta + d \cos \phi$$

$$y = r \sin \theta + d \sin \phi$$

As well may be imagined, the physics of the transition from phase II (in flight) to phase III (landing) are nontrivial. This nontriviality is manifest in the

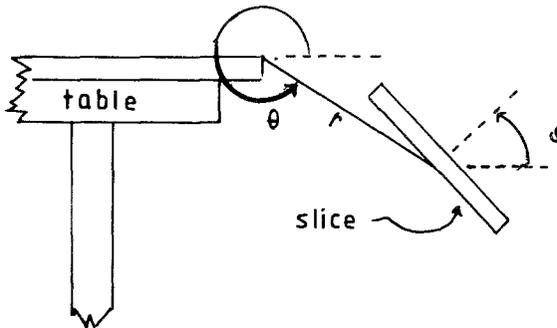


Fig. 2. Phase II—Slice is moving towards bottom of page.

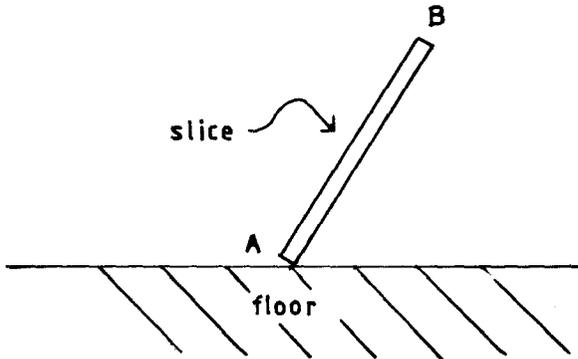


Fig. 3. Phase III—immediately following contact.

following nonstable contact scenarios. [To simplify this discussion, we introduce the unphysical concept of “bare slice,” that is, one which is devoid of butter and jam; and the two end configurations (recall Figure 1) $A—B$ and $B—A$.]

- (1) The slice lands as in Figure 3 with $\phi < 0$ leading unavoidably to end configuration $A—B$ (table is to left of slice in Figure 3).
- (2) The slice lands as in Figure 4 with an angle $\phi > \phi_{crit}$ (see below) such that the end configuration is $B—A$.
- (3) The slice lands such that $\phi_{crit} > \phi > 0$, and depending on horizontal velocity, coefficient of friction between bread and floor, and magnitude of bread’s angular momentum, the energy associated with the angular momentum may be converted into flip energy, which once again results in the end configuration $A—B$.

To return to the real world, we dress our bare slice with butter and jam on one side. This then gives rise to six distinct possibilities.

To simplify the discussion of case 3, we will use a critical coefficient of friction μ_{crit} , which is defined to be the minimum coefficient of friction between

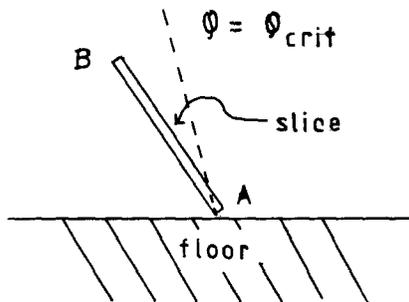


Fig. 4. Visualization of ϕ_{crit} .

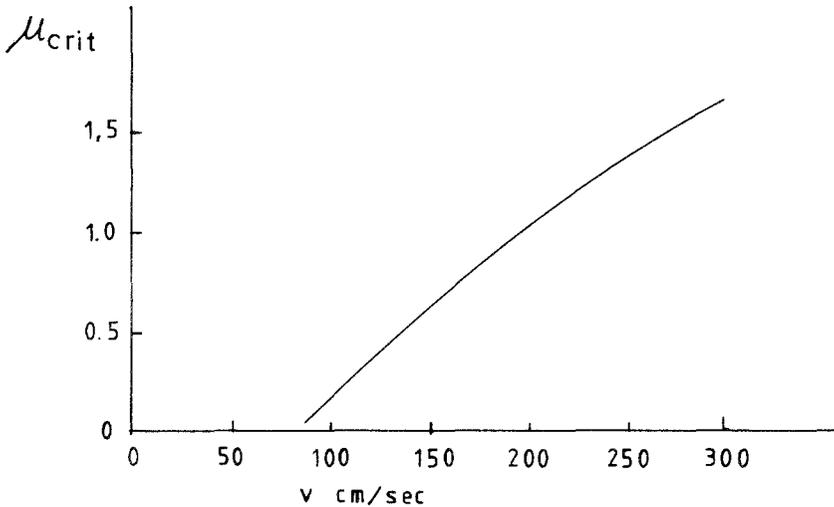


Fig. 5. μ_{crit} vs. initial horizontal velocity.

bread and floor which is required, for a given angular momentum, contact angle ϕ , and horizontal velocity, to flip the slice. In some cases μ_{crit} is negative. We have interpreted this to mean that the kinetic energy of the slice after contact was insufficient to cause a flip and hence deduced no flip in these cases.

§(5): Results

As the results turned out to be insensitive to the slice parameters, we show in Figure 5 a plot of μ_{crit} as a function of initial velocity v for the parameter values “toasted presliced American bread, thickly jammed.”

The proverbial perceptive reader will notice that the graph does not extend to the left of $v = 90$. (For the rest of you clots we point it out.) This effect arises because below this velocity the slice unconditionally lands JSD in accordance with Murphy’s law. Thus our results agree with Murphy’s law in *all* cases provided that the slice–floor coefficient of friction is in excess of 1.65. Obviously in the case of deep-pile rugs (which by further application of Murphy’s law are most likely to lie under falling jammed bread) the value 1.65 is easily exceeded. In an extensive search of the literature we were unable to locate a bread–linoleum coefficient of friction. We have therefore chosen a reasonable approximation, namely tungsten carbide (clean) on tungsten carbide (clean) at 1600°C, for which the coefficient of friction is 1.8 [3].¹³ This suggests that we may safely claim a bread–linoleum coefficient of friction of more than 1.65 as required.

¹³We have neglected edge effects. It is clear that any jam drooling over the edge will raise this figure by a not inconsiderable amount.

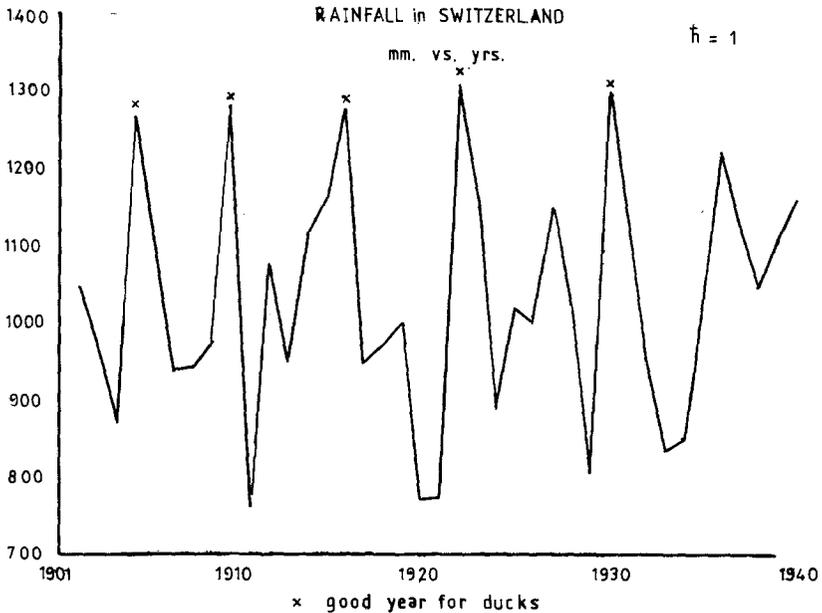


Fig. 6.

§(6): Discussion and Conclusion

As is well known, Murphy's law is true.¹⁴ We have seen that the laws of physics as applied to falling bread are not in contradiction with the universal truth of Murphy's law. We therefore conclude that these laws are to some extent valid. Moreover, see Figure 6.¹⁵

Note Added in Proof: After reading a preprint of this article, a colleague from the department of experimental physics¹⁶ suggested that we actually do the experiment. Although unable to see the relation of such a procedure to theoretical physics, we agreed to the test. To our amazement, the bread landed jam side up (JSU). The problem whether this constitutes a proof of or a counterexample to Murphy's law we bequeath to this and future generations of philosophers.

Note Added to Note Added in Proof in Proof: Professor W. Israel on reading the proofs related the following which he feels may be essential to the true understanding of the implications of the above.

¹⁴The reader who did not supply a verification from personal experience when gently asked to do so in footnote 5 is now required to do so.

¹⁵This graph has nothing to do with the problem under discussion. It is inserted purely in order to pad out this paper.

¹⁶He expects to have his name mentioned here. He is wrong.

Many years ago in a small städtl in Russia there lived a schlemiel. One day as he was having his breakfast, his bread as usual fell off of the table. However to his surprise the bread landed goose fat side up—something which had never happened to him before. He regarded this as mildly amusing, but thought no more of it. The following morning when again he knocked his bread off of the table it again landed goose fat side up. This gave him cause for thought. When on the third consecutive morning his bread fell and once again, to his utter amazement, landed goose fat side up, he decided that this was a matter of great import. He promptly went to the villege elders, told his tale, and then asked if it were possible that he were no longer a schlemiel. The elders were puzzled and after much discussion decided that there was indeed something here that they did not understand and so they decided to go to the local Rabbi for his interpretation. This they did.

The Rabbi was a man of great wisdom and learning, whose reputation was known far and wide. He listened attentively while the elders explained what had happened and posed to him the problem “Is the schlemiel still a schlemiel?” He nodded sagely and said that he could not answer the question immediately but would retire to his study to contemplate the matter.

Several hours later he emerged and announced triumphantly that the problem was solved. The schlemiel was still a schlemiel—“the bread,” he said, “had, as was to be expected, fallen goose fat side down—but the schlemiel, being a schlemiel, had smeared his goose fat on the wrong side.”

Appendix

A convenient point of departure is provided by the famous Clarke-Trimble experiments of 1935. Clarke-Trimble was not primarily a physicist, and his great discovery of the Graduated Hostility of Things was made almost accidentally. During some research into the relation between periods of the day and human bad temper, Clark-Trimble, a leading Cambridge psychologist, came to the conclusion that low human dynamics in the early morning could not sufficiently explain the apparent hostility of Things at the breakfast table—the way honey gets between the fingers, the unfoldability of newspapers, etc. In the experiments which finally confirmed him in this view, and which he demonstrated before the Royal Society in London, Clark-Trimble arranged four hundred pieces of carpet in ascending degrees of quality, from coarse matting to priceless Chinese silk. Pieces of toast and marmalade, graded, weighed and measured, were then dropped on each piece of carpet, and the marmalade-downwards incidence was statistically analyzed. The toast fell right-side-up every time on the cheap carpet, except when the cheap carpet was screened from the rest (in which case the toast did not know that Clarke-Trimble had other and better carpets), and it fell marmalade downwards every time on the Chinese silk. Most remarkable of all, the

marmalade-downwards incidence for the intermediate grades was found to vary **exactly** with the quality of carpet.¹⁷

References

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¹⁷Reprinted with permission of The Bodley Head from *Oddly Enough* by Paul Jennings.