EINSTEIN CROSS-EXAMINED BY SOCRATES
ABOUT HIS "ELEVATOR" THOUGHT-EXPERIMENT

recorded by Aristocles

in June 2014 in the Elysian Fields, "where the good receive a life free from toil"

Socrates is strolling along in the Elysian Fields deep in thought, when he espies Einstein walking in the distance.

SOCRATES: Oh dear me. Look who's here. Professor Einstein! *(Shouting to get the latter's attention). Professor Einstein!*

EINSTEIN: *(Turning around)* Yes?

SOCRATES: Professor Einstein! Can I ask you a few questions?

EINSTEIN: *(In surprise)* It's Socrates, as I live and breathe! Or rather, as I'm dead and breathe. My goodness! You, my dear sir, are so *very* like your bust in the Vatican museums!

SOCRATES: And you, my dear professor, are so well known that people can recognize you a mile away. But seriously: I've been dying to ask you a few questions about one of your thought-experiments.

EINSTEIN: Dear me! Am I to be cross-examined by Socrates himself! *(Wry smile).* But of course. By all means carry on. In point of fact, I have often doubted my own theories, especially after the mathematicians got a hold of them! *(Smiling).*

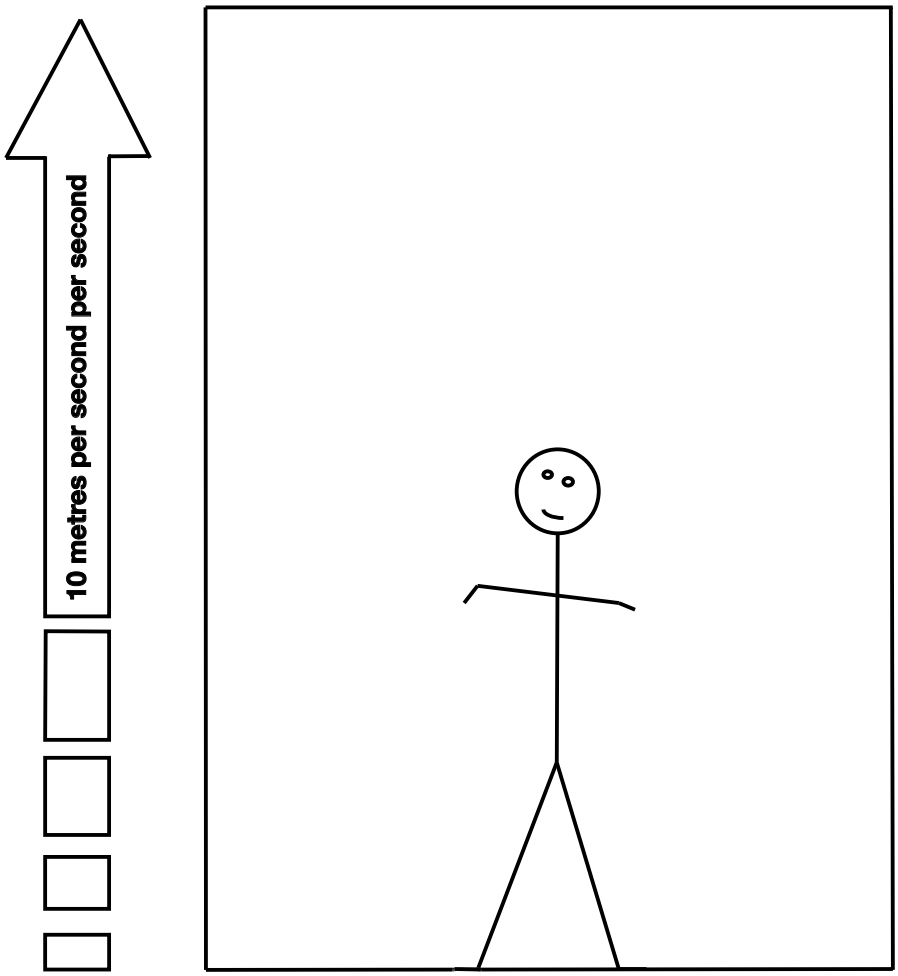
SOCRATES: Yes; I was told that you once uttered words to the effect, and I'm quoting from memory: "Ever since the mathematicians have attacked – that is, reformulated – Relativity Theory, I myself no longer understand it any more." But wasn't that just a joke?

EINSTEIN: Well, only partially. You see, I was never very expert at mathematics. I did have a certain ordinary mastery of mathematics, but then, so do many other people in many other fields! But with Relativity I was helped tremendously by the mathematician Hermann Minkowski from Göttingen, Germany, who once described me – and rather correctly, I'm afraid – as a "lazy dog who never bothered about mathematics at all." And another person who helped me with mathematics was my very good friend Marcel Grossman. Admittedly I was sometimes referred to as a "mathematician" in the popular press in the early 20th century, but that was only because the term "theoretical physicist" was not in wide popular use in the newspapers of the time. I collaborated with mathematicians like Grossman to help me with mathematical details – I had to, you see, not being very expert in the subject.

SOCRATES: Oh, good! I myself never cared for mathematics very much, and would be hard put to explain even the simplest of the theorems of my earthly contemporaries. So seriously, I shan't be asking you many mathematical questions at all. I shouldn't even know how to formulate most of them.

EINSTEIN: Thank you. I should be hard put to answer them, if you were to ask me any such questions!

SOCRATES: But one of the questions that was uppermost in my mind was your "elevator" thought-experiment. If I understand it correctly, you imagine a person in a windowless "box", like an elevator, which is being accelerated upwards, increasing its speed by 10 metres per second every second – which is, I understand, the rate of acceleration due to gravity on the surface of the Earth, or what's called one "g" – and you claim that there is no way the person inside the elevator would be able to tell whether he was in a room stationary on Earth, or was being accelerated inside the same room in empty space at 10 metres per second per second. Is that not so? I shall make a crude drawing of your elevator here, just for you to check that I have understood what you claim – and do correct me if I am wrong. *(Draws something like the following crude picture in the sand with a stick).*



EINSTEIN: Well, yes and no. That's not *all* I am claiming, you understand …

SOCRATES: Oh yes, of course – quite so; but I shall deal with the rest of your claims in due course. But isn't what I said at least *partially* what you claim?

EINSTEIN: Yes, indeed it is.

SOCRATES: That was some years ago, wasn't it. Upon reflection, is that *still* what you claim?

EINSTEIN: Is this a trick question?

SOCRATES: Not at all. Just want to be sure that it is indeed what you claimed then, and still claim even now.

EINSTEIN: Yes, it certainly is.

SOCRATES: So you still claim that there is *absolutely no way* for the man inside the elevator to tell whether he – along with the elevator he is in – is being accelerated upwards at an increasing speed of 10 metres per second every second, or whether he and the elevator are stationary on earth? *Absolutely no way?*

EINSTEIN: Indeed. Do *you* know of such a way, Socrates?

SOCRATES: And if I were to say that I did not: would *that* prove your claim?

EINSTEIN: *(Thinking about it)* Well, no; I would claim, however, not only that *you* can't think of such a way, but that *nobody* can think of such a way. But surely, if neither *I* nor *you* nor *anyone else* can think of a way to do so, then there *isn't* any such way … wouldn't you agree?

SOCRATES: *Should* I agree? Surely not. Why should the mere fact that no one has *thought* of a way to do something, prove that it's *impossible* to do it? Wasn't there a time when no one could think of a way to devise heavier-than-air flight? Yet these days it's commonplace.

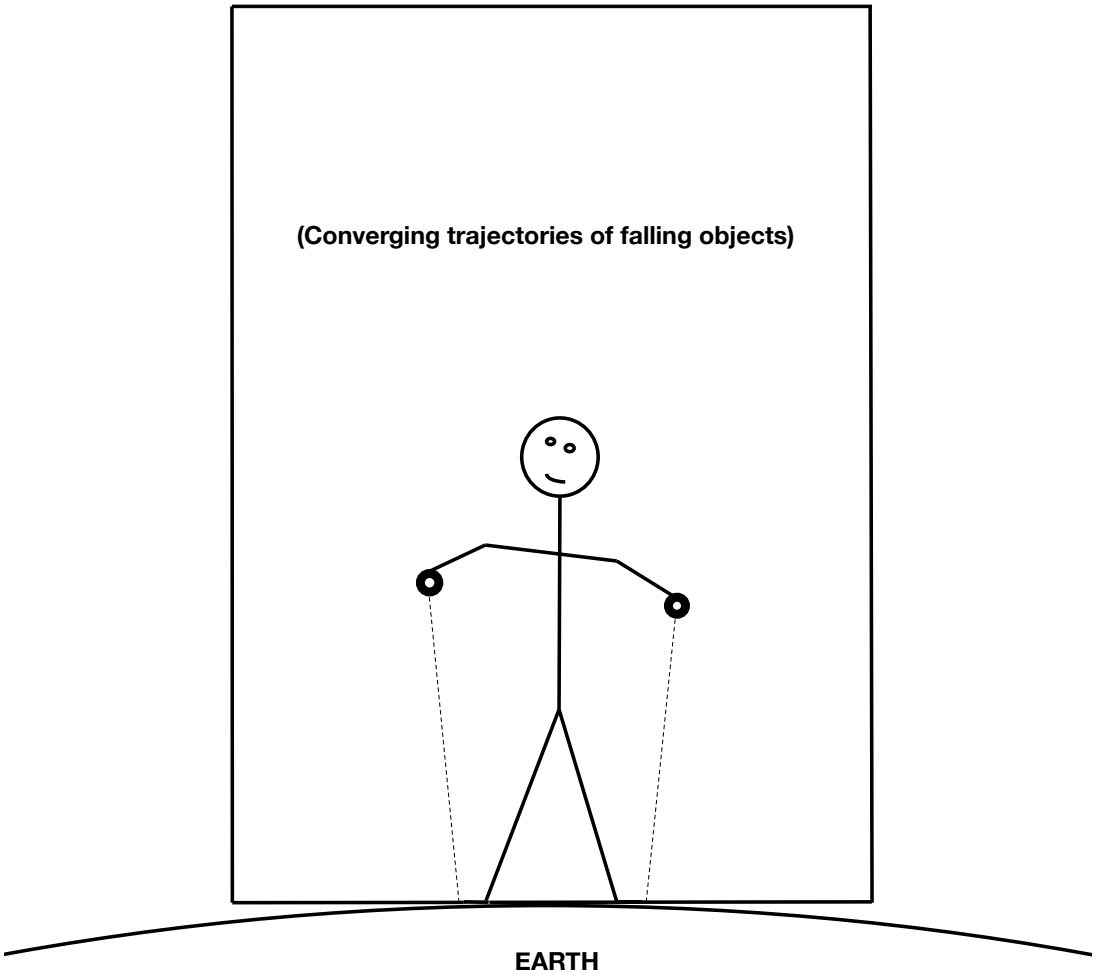
EINSTEIN: *Touché*. Yes, I do admit that someone *may* find a way to do it, at some time in the future, and if they do, then I might have to revise my Theory. But as long as no one has *yet* found a way to do it, I may confidently say that my Theory stands!

SOCRATES: Ah. But how do you *know* that no one has yet been able to find such a way?

EINSTEIN: Admittedly I don't know that for *sure*, but I imagine if some *had* found such a way I would have heard about it by now.

SOCRATES: Well, it just so happens that someone has … and you haven't. I was videoconferencing the fellow only yesterday. Big black beard and scary longish hair, and darkish skin: very like the typical image of a terrorist in the American media, but quite peaceable all the same. (I forget his name, though, so let's call him "Blackbeard" for the present – no disrespect intended.) Blackbeard claims – and, I think, correctly so – that in a *true* gravitational field, trajectories of falling bodies *converge* as the bodies fall towards the centre of gravity of the planet – or whatever – that's attracting them; while in your elevator, falling bodies would fall in trajectories that are perfectly *parallel*. And he says that with adequately sensitive instruments, these differences *could* be detected, although

he admits that humanity may not *have* instruments of such sensitivity at our present stage of technology. Like this *(draws in the sand a crude picture similar to the one below):*



SOCRATES: *(Continuing)* Besides, he says – and, I believe, correctly again – that the force of attraction exerted on a body in a *true* gravitational field is not *constant*, but gets gradually *stronger* as the body approaches the centre of gravity of the attracting planet (or whatever) – in other words, that there is a *gradient* to the gravitational force; while in your elevator, this force is always a *constant:* in other words, exhibits *no* gradient. And again, he claims – and again, I believe he's right – that with sufficiently accurate instruments, this gradient, or its absence, could be detected. In addition to that, he argues that a true gravitational field has a *centre of gravity*, and as a result, an *orbital velocity;* while clearly there can be no such thing as either a centre of gravity or an orbital velocity when we are speaking about your elevator. So he claims that a *true* or *genuine* gravitational field is *ontologically* quite different from a *simulated* or *pseudo*-gravitational field like in your elevator. Or, for that matter, from the "artificial gravity" created in spinning space stations of the kind designed by our mutual friend Arthur C. Clarke, and portrayed with great effect by *his* friend Stanley Kubrik in the movie "2001: A Space Odyssey". Now my question is: would you agree with Blackbeard's assessments? In other words, would you agree that

your hypothetical "man in the elevator" *could* find out, performing experiments conducted entirely *inside* the elevator, and *without* being able to look out of it, whether the elevator was stationary on Earth, or was instead being accelerated upwards by some force unknown to him, thereby increasing its speed by 10 metres per second every second?

EINSTEIN: Ah. *(Pauses, deep in thought).* I do agree, yes; I confess I had not thought of all this. But surely it's *irrelevant?* If we have a *large enough* planet attracting objects with a force of one "g", the lines of gravitational force surrounding that planet would tend to become more and more parallel, and the gradient of the gravitational force would tend to become less and less pronounced, and so on, yes? Surely you agree that if the planet were large *enough,* the differences couldn't be measured with any instruments we could devise?

SOCRATES: But surely you admit that even on *the very Earth itself,* the convergence of the lines of force, and the gradient of the gravitational field, would not be measurable with instruments yet devised? At least if we confine ourselves to the dimensions of a typical elevator, or even if we were to think of the largest elevator ever constructed? That's what Blackbeard claimed, remember. But *in principle* these phenomena – the gravitational gradient, the converging trajectories of falling bodies, a centre of gravity, an orbital speed, *etc.* – would exist on *any* planet, no matter how large, would they not? While *in principle* they would *not* exist in *any* elevator … isn't that so? Or are you saying that *in principle* the trajectories of falling bodies on the surface of a really huge planet exerting one "g" of gravitational force thereon *would* become *actually* parallel, and that it would *not* possess a centre of gravity, *etc., etc.* … ? Surely not!

EINSTEIN: Well, how about an *infinitely large* planet? In principle they wouldn't exist *there*, right?

SOCRATES: But *does* such a planet exist?

EINSTEIN: Not that I know of; but if we are talking in *principle only,* and not making any *actual* measurements, then why can't we *imagine* such a planet for our thought-experiment? After all, it *is* just a *thought*-experiment, isn't it?

SOCRATES: I would hardly call it "just" a thought-experiment. Do you not intend it to apply to *the known, or physical, Universe?* Or do you intend it to apply to some *hypothetical* "universe", regardless of whether it exists or not, or whether it is known or not?

EINSTEIN: Well, I think it's abundantly clear from everything I have ever said and written that I intend it to apply to the *physical* Universe as *we* know it.

SOCRATES: Which is as I thought. After all, it *is* intended to help formulate a theory of *physics,* and "physics" is surely something that applies to the *known, physical* Universe, isn't it? But then, surely you would admit that a thought-experiment which requires for its validity a planet of *infinite* size – a planet that cannot possibly *exist* in the physical Universe as we know it – *such* a thought-experiment *cannot* apply to the *known,* or *physical,* Universe?

EINSTEIN: All right, I admit; let's forget planets of infinite size. But the differences between the converging trajectories of falling bodies on planets and the absolutely parallel ones inside our elevator are so tiny that they hardly *matter* for the purposes of our thought-experiment. And the same applies to all the other differences you mentioned earlier.

SOCRATES: But were you not trying to demonstrate, with this thought-experiment, that gravitational force is exactly *equivalent* to the force imparted on a body in an elevator accelerating at

one "g"? Didn't you call it – in your own words – "… the law of the *equality* of the inertial and gravitational mass"?

EINSTEIN: Yes, indeed.

SOCRATES: In that case, aren't you mistaken, since between *true* gravitational force on the one hand, and the *pseudo*-gravitational effect arising as a result of inertia on the other hand, there is merely a very, very great *similarity*, but they are not exactly *equivalent?*

EINSTEIN: They aren't *if* you wish to use the term "equivalent" in a *very* strict way; I admit that. But they're close *enough* to each other – wouldn't you say? – given that the differences between them are minuscule? Especially if we make the elevator in deep space really, really *tiny* compared to the planet on which it would otherwise be, alternatively, stationary. In fact, if we go for an *infinitesimally* small elevator, it *does* turn into an *actual* equivalence between gravity and inertia, doesn't it?

SOCRATES: But *does* an infinitesimally tiny elevator exist in the *known* Universe? Again, surely you aren't denying that your thought-experiment applies to the *known* Universe, and not to any *hypothetical* "universe" you or I can imagine.

EINSTEIN: Well, an infinitesimally tiny *elevator*, no, such a thing doesn't exist; but surely you will admit that infinitesimally tiny *entities* do exist in the known Universe. Such as the one you yourself mentioned earlier: namely, the centre of gravity of a planet. This "centre of gravity" is a geometrical *point* in space, isn't it: not a *volume?* Surely centres of gravity *do* exist in the known Universe?

SOCRATES: Well, are they not in fact *abstractions* rather than actual physical *entities?*

EINSTEIN: Well, I would argue that they are actual physical *entities,* at least in *some* sense – because if they weren't, they would not exist in a *description* of the known Universe!

SOCRATES: All right, even supposing we do grant them actual ontological status, we'd still be left with an infinitesimally small *volume* – namely, the volume of space inside your elevator – *inside* which there would be even *smaller* objects, such as your man – or rather your homunculus, as I might call him now – and the objects and gadgets with him, wouldn't we? Now I must ask: how can an *infinitesimally small* volume contain even *smaller* objects inside of it: one of them being a living person? Can such a combination of things exist in a truly *physical* Universe, and not just a purely mathematical one?

EINSTEIN: As one of my colleagues at the Institute for Advanced Studies at Princeton once said: "Them's the properties of infinitesimally small thingies, weird though they might sound!"

SOCRATES: But is there even a *shred* of evidence, let alone *proof*, that such things – not just infinitesimally small entities like a centres of gravity, but infinitesimally small *volumes* inside which there are *even smaller physical objects* – actually exist in the known, *physical* Universe? If so, where can I find such evidence? Do you know of any?

EINSTEIN: I confess I don't; but didn't you yourself point out earlier that just because neither I nor you nor anyone else can think of something existing, it doesn't mean it *can't* exist?

SOCRATES: Now it's my turn to say *"touché!"* But what if there were a *logical* flaw in postulating such an entity? If we can find a *logical* flaw – such as a contradiction – arising from postulating that such entities exist, *then* would you admit that they *can't* exist?

EINSTEIN: Sure; but *can* you find a logical flaw in such entities as we described earlier?

SOCRATES: Perhaps I can. But before I do, may I ask if you would be willing to *change your mind* if I can demonstrate any flaw in your Theory?

EINSTEIN: Come again?

SOCRATES: What I mean is, would you stick to your Theory *no matter what,* or would you be willing to *abandon* it if I were to demonstrate a flaw in it?

EINSTEIN: I shall stick to my Theory to my dying breath! – Oh, wait: I am dead already; so scratch that. Okay, not to my dying breath, then. But I will indeed defend my Theory as strongly as I possibly can.

SOCRATES: I should expect no less. But you *would*, I hope, be willing to abandon your Theory *if* it were proved that it cannot possibly be true … or wouldn't you?

EINSTEIN: I would most emphatically *not* be willing to abandon my Theory! It's my life's work, you understand …

SOCRATES: Then wouldn't you have to admit that your Theory is no better than dogma? That it isn't a Theory of science at all, but a dogma, like the doctrine of the Trinity?

EINSTEIN: *(Thinking)* Okay, I admit that you're right. Okay, I must be willing to abandon my Theory *if* proved untrue. *If*, mind you. *If*.

SOCRATES: Well of course: *if.* And would you be willing to take a solemn oath to that effect?

EINSTEIN: Are we in a court of law? *(Smiling).*

SOCRATES: No, not really; but surely it would be pointless continuing our discussion unless both you and I promise to stick to the *truth* … or would you not agree about *that?*

EINSTEIN: I do agree. But any proof of my Theory being untrue must be very, *very* strong!

SOCRATES: Of course. But then, shall we both take an oath, together, that throughout this discussion we shall *stick to the truth* as best we can? Or, as my good friend Mohandas Gandhi says, that we shall be what he calls *"satyagrahis"*, or "strict adherents to the truth"? Of course neither of us is perfect, so I won't say "we shall stick to the truth, the *whole* truth and *nothing but* the truth", but just "we shall stick to the truth". Period. As *best* we can. And we're going to have to be *honest* about *trying* our best.

EINSTEIN: Yes, indeed: let's agree to all that. I think highly of Gandhi myself. In fact, I consider him to be a most extraordinary fellow. Couldn't believe my eyes when I first read about his life. Remarkable chap.

SOCRATES: Shall we shake on it, then? That we shall both stick to the truth to the best of our ability, and be willing to change our minds if proved wrong?

EINSTEIN: Yes. *(They both shake on it).*

SOCRATES: Well coming back to infinitesimal quantities, which we were discussing earlier.

EINSTEIN: Yes. Remind me, would you?

SOCRATES: I had said, what if there were a *logical* flaw in postulating an "infinitesimal quantity"? If we can find a *logical* flaw – such as a contradiction – arising from postulating that such entities exist, *then* would you admit that they *can't* exist?

EINSTEIN: Yes, I remember now. Yes, let's pick up our discussion from that point.

SOCRATES: Good. Then in such a case, would you agree that the definition of an "infinitesimal quantity" is "one which, while not coinciding with zero, is in some sense smaller than any finite quantity"?

EINSTEIN: *(Thinking)* Yes, I can see how *this* definition of "infinitesimal" might lead to a contradiction – under this definition, the objects in an infinitesimally small elevator could not be smaller than the elevator itself, and so couldn't fit inside the elevator – but that's an older definition of "infinitesimal". The more modern definition depends on the concept of *limits*.

SOCRATES: And what's that, then?

EINSTEIN: One definition I can quote off the top of my head is this: "A function or variable continuously approaching zero as a limit".

SOCRATES: *(Thinking hard).* Well, would not that apply to *any* variable? For example, within the context of our modified thought-experiment, would not *any* continuously shrinking elevator – one which shrinks, let's say, to half its size every minute – satisfy such a definition: *no matter how large the elevator is?* Even if the elevator were, let's say, as large as the entire Coliseum, as long as it were continuously shrinking to half its size every minute, under *such* a definition, wouldn't it be classified as "infinitesimally small"? No matter how large it is, as long as it is continually shrinking to half its size every minute, wouldn't it be "continuously approaching zero as a limit"?

EINSTEIN: Well, yes; but that's cheating. That's not how we're supposed to interpret this definition.

SOCRATES: Then *how exactly* are we supposed to interpret it?

EINSTEIN: The "infinitesimally small object" is the object that actually *reaches* the limit.

SOCRATES: But the limit is *zero*, isn't it?

EINSTEIN: Of course. That's what I said.

SOCRATES: But then an infinitesimally small object would have to be of *zero size,* wouldn't it? So wouldn't it *cease to exist* altogether at the limit? Is an "infinitesimally small object", then, an object that doesn't exist at all? Is that what you mean?

EINSTEIN: No, I misspoke: an "infinitesimally small object" is an object that stops shrinking *just barely short of* actually reaching the limit, which as you say correctly, is zero.

SOCRATES: But barely short by *how much?*

EINSTEIN: As I said, *just* barely.

SOCRATES: Meaning?

EINSTEIN: Let's say, by an infinitesimal amount.

SOCRATES: Well, wouldn't that make your definition of "infinitesimally small" rather *circular?*

EINSTEIN: Okay: let's say, instead, by a *tiny* amount, but *not* an infinitesimally small amount.

SOCRATES: Then would it not be possible for the "infinitesimally small" object to get shrink even *further,* and thereby get even *closer* to the limit? And if so, would it not, in that case, *not* be infinitesimally small at all?

EINSTEIN: Okay, I see the problem. *(Thinking).* Well, I believe we're supposed to interpret the definition to mean something like "Let's start with something very, very small already, and *then* imagine it shrinking to half its size every minute, with a size of zero being the limit."

SOCRATES: Well, what's the phrase "something very, very small already" supposed to mean, *exactly*?

EINSTEIN: Let's call it "something immeasurably small".

SOCRATES: When you say "immeasurably", do you mean incapable of being measured by *current* technology, or incapable of *ever* being measured? Because if you say "incapable of being measured by *current* technology", wouldn't you have to admit that the definition of "infinitesimally small" could change over time, with advancing technology; and wouldn't that overthrow your thought-experiment the moment someone discovers a way to measure it? Is *that* what you intend it to mean?

EINSTEIN: You are splitting hairs here, Socrates!

SOCRATES: But isn't the "splitting of hairs" *necessary* to your thought-experiment, given that we *have* to be dealing with very, *very* tiny entities, indeed *infinitesimally* small entitles: as per your own insistence a while back? Didn't you yourself admit that an *exact* equivalence between gravity and inertia can only exist for an *infinitesimally* small elevator?

EINSTEIN: *(Reluctantly)* Okay, I admit that. I don't have any rebuttal to your argument right at this moment, though if you give me some time I may be able to think one up in future. But at present I reluctantly admit the necessity and validity of splitting hairs when arguing about infinitesimals and immeasurables.

SOCRATES: So then: what's your answer? When you say "immeasurably", do you mean incapable of being measured by *current* technology, or incapable of *ever* being measured?

EINSTEIN: The latter.

SOCRATES: If so, then have you ever considered *how* things are measured, especially in size?

EINSTEIN: *(Raises his eyebrows questioningly)* ???

SOCRATES: Don't we measure the sizes of things by comparing them to other things? For instance, don't we measure the size of a room by comparing it with the size of a ruler, or a tape?

EINSTEIN: Yes, but that's not the *only* way to measure the size of something. We can measure it by, say, shining a light from one end of the thing being measured, and measuring how much *time* the light takes to reach the other end. We *know* the speed of light, and so we can *calculate* the size of the thing being measured this way.

SOCRATES: But to determine the speed of light *itself*, in the *first* instance, don't we have to *physically* measure the *actual* distance that light travels in a given time interval, using a straight edge or rod or tape or some such *physical* thing?

EINSTEIN: *(Reluctantly)* Yes.

SOCRATES: And surely we couldn't do that using the *speed of light* in our calculations, because that would be trying to *measure* the speed of light *assuming* a value for the speed of light itself – a value *not* supported by measurement: isn't that so?

EINSTEIN: *(Brightening up)* No, that's not true: these days we *know* that the speed of light is a constant, so we can use that constant in *all* our calculations!

SOCRATES: But *how* do we know that the speed of light *is* a constant, and *how* do we know that the value of this constant is a-certain-number-of-metres-per-second, whatever this number may be? Isn't the speed of light *itself* measured by *first* measuring *some* distance with a *physical* object – that is to say, *without* using the speed of light in any calculations?

EINSTEIN: *No*, Socrates: no. We can define our unit of length as a certain fraction of a light-second – the distance light travels in one second. For example, these days the "metre" is defined as a certain fraction of a light-second. Thus we actually use *time* to measure distances, strange though it might sound.

SOCRATES: *(Thinking deeply).* You may be right, professor: possibly. But it doesn't change my counter-argument in the least. If the elevator itself is too small to be measured, doesn't that imply that there *is nothing in the entire Universe* smaller than the elevator, compared to which its size could be measured? That no object which could measure it even *exists?* For surely, if an object smaller than the elevator *were* to exist, then it *could* measure the elevator, could it not: just as a rod which is itself a centimetre in length, even if were not subdivided into smaller units, *could* measure objects longer than a single centimetre, or at least longer than two centimetres? For instance if there were an object longer than two centimetres but shorter than three, could it not be said with certainty, using a rod just one centimetre in length – one which is not subdivided into smaller units – that the object being measured *is* longer than two centimetres but shorter than three … even if we wouldn't be able to tell the *exact* difference in its length between two centimetres and three?

EINSTEIN: *(Thinking).* Yes, I expect you are right; at all events, I myself can't think up a counter-argument on the spur of the moment. But if you give me some time …

SOCRATES: Well then, as things stand at *present* at all events, doesn't it all end up in a contradiction?

EINSTEIN: What does?

SOCRATES: Your argument that an infinitesimally small elevator – which you have now defined as an "immeasurably small elevator" – could have objects in it that that are even smaller than itself? If it *is* in fact immeasurably small, doesn't it imply that there *is* nothing smaller than itself: for if such a thing existed, the elevator *wouldn't* be immeasurably small?

EINSTEIN: *(Thinking about it).* You've got me there. But let's change the definition of "infinitesimally small", then: let's call it "something very, very small", *without* specifying whether it could be measured or not.

SOCRATES: Isn't that a bit vague and imprecise?

EINSTEIN: It's as precise as I *want* to be, at least *now*.

SOCRATES: Okay, then: let's go with this new definition, though it's a bit vague in my opinion. But even if we accept it, how would you *prove* that the definition "something very, very small" fits the meaning of "infinitesimally small" when this latter is defined as "A function or variable continuously approaching zero as a limit"? Or in other words, wouldn't you admit that the definition becomes *ambiguous*, since it can be used to define a *number* of small sizes, each *different* from the other, rather than just *one* single (small) size?

EINSTEIN: Yes, but so what?

SOCRATES: But don't you admit that the introduction of ambiguities into a *rational* or *logical argument* is a fallacy, for it allows one to draw incorrect conclusions from a *seemingly* correct argument? Isn't it, in fact, one of the most *common* fallacies in reasoning?

EINSTEIN: Yes, I agree that ambiguity is to be avoided in any logical or rational argument; but in the present case, I don't consider this ambiguity to be very *relevant.*

SOCRATES: You do admit, though – don't you – that unless we are talking about the *proved* existence of "infinitesimally small" volumes, the claimed *equivalence* between gravitational force and the pseudo-gravitational force arising from inertia does *not* truly exist? That, in other words, in volumes that are "very, very small" – as you put it – there is no actual *equivalence* between true gravitational force and the pseudo-gravitational force due to inertia, but rather a only very, very strong *similarity?*

EINSTEIN: Yes, but I also claim that the difference is so small that it doesn't really *matter* – that it's not, as I said, *relevant.*

SOCRATES: Very well then: I am prepared to accept this as a provisional argument. But aren't you going to be implying, then, that your thought-experiment applies only to volumes that, in your own words, are "very, very small", while for any volumes that aren't, it doesn't apply?

EINSTEIN: No, it applies to volumes that are larger, too!

SOCRATES: With what justification can you say so, given that you have admitted that even in a volume that's "very very small", there is no *exact equivalence* between true gravity and inertial pseudo-gravity, but only a very strong *similarity?*

EINSTEIN: I justify it by giving you an analogy. Just as a circle can be made up of a multitude of *straight* lines that are very, very short, but which, when seen from a distance, appear like a smooth curve, so too a large volume can be made up of a multitude of very, very small

volumes, each of which represent an *almost* exact equivalence between inertial and gravitational force.

SOCRATES: But isn't the term "almost" the crucial one here? By saying that the small volumes provide an *almost* exact equivalence between true gravity and inertial pseudo-gravity, aren't you implying that they do not provide an *exact* equivalence in that respect … and thus, that there is a *difference* between a volume possessing an *almost* exact equivalence and one possessing an *actual* exact equivalence between true gravity and inertial pseudo-gravity … even though the difference is very, very tiny?

EINSTEIN: Yes, you're correct; but I contend that it doesn't *matter*, since the difference is too tiny to be *relevant*.

SOCRATES: That may be true as regards any *single* such volume; but when you speak of a *multitude* of such volumes, wouldn't all the tiny differences *add up?* And the greater the number of such volumes, wouldn't the differences add up *more?* Just as in the case of your "circle": the *angles* between each of the adjoining straight lines that compose your "circle" is very *slightly* different from 180° – *i.e.,* from two right angles – which would make any two such adjoining straight lines appear *almost* like a single straight line; but since there are *many* such straight lines, the *appearance* of *all* of them from a distance is that of a curve?

EINSTEIN: *(Thinking about it)* Yes, I can see how the tiny, even minuscule, differences would add up eventually – a bit like in differential calculus.

SOCRATES: *What?!?* I haven't the faintest idea what you're talking about. What in the name of heaven is "differential calculus"?

EINSTEIN: Never mind. I won't bring up mathematics again. All I wanted to say is, I agree with you.

SOCRATES: Oh. All right then! *(High five!)*

EINSTEIN: *(High five).*

SOCRATES: Why the frown?

EINSTEIN: I am still wondering whether there isn't a way my "equivalence principle" could be saved.

SOCRATES: Perhaps it can be; but even if it could be, I wonder quite a bit about your *entire* thought-experiment. Isn't it designed to show that space itself can be "bent" or "curved"?

EINSTEIN: Yes, that is correct.

SOCRATES: And just to clarify, I presume you mean by space being "bent" or "curved" that any lines which are absolutely *straight* when the same space is *not* bent or curved, would *become* bent, or curved, *when the space itself gets bent or curved?*

EINSTEIN: *(Thinking deeply)* Yes, I suppose so. Yes. I hadn't thought of it, but yes, I guess that's right. Otherwise it would make no sense whatsoever to speak of a bent or curved space.

SOCRATES: So let us see how you go about establishing that space can become bent, or curved, due to acceleration. By the way, I personally think "curved" is a better term than "bent", because we're not talking about not an *angular* bend like in an elbow or a knee, but a

smooth bend like in a river or a road. But for the sake of our discussion, I don't mind if we use the terms "curved" and "bent" interchangeably. We won't have a problem with the terminology as long as we both understand clearly what the terms mean.

EINSTEIN: Yes, all right. Fine. So allow me to explain in greater detail my thought-experiment …

SOCRATES: No, allow *me*. Let *me* try to explain it to you in *my* own words, so that you can judge whether I have understood you correctly to begin with – before I inform you of my problems with it.

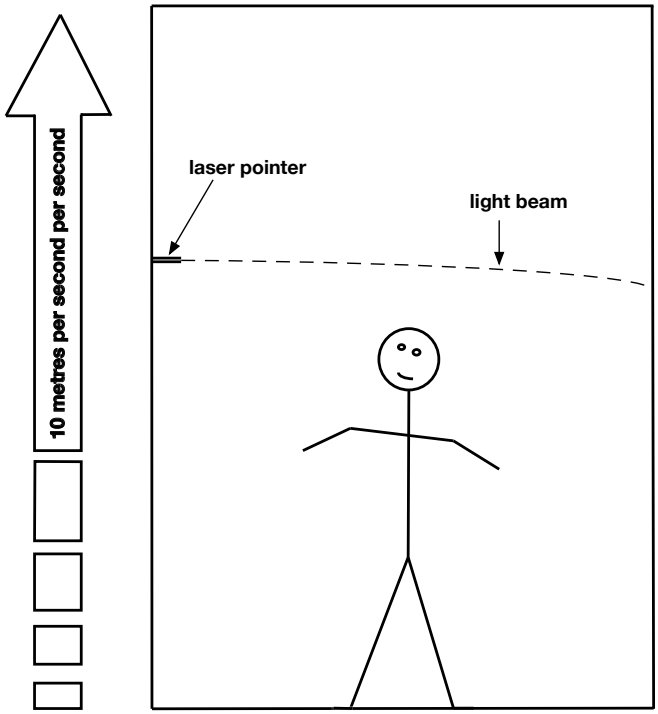
EINSTEIN: Good idea.

SOCRATES: *(Marshalling his thoughts).* Let's see. We imagine that we have a "box" or an elevator in empty space, far away from any detectable gravitational field. This elevator is being accelerated upwards at an increasing speed – by what means, we do not specify, and consider to be irrelevant for the sake of our thought-experiment. The speed of the elevator is caused to increase by 10 metres per second with every passing second – just as it would on Earth if it were freely falling towards the Earth in a space empty of air, but in the opposite direction. (Just so you know that I understand, that's the "acceleration due to gravity" on the surface of the Earth: but in *approximate* figures, not absolutely *accurate* figures. I understand that the more accurate figure is something like 9.81 metres per second every second, but we don't need such great accuracy for *our* purposes, right?) We also imagine that there is a man in the elevator. There is in addition a laser pointer attached to one of the walls, horizontally pointing a laser beam at the opposite wall, in such a way that if the elevator were *not* being accelerated, the beam would strike the opposite wall at *exactly* the same height above the floor as the location where the laser pointer is attached. We also assume that the floor of the elevator is *perfectly* horizontal and its walls are *perfectly* vertical; or in other words, the acceleration imparted to the elevator is *exactly* in the direction of all the walls, and the floor is *exactly* at right angles to all the walls. (Again, we don't specify by what means we achieve this absolute precision, and consider it irrelevant). How am I dong so far?

EINSTEIN: Great. Except that in my original thought-experiment I didn't say "laser pointer", since they hadn't been invented during my time on Earth. Instead I spoke of a small hole in one of the walls of the elevator though which a light beam running parallel to the floor of the elevator would be introduced. But a laser pointer would do the same thing. Do carry on.

SOCRATES: Right then. *After* the elevator is accelerated and the laser pointer is turned on, we ask: at what *exact* location will the light shine on the opposite wall? (We're talking of exactitudes of *far* less than the thickness of a hair, of course; but as we agreed earlier, "splitting hairs" is quite a valid procedure in this thought-experiment.) Now *you* contend that the light would shine a little bit *below* the point where it shone on the opposite wall when the elevator was *not* being accelerated. And the *reason* you give is, that light takes a bit of *time* to go from the laser pointer – which is firmly fixed to one of the walls – to the opposite wall; and in that brief amount of time, the elevator is being accelerated *upwards*, thus causing the light beam to strike the opposite wall a tiny bit *below* the location where it used to shine when the elevator was *not* being accelerated. Indeed, if the elevator were provided with a small amount of smoke, so as to *reveal* the trajectory of the light beam, the beam would appear very slightly *bent* to the man in the elevator, due to the fact that there is an *acceleration* being imparted to the elevator during the brief period of time the light takes to go from one wall to the opposite wall. Admittedly the effect in any decent-sized elevator would be too small to be *visibly* noticed, but *theoretically*, given sufficiently

precise instruments, the effect *could* be revealed. Just to make it clear to you that I understand your argument, I am making a crude drawing of your elevator here, exaggerating the effect of the bending of the light, merely for the sake of illustration. *(Draws in the sand with a stick).* Am I being fair to you up till now?



EINSTEIN: Indeed you are.

SOCRATES: As a result – and we now come to the tricky part – you claim that acceleration, such as that imparted to the elevator, imparts a *curvature* to the beam of light: is that not correct?

EINSTEIN: Yes, I do. Clearly the beam of light is *bent* when observed by the man in the elevator. You yourself said that a few seconds ago!

SOCRATES: Surely not. I said, and I repeat my words: "the light beam would *appear* slightly bent to the man in the elevator" – not that it *would be* bent. Am I not correct?

EINSTEIN: And what did *I* say?

SOCRATES: You, my dear Professor Einstein, said it *is* bent: I recollect that perfectly (don't you)? So my next question to you is: does it merely *appear* bent, but in actual fact it *isn't*, or *is* it *actually* bent, and doesn't merely *appear* so?

EINSTEIN: Good point. I claim that it *is* bent, while you claim that it may only *appear* bent, while not *being* bent in actual fact. Am I accurately getting the gist of your counter-argument?

SOCRATES: Yes you are. We both know that things can often *appear* to be what they are actually *not*. Isn't that so? For example, in cases of optical illusions.

EINSTEIN: Yes, true. But I claim that the light beam doesn't *only* appear bent, but that it *actually is* bent … and I don't think you can prove me wrong!

SOCRATES: Well, how can we *test* to see whether what we are observing is a mere appearance, or a true reality?

EINSTEIN: Ah-*hA!* I have a *terrific* answer for you. There *isn't* any such test – not *really,* not in the *ultimate* analysis. Let me explain. You see, in my youth I used to avidly read the British philosopher Hume, and other so-called "empiricist" philosophers, who argued – and I think, most convincingly – that appearance *is* reality: that any "reality" apart from appearance can *never* be known. The German philosopher Kant called any reality that is *not* appearance using his coined term "noumenon", and argued – again, most convincingly – that the "noumenon" was altogether *unknowable*. You probably don't know much about these philosophers, since they came after your time …

SOCRATES: Oh no, you are quite mistaken; in my sojourn of more than two millennia in these Elysian Fields, I have had the pleasure of meeting the good Bishop Berkeley several times, and discussing with him all such conundrums, and especially his favourite one: "If a tree falls in an uninhabited forest, does it make a sound?" – and he has in fact persuaded me that all my previous ideas about what is reality and what is not were very possibly mistaken. So I am quite familiar with the British and German empiricist philosophers, I assure you.

EINSTEIN: Ah. My apologies. I thought you were only familiar with the Greek philosophers.

SOCRATES: Dear me, no. While alive on Earth I was never familiar with *any* philosophers, even the Greek ones, for most of them became famous, and wrote their best works, after I died. Besides, I wasn't very well read during my time on Earth – indeed, I am not so even now. I have tried to make up for my lack of reading by *talking* to the *dead* philosophers, at least the ones I have been able to track down in my wanderings in these Elysian Fields. In fact, that was one reason I was so intent on making the acquaintance of *your* good self.

EINSTEIN: You flatter me. *(Blushing).* That's a *huge* compliment, coming from Socrates himself! I am most honoured.

SOCRATES: Oh no, really, no: the honour is all mine!

EINSTEIN: No, trust me. You are far more prestigious in the minds of humanity that I am; or, indeed, ever will be. You practically *invented* the scientific method!

SOCRATES: Not the *entire* scientific method, just the *elenchos* or "questioning" part of it. And I did not actually *invent* even that. I just *used* it – perhaps more than anyone else. *Perhaps.* And it seems to have become much more popular in courts of law than in science!

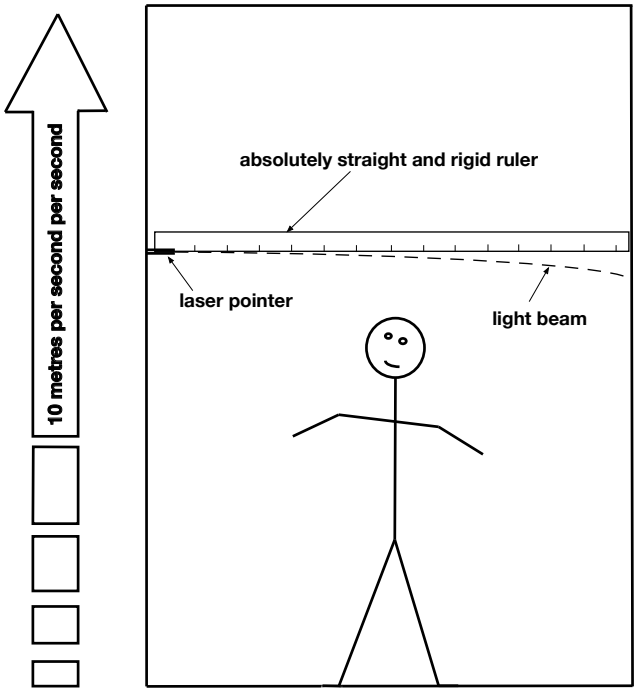
EINSTEIN: Indeed. I personally think science could do with *much* more of your "questioning" than is at present being used. But anyway, to resume our discussion about the bent light beam: what do you say to my knock down, cast iron argument: that the bent appearance of the light beam *is* the reality – the light beam not only *appears* bent, but *is* bent in reality?

SOCRATES: Well, I wonder what would happen if, before the elevator were accelerated, we were to extend an *absolutely* straight and rigid straight edge – that is to say, an *absolutely* rigid ruler possessing at least one *absolutely* straight edge – from the laser pointer to the opposite wall, running *alongside* the beam of light? (We shan't specify how we obtain

absolute straightness and rigidity in the ruler, and in fact we'll consider it irrelevant for the present purposes.) We agreed that the light beam would at the very least *appear* bent after the elevator was accelerated – you claim that it would not only *appear* bent but it would also *be* bent; but even you admit that it would also *appear* bent – but would the straight edge *also* appear bent, or would it appear straight, at that same time?

EINSTEIN: It would appear straight, of course. Just as it does on Earth!

SOCRATES: Like this? *(Draws in the sand):*



EINSTEIN: Yes.

SOCRATES: But then, wouldn't you say that there *is* a difference between appearance and reality? If the light beam appears bent and the straight edge appears straight, then the light beam would merely be bent *in appearance*, wouldn't it?

EINSTEIN: *(Thinking about it a while).* I confess that now I don't know what to think. *(Thinking)* I now think the straight edge *may* appear bent, or it *may* appear straight. I can't say for sure.

SOCRATES: Well then, shall we examine *both* possibilities?

EINSTEIN: Yes, let's do that.

SOCRATES: First let's assume the straight edge appears *straight* after the elevator undergoes an acceleration. In that case, by your own "empiricist" argument earlier, the straight edge must actually *be* straight, mustn't it?

EINSTEIN: Yes.

SOCRATES: But at that same time, by your argument, the light beam *is* bent: right?

EINSTEIN: Yes.

SOCRATES: So the acceleration has an effect on the *light* but not on the *straight edge* – right?

EINSTEIN: *(Reluctantly)* Yes.

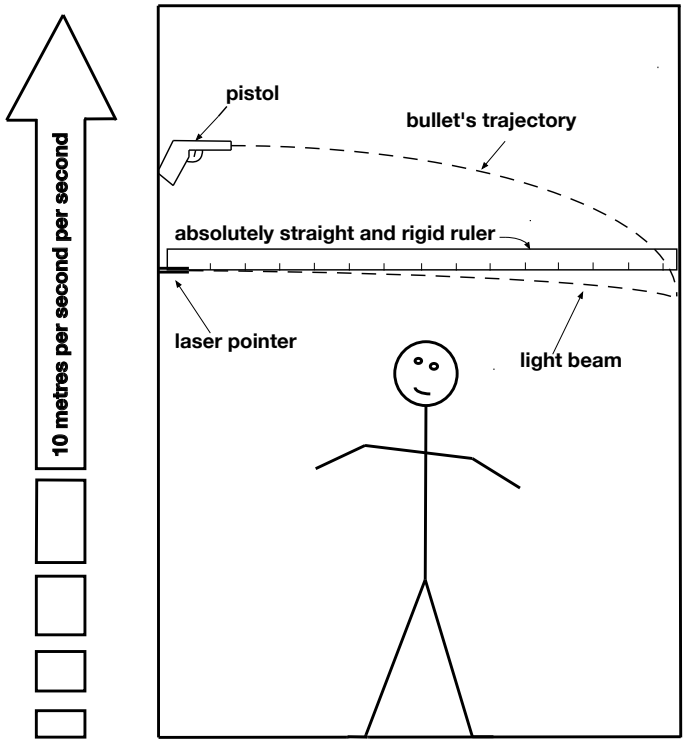
SOCRATES: But shall we analyze the *reasons* for this difference, then?

EINSTEIN: Yes, sure.

SOCRATES: Isn't the difference due to the fact that light takes a bit of *time* to go from one wall of the elevator to the opposite wall, while that's not the case with the straight edge at all?

EINSTEIN: *Huh?*

SOCRATES: Well, let me illustrate it another way. Suppose we affix to the wall a *pistol* which fires bullets at right angles to the wall. If the pistol were to be fired *after* the elevator is accelerated, the bullet would strike the opposite wall, not at the spot which it would strike when the elevator were *not* being accelerated, but at a spot slightly *lower* than that: right? Because, in the brief period of time the bullet takes to go from the muzzle of the pistol to the opposite wall, the elevator is accelerating upwards at a speed increasing by 10 metres per second every second – yes? So that, in fact, the *trajectory of the bullet* would now appear to the man in the elevator to be *curved:* indeed, far *more* curved than the trajectory of the *light* from the laser, due to the much *greater* period of time the bullet takes to go to the opposite wall than light … the bullet being many hundreds of thousands of times slower than light? Let me draw the situation here: *(Draws in the sand again).*



EINSTEIN: Yes, I do admit that.

SOCRATES: So we see that in case of the trajectories of things like photons, or bullets, which take a bit of *time* to go from one wall to the opposite wall of the elevator, there is an appearance of *curvature* – and in fact the *more time* those things take to go from one wall to the opposite wall, the more *pronounced* this curvature; while in the case of things like the absolutely straight and rigid ruler, or straight edge, stretched between the two walls – things which take *no time at all* to "go" from one wall to the opposite wall: in fact they don't "go" anywhere at all – there is *no* appearance of curvature (by our own agreed-upon assumption above, for surely you remember that for this argument, we are assuming that the straight edge appears *straight* after the elevator undergoes an acceleration)?

EINSTEIN: Yes. That was the very *gist* of my original argument regarding light, in fact: it's due to the *time* it takes for the light to go from one wall to the opposite wall – a time period during which the elevator is being *accelerated* upwards – that the beam of flight appears curved.

SOCRATES: Indeed, if we have pistols that shoot bullets at *different* velocities, so that the *amounts* of time the bullets take to go from one wall of the elevator to the opposite wall are all very *different*, the curvatures of the trajectories of the bullets will also all be very *different?*

EINSTEIN: Yes, I shall most confidently admit that.

SOCRATES: So would you admit that the *degree* of curvature of the trajectory of a bullet or photon depends on the *time* it takes for the object – whether bullet or photon – to go from one wall of the elevator to the opposite wall? That the *longer* this amount of time, the *greater* the curvature of its trajectory, and *vice versa* … and so if anything takes *no time at all*, like in the case of a rigid and straight ruler stretched between the two walls, there is absolutely *no* appearance of curvature? That, in fact, such a rigid and perfectly straight ruler *appears* – and therefore, by your empiricist philosophical argument, also *is* – altogether straight *no matter* whether the elevator is under acceleration or not?

EINSTEIN: Yes, I shall – reluctantly – have to admit that too.

SOCRATES: In which case your thought experiment collapses, does it not?

EINSTEIN: How so?

SOCRATES: Well, a straight edge which *is* straight whether the elevator is in acceleration or not, establishes – does it not? – that straight objects, and therefore the straight *lines* which are *part* of those objects, *remain* straight no matter whether they are being accelerated or not? Or in other words, that acceleration does *not* actually bend space *itself?* And that therefore, even if acceleration and gravity were *exactly* equivalent – which, as we concluded earlier, is not the case for any volumes larger than infinitesimally small ones, but even we *were* to grant that they are in fact exactly equivalent for *all* volumes – gravity would not bend space *either?*

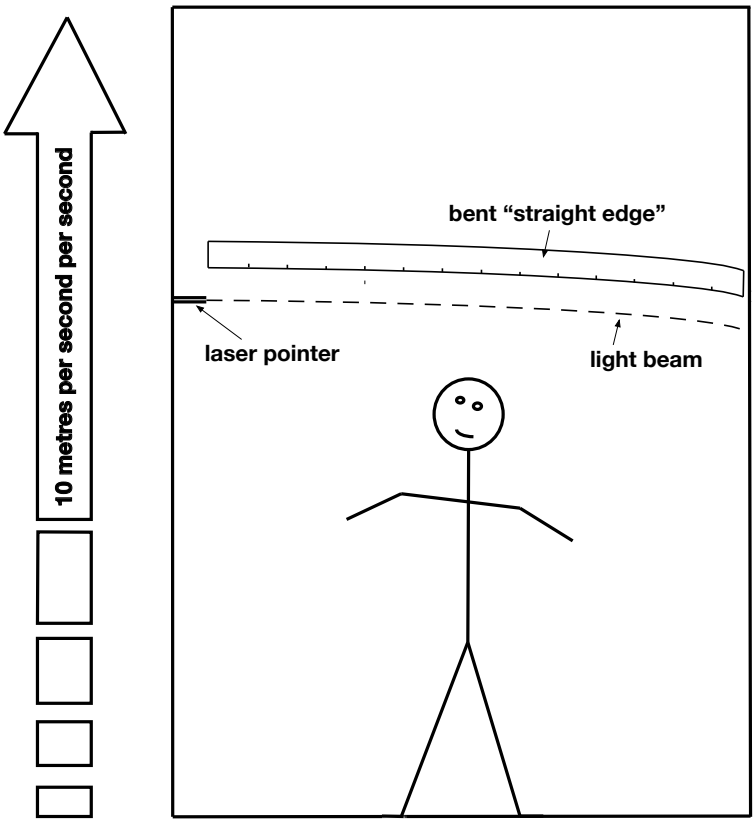
EINSTEIN: Hmm. *(Sad).* I don't like to admit it, but I don't see a refutation to your argument right at this moment. *(Cheering up a bit)* However, what if we assume that the straight edge *also* appears bent? We have up till now assumed that the straight edge would appear *straight* whether the elevator were accelerated or not, but what if we assume the opposite: that the straight edge appears *bent* after the elevator is accelerated? In that case, it would actually also *be* bent … and as you pointed out yourself, that's the whole *point* of my

thought-experiment: that the acceleration of the elevator would bend *space itself*. If space *itself* is bent, then any straight straight edges in that space must also *be* bent!

SOCRATES: *(Raising his eyebrows)* Did you just say that a *straight* edge is *bent*? Or in other words, that a straight edge is *not* a straight edge? Isn't that a veritable contradiction in terms?

EINSTEIN: Sorry: I misspoke. What I meant say is, that the straight edge which *was* straight when the elevator was *not* under acceleration, now *becomes* bent when the elevator is accelerated.

SOCRATES: Like this? *(Draws in the sand):*



EINSTEIN: Yes.

SOCRATES: I see. Then could you explain what exactly *makes* it bent?

EINSTEIN: Obviously, the fact that *space itself* becomes curved due to the acceleration imparted to the elevator!

SOCRATES: Hmm. Isn't that assuming something which is yet to be proved? Isn't your thought-experiment intended to establish the *truth* of your assertion that space *does* get bent due to acceleration? Aren't you now making that assertion *before* establishing its truth?

EINSTEIN: Didn't I already establish that?

SOCRATES: How, *exactly*, did you establish it?

EINSTEIN: Let's see now. We saw that if the elevator were *not* being accelerated, both the light beam and the straight edge would appear perfectly *straight*, while when the elevator *is* accelerated, both the light beam and the straight edge would appear *curved*. So, going by the claims of all the empiricist philosophers, including your good friend Bishop Berkeley – whose motto, as I understand it, is *esse est percipi,* which loosely translated means "reality *is* appearance" – both the light beam and the straight edge *were* actually straight before the elevator underwent acceleration, while they both actually *became* curved – or bent – when the elevator *underwent* acceleration!

SOCRATES: Ah, but not *quite.* I wonder if you noticed it, but you actually – and indeed confidently – *explained why,* due to acceleration, *trajectories* of moving bodies like photons or bullets become bent, but you did not actually *explain why* perfectly *rigid* objects such as straight edges would *also* become bent, or curved! You only *assumed* that to be the case, because you were not *confident* enough to say whether the straight edge would become bent, or remain straight – in which *latter* case, your thought-experiment collapses, by your own admission.

EINSTEIN: Ah. Yes. We *assumed* that the straight edge becomes curved: yes.

SOCRATES: So then, if I may ask: exactly *how* does the straight edge become curved? Or, to be more precise, what *shape* is its curvature?

EINSTEIN: Pardon me?

SOCRATES: Well, is the curvature like a circle (or part of a circle), or an ellipse or part of an ellipse, or of a parabola or hyperbola, or what? What is the exact *nature* and *degree* of this curvature?

EINSTEIN: Well, I should say its curvature is of the *same* nature and degree as that of the light beam – of course.

SOCRATES: Why not more, or less?

EINSTEIN: Well, the whole point of my thought-experiment is to show that space can be curved due to acceleration, *using the example of a light beam to show by how much.* If I had used bullets from a pistol in my thought-experiment, then the curvature of the straight edge – and thus of space – would be that of the trajectories of the bullets; but since bullets all have different speeds, I was very careful *not* to use bullets for my thought-experiment! But we all know that *light* travels at a *constant* speed – and indeed, prominent people have tried hard, but failed miserably, to show that it doesn't – so I contend that *light itself* is what we should use to demonstrate the nature and degree of curvature of space.

SOCRATES: Well then. If I may propose a small modification to your thought-experiment? One that should not alter the *essentials* of the thought-experiment in any relevant way?

EINSTEIN: By all means.

SOCRATES: Shall we suppose that before the elevator is accelerated, the absolutely straight and rigid ruler we spoke of earlier is not merely *extended* from one wall to the opposite wall, but is actually *firmly fixed* – say, by welding – to both the walls: one end of the lower edge of the ruler being firmly fixed right next to the laser pointer, so that the lower edge of the ruler and the lower edge of the light beam, at the point where the light beam leaves the laser pointer, are the *same* distance above the floor of the elevator. And let's suppose that the *other* end of the ruler is firmly fixed so that its lower edge is right next to the lowest point of the spot where the light beam strikes the opposite wall. Or, to express it in another way, and to make things *absolutely* clear, we shall specify that when the elevator is *not* being accelerated, the bottom edge of the ruler is *exactly* parallel to – and therefore *absolutely* equidistant from – the bottom edge of the light beam, *at every point along their lengths*. (Again, we shan't specify how we *obtain* such absolute precision, and shall consider it irrelevant.)

EINSTEIN: *(Thinking for a while).* Yes, I suppose we can do this, and not alter the thought-experiment in any *relevant* way.

SOCRATES: Well then. *Now* shall we analyze what happens when the elevator is accelerated upwards at a speed which increases by 10 metres per second with every passing second?

EINSTEIN: Yes, let's do that.

SOCRATES: You claim – and, in fact, I agree – that when the elevator is accelerated, the light beam would strike the wall opposite the laser pointer a little bit *below* the point where the light used to shine on the same wall when the elevator was *not* being accelerated: do you not?

EINSTEIN: Yes, indeed – that's *exactly* what I claim.

SOCRATES: Do then you do claim, don't you, that when the elevator is *being* accelerated, the distance between the *curved* bottom edge of the light beam and the floor of the elevator is now *diminished* by a small amount, while under those same conditions, the distance between the *straight* bottom edge of the *ruler* and the floor of the elevator is *not* diminished in the slightest? And that, therefore, the bottom edge of the light beam is *no longer* absolutely equidistant from the bottom edge of the ruler at every point along their lengths?

EINSTEIN: *(Thinking a bit).* Yes … I suppose so.

SOCRATES: But then you *are* claiming, aren't you, that the straight edge is *not* bent – or curved – by the same amount as the light beam?

EINSTEIN: *(Thinking a bit more).* No, sorry – I misspoke. The distance between the bottom edge of the light beam and the floor of the elevator is not diminished in the slighted either. That, in fact, is because the *straight edge* will *also* now be curved in exactly the same manner and to the same degree as the light beam!

SOCRATES: But then you would be *wrong* in saying that when the elevator is accelerated, the light beam strikes the wall opposite the laser pointer a little bit *below* the spot where the light shone on the same wall when the elevator was *not* being accelerated – would you not?

EINSTEIN: You're totally confusing me now.

SOCRATES: Well, if you assume that the straight edge – and thus, as a result, space itself – is *bent* by the acceleration of the elevator, and indeed bent in exactly the same way and to the same degree as the *light beam* is bent by that same acceleration, then the light beam should strike the *same* spot on the wall opposite the laser pointer whether the elevator is being accelerated or not – right? That the bending of the straight edge should *exactly* compensate for the bending of the light beam … ? Is that not so?

EINSTEIN: I still don't get it.

SOCRATES: Well, let's use some actual figures: some simple ones, nothing complicated. Let's suppose that *before* the elevator is accelerated, the laser pointer and the ruler are so affixed to the walls of the elevator that the lower edges of both the ruler and the light beam are *exactly* one metre above the floor of the elevator. And when I say "exactly", I mean *absolutely precisely.* Again, just *how* we achieve such fantastic precision will not be specified, for we shall consider it irrelevant to our thought-experiment – just as you yourself, my good Professor, consider the matter of *how* we accelerate the elevator to be unspecified and irrelevant. Let's further suppose that at that time, the elevator's floor is *perfectly* horizontal and flat *everywhere* along its surface, and its walls all *perfectly* vertical and flat everywhere along their surfaces; and the bottom edges of both the light beam and the ruler are also *perfectly* horizontal. Moreover, we shall specify that when we do finally accelerate the elevator, we shall accelerate it *perfectly* vertically. So, *before* the elevator is accelerated, the light beam strikes the opposite wall in such a way that the bottom of the light beam – or the bottom of the spot of light on that wall indicated by the laser's light – is *exactly* one metre above the floor of the elevator: right?

EINSTEIN: Right.

SOCRATES: So, if *after* we accelerate the elevator, the spot of light shone by the laser on the opposite wall is a small, but *measurable,* amount *below* the original spot where it struck the same wall when the elevator was *not* being accelerated, then the bottom of that spot would be measurably *less* than exactly one metre above the floor, right?

EINSTEIN: Right.

SOCRATES: But at the *other* wall – the wall to which the laser pointer is fixed – the bottom of the light beam *just* where it exits the laser would still be *exactly* one metre above the floor: right?

EINSTEIN: Right.

SOCRATES: And at *that* same wall, the bottom edge of the straight edge fixed to the wall would *also* be exactly one metre above the floor: right?

EINSTEIN: Yes, that's right too.

SOCRATES: Now where *exactly* would the bottom edge of the straight edge affixed to the *opposite* wall be? Would it be *exactly* one metre above the floor, or a measurable amount *less* than exactly one metre above the floor?

EINSTEIN: You're making me dizzy, Socrates!

SOCRATES: Well, let's consider *all* the possibilities.

EINSTEIN: Okay …

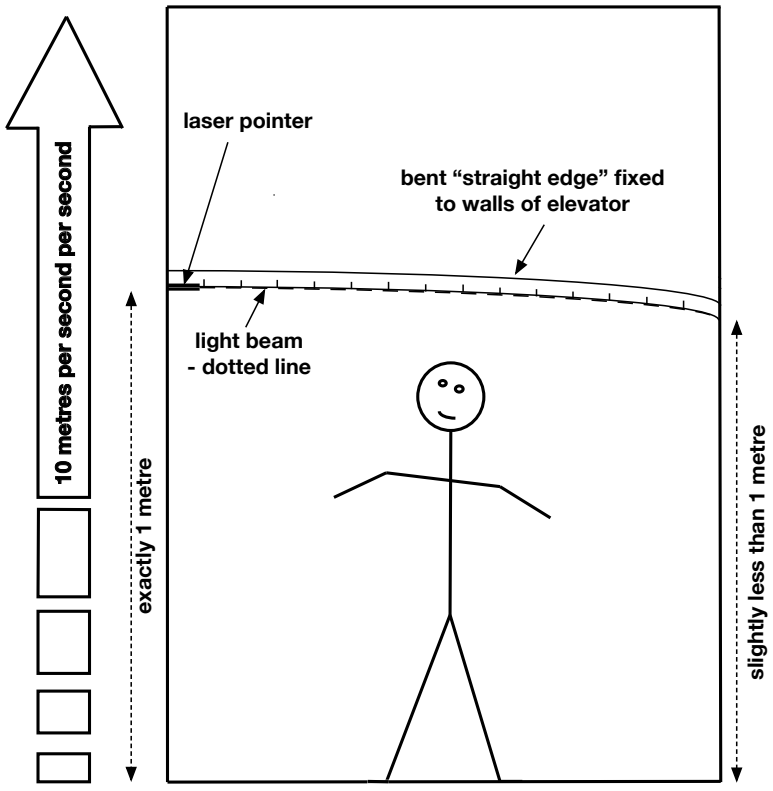
SOCRATES: Suppose the straight edge is *not* bent in the slightest by the acceleration imparted to the elevator. In that case, its bottom edge would be *exactly* one metre above the floor of the elevator both before *and* after the elevator is accelerated, right?

EINSTEIN: Right.

SOCRATES: In which case, as we said, your thought-experiment collapses, for the straight edge of the ruler would remain absolutely straight even *after* the elevator is accelerated, showing that straight lines in space do *not* become bent by acceleration. We saw that earlier, right?

EINSTEIN: *(Reluctantly)* Yes.

SOCRATES: So for your thought-experiment to be valid, the bottom edge of the ruler *can't* be exactly one metre above the floor all along its length, can it? Yes, it *would* be exactly one metre above the floor *at the spot where it is affixed to the wall on which the laser pointer is affixed;* but on the *opposite* wall – the wall on which the light from the laser is caused to shine – the bottom edge of the ruler is now measurably *less* than one metre above the floor … right? Like this *(draws in sand again):*



EINSTEIN: Yes. Although as you have drawn him here, the man in the elevator would have to be much shorter than one metre in height, and that's *very* short … but before you object, I shall stipulate that that's irrelevant to our thought-experiment.

SOCRATES: Indeed. Because in your thought-experiment, the light beam would strike the wall opposite the laser pointer a little bit *below* the spot where it shone before the elevator was accelerated: yes?

EINSTEIN: Yes.

SOCRATES: For *if* the bottom edge of the ruler is one metre above the floor at *both* its ends, your thought-experiment would amount to a re*ductio ad absurdum*, yes? Or in other words, it would prove that as you have expressed it, your thought-experiment would *not be possible,* even in *theory,* yes?

EINSTEIN: Yes, true … but shall we follow this trend of thought to the end? I'd really like to see where it leads us.

SOCRATES: All right, let's carry on. So let me ask: what would cause this distance to shrink from *exactly* and *precisely* one metre, to a smidgen *less* than one metre, as the drawing shows? Given that the straight edge is, and always remains, *firmly fixed* to the wall … say, by welding?

EINSTEIN: *(Thinking about it a bit)* Ah! I think I have it. You see, according to my *Special* Theory of Relativity, *objects shrink in the direction of their motion.* So, since the elevator is being accelerated upwards, the wall *shrinks* a bit, and *that* accounts for it.

SOCRATES: But, my *dear* Professor! Since the walls of the elevator are, according to our previous agreement, all *exactly* vertical, and since *all* of them are moving upwards at the same rate of acceleration, should not the distance of the bottom edge of the light beam above the floor – and also of the bottom edge of the straight edge above the floor – shrink *equally* all along their lengths? But you yourself agreed earlier that the bottom edge of the ruler where it is affixed to the wall next to the laser pointer will *always* remain one metre above the floor, did you not?

EINSTEIN: *(Thinking about it a bit more)* No, I misspoke: you're right. The shrinkage of the walls would be – *must* be – the same for *all* the walls. So, after the elevator is accelerated, the bottom edge of the light beam – as also the bottom edge of the straight edge – at *both* walls will be a smidgen less than one metre.

SOCRATES: And will both these lengths be *equal?*

EINSTEIN: Yes.

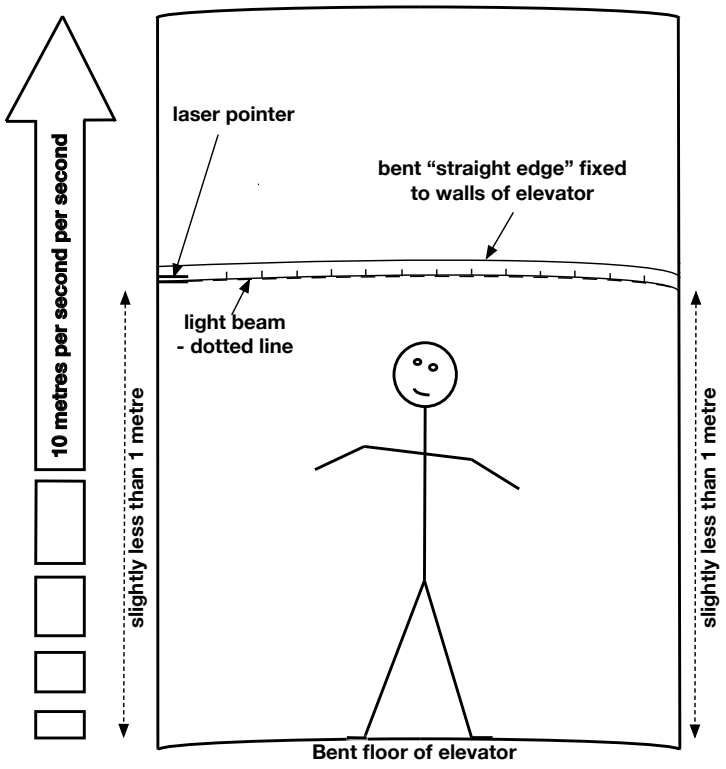
SOCRATES: And what about in the middle, *between* the two walls? Will the bottom edge of the light beam and of the straight edge also remain at the same distance above the floor all throughout its length?

EINSTEIN: Yes, of course.

SOCRATES: Then the light beam would *not* be bent in the least, would it? Nor, in fact, would the straight edge be. Both would be as straight as an arrow: in fact, much straighter!

EINSTEIN: No, not so: because the *floor* of the elevator would be bent!

SOCRATES: Like this? *(Again draws in sand):*



EINSTEIN: Yes: that's *exactly* what I mean!

SOCRATES: Well, I have to ask, then: exactly *why* would the floor of the elevator be bent?

EINSTEIN: Because, my dear Socrates – my esteemed Sir – I'm afraid you *still* don't get it. *Space itself gets bent by the acceleration of the elevator!* Everybody *knows* that nowadays. And *that* is why the the floor of the elevator would get bent when the elevator is accelerated.

SOCRATES: *(Smiling).* Well, you know, if I were in a court of law, I might say at this point, "No further questions; I rest my case!" But since we *aren't* in a court of law, I should like to explain to you exactly how your argument here is invalid, for it assumes in advance that which is yet to be demonstrated! – May I?

EINSTEIN: Certainly.

SOCRATES: You claim, don't you, that *space itself* gets bent by acceleration?

EINSTEIN: Yes, that's what I said, isn't it?

SOCRATES: And you also said that everybody *knows* that.

EINSTEIN: Yes, I did indeed!

SOCRATES: Now my question is, *how* does everybody know that?

EINSTEIN: Because my General Theory of Relativity *demonstrates* it!

SOCRATES: Right. And exactly *how* does your Theory demonstrate it?

EINSTEIN: Well, let's imagine an elevator that's being accelerated upwards … *Ohhhh!* I see what you mean. I'm assuming I *have* the demonstration even in order to *formulate* the demonstration.

SOCRATES: *Indeed* you are, my dear Professor!

EINSTEIN: But surely there are *other* ways of demonstrating the same thing.

SOCRATES: Well, do *you* know of any?

EINSTEIN: Off the top of my head, no, I have to admit I don't; but I'm sure there *are.*

SOCRATES: And who, exactly, would know them?

EINSTEIN: How should *I* know who would know them?

SOCRATES: Well, isn't it *your* Theory of Relativity?

EINSTEIN: Yes, of course it is!

SOCRATES: Then should you not be required to provide such a demonstration … or else, if you can't, admit that *your* Theory isn't yet *complete?*

EINSTEIN: Well, okay – for the time being I have to say I don't have a rebuttal. *For the time being only*, mind you.

SOCRATES: Yes, for the time being only. But you *do* admit that *for the time being,* your Theory isn't complete? In other words, that it hasn't actually *demonstrated* that space can get bent?

EINSTEIN: Yes, *for the time being only.*

SOCRATES: Right. Then I have another question for you. If, as you say, the straight edge – and indeed, if we accept your claim that the floor of the elevator as well – is curved in exactly the same way and to to same degree as the beam of light, then would they also *appear* to be curved to the man in the elevator, or would they appear straight?

EINSTEIN: Come again?

SOCRATES: Well, to put it another way: how can we *test* to see whether a straight edge *appears* – and therefore, by your earlier "empiricist" argument, also *is* – straight, or not? Do we not put one end of the straight edge to one eye, and take a line of sight along it … so that if it *is* bent or curved, we can easily *notice* it?

EINSTEIN: Yes, that's *one* way to check for straightness, admittedly. Not the *only* way, however.

SOCRATES: Yes, agreed. One can also check for the straightness of an edge by drawing a line with it, flipping the edge over, and then drawing a second line with it while trying to make both the lines coincide *exactly*. If they don't, the edge *isn't* straight.

EINSTEIN: Yes, true enough.

SOCRATES: But let's consider the line-of-sight method for now. If, *before* the elevator were accelerated, the straight edge *were* absolutely *straight*, then if, after acceleration, the man were to put one end of the straight edge to his eye, would he see it straight, or bent?

EINSTEIN: *(Thinking about it a bit)* I imagine, he would still see it *straight*, because he is using *light* to test whether the straight edge is straight or not; and the ruler and the light being bent in *exactly the same way and exactly to the same degree*, the light would now come through from one end of the straight edge to the other in a line exactly *parallel* to the edge!

SOCRATES: So then, if the man uses the *line-of-sight* method to test whether the straight edge remains really straight or not, it would *appear* straight to him both before *and* after the elevator undergoes acceleration … yes?

EINSTEIN: Yes, true.

SOCRATES: And that would be so *even if space were "bent" by the acceleration?*

EINSTEIN: Yes … . Hmm. Admittedly this is weird – a bent edge appearing straight – but your argument does seem foolproof.

SOCRATES: But then, by your "empiricist" argument, wouldn't the straight edge actually *be* straight, and *not* bent? In other words, if you claim, as you did earlier, that appearance *is* reality, then would it not be a proof that the straight edge – and therefore space too – would not *appear* bent, and as a result, could not *be* bent *in reality* either?

EINSTEIN: *(Thinking about it).* Well, clearly we can't take this empiricist argument *too* far: not if we want to take leave of our common sense altogether. Not *all* appearance *is* reality, surely. In *this* particular case, I contend that the straight edge *appears* straight but *is* bent. *In reality* it *is* bent, even though it may *appear* straight.

SOCRATES: But then, could I trouble you to *make up your mind* as to whether you wish to *stick* with the empiricist view, which claims – in Bishop Berkeley's words – that *esse est percipi,* and which as per your translation means "reality *is* appearance" … or whether you wish to *abandon* this empiricist view?

EINSTEIN: Well, I think we have to take the empiricist view "with a bit of salt", as it were. When it agrees with our common sense we should accept it, and when it doesn't, we shouldn't.

SOCRATES: Are you now claiming that appearances *can* be appearances at times, and *not* reality?

EINSTEIN: When you put it like that – yes, I suppose I am.

SOCRATES: Then are you saying *now*, that you are *repudiating* the answer you gave when we first spoke about the bending of the light beam in the elevator and I asked you whether it could be a mere appearance and not a reality, and you answered that it was definitely *a reality?* In other words, are you now admitting that it *could* be a mere appearance?

EINSTEIN: Er … yes, I suppose I am.

SOCRATES: So I must now ask, again: in what way does the claim that the light beam *is* bent, and doesn't merely *appear* so, agree with our common sense?

EINSTEIN: Well, obviously, if the man in the elevator *observes* it bent, then it must *be* bent, right?

SOCRATES: But why can't it merely be bent *in appearance?*

EINSTEIN: Well, this man *is* the only observer, isn't he now. Science is all about *observation!*

SOCRATES: So it is; but this man is hardly the only *possible* observer, is he.

EINSTEIN: Of course he is. In our thought-experiment he's the *only* man – indeed, the only *sentient being* – in the elevator!

SOCRATES: *In* the elevator, yes. But what about possible observers *outside* the elevator – observers who are *not* being accelerated in the direction the elevator is being accelerated? Observers who would be at *rest* relative to the elevator *before* it underwent acceleration?

EINSTEIN: Well, such a person or persons couldn't *look into* the elevator, could they now, so they couldn't *observe* anything in it. They wouldn't actually be "observers", would they.

SOCRATES: Well, if I might be permitted to make another small change in your thought-experiment – something that would not affect the essentials of the thought-experiment in any way … ?

EINSTEIN: By all means.

SOCRATES: Suppose that one of the *other* walls of the elevator – one of the walls on which *neither* the laser pointer *nor* the straight edge is attached – is *semi-transparent:* suppose, let's say, that it's made of semi-reflective glass or plastic, like windows in police interrogation rooms, so that people outside the elevator could look *in,* but the man inside couldn't look *out.* And suppose in addition that there is a woman *outside* the elevator – of course dressed an an appropriate space-suit to withstand the rigours of empty space – who *can* observe the inside of the elevator after it has been accelerated. And let us further suppose that the laser pointer is set to fire sub-nanosecond *bursts* of light at intervals, say one-tenth-of-a-second intervals. (I say "sub-nanosecond bursts of light at intervals" because, as you probably know – or can readily calculate – light travels almost exactly one-third of a metre, or 33 centimetres, in one nanosecond, and so sub-nanosecond bursts of light would be less than 33 centimetres in length; and that would allow the observation of the *actual* trajectory of light, and not its *apparent* trajectory – which is what would be observed if a continuous *beam* were generated. The latter would be much like observing a stream of water from a hose, which *appears* bent when the hose is swung around, even though the water *actually* moves straight when it leaves of the nozzle, except of course with regard to the effects of gravity and air on it.) In fact, once again let's suppose the elevator is provided with a small amount of smoke, so that each of the bursts of light is rendered clearly *visible* to the woman during its passage from the laser pointer to the opposite wall; and suppose the woman has a high speed camera which, as the elevator accelerates past her, takes snapshots of each of the individual bursts of light fired by the laser pointer, illuminated as they are by the smoke. Would her photographs show the trajectory of each burst of light as *bent*, or would it show it as *straight?* I personally think she would see all their trajectories as absolutely *straight,* but I am open to counter arguments.

EINSTEIN: *(Long pause. Then, after thinking about it quite a bit):* I believe you're right: *to the woman* who is *outside* the elevator, and who is *not* being accelerated, the *trajectories* of the bursts of light from the laser pointer should appear absolutely *straight*.

SOCRATES: Well then: you do agree that the bursts of light would move in *straight* trajectories as far as the woman is concerned, but *not* as far as the man is concerned?

EINSTEIN: *(Again thinking a bit more about it)* Yes, I think so. Yes. Yes, they would.

SOCRATES: And if there were also a couple of *pistols* in the elevator, the trajectories of the *bullets* fired by them would also appear straight to her – right? Of course, if she *could* observe them. But doing so wouldn't be too hard to arrange. Suppose she had a high speed camera taking *successive* snapshots of the bullets as they were fired, with, say, sub-microsecond intervals between successive snapshots. Since bullets travel at speeds ranging from approximately a couple of hundred to about fifteen hundred metres per second, and since the elevator is most likely to be between three and ten metres in width, she could obtain anything from a few hundred to a few thousand snapshots of each bullet in its flight – right? If all the snapshots were transposed on to a *single* frame – that is to say, on to a *single* photograph – one could easily tell that the bullets are all moving in *straight* trajectories, and that the difference in the points where they struck the opposite wall of the elevator was merely due to the difference in the *durations* of their flights, because the elevator was being *accelerated* during these durations. Right?

EINSTEIN: Yes. I think you're *absolutely* right. Yes.

SOCRATES: And we can also give a very good *reason* why the bullets – and the light, too – would all appear to show *straight* trajectories to the woman: am I not right?

EINSTEIN: Yes, of course. Once the bullets have *left* the pistol from which they are fired, no further lateral force would be imparted to them; and the same applies to the bursts of light once they have left the laser. Besides, they would not be in acceleration, either, so space would not be curved as far as *they* are concerned. So, according to Newton's first law – which says that a body continues to move in a straight line unless acted upon by an external force – they would continue to move in a *straight* line until they hit the opposite wall. Of, if we wish to bypass Newton, and use my Theory of General Relativity instead, then due to the fact that the bullets and photons are *not* being accelerated, and neither are they in the vicinity of any perceptible *gravitational* field, the space around them could *not* be curved, at least not perceptibly; and so their trajectories would perforce be perfectly *straight* – or at least, as perfectly straight as is ever possible for them to be in *our* Universe, in which gravity is never *totally* absent. Trust me, I have thought this through most thoroughly!

SOCRATES: *Indeed* you have; and you are also *quite* right! So now my question to you is this: since to the *woman*, the bullets and the photons all appear to move in *straight* trajectories, while to the *man* in the elevator they appear to move in *curved* trajectories, which of the two would be observing *actual* reality: the man or the woman?

EINSTEIN: *(Thinking).* Hmm. A bit of a conundrum, I must admit. *(Brightening up).* Why can't they *both* be observing the reality? I claim that reality is *relative:* what's reality for one observer may not be so for another.

SOCRATES: But *can* multiple "realties" *really* exist? Isn't the entire *point* of science to try to determine the laws of *the* reality – the *real* reality? Even if, hypothetically, multiple "realities" did exist, would that not merely mean that there is a *single* reality – a single *real* reality – and that *real* reality *is that* multiple so-called "realities" exist? In other words, doesn't a *contradiction* arise from postulating multiple "realities"? *Really?*

EINSTEIN: *(Thinking).* Yes, I see how that might be the case. But in your example earlier, I would say that *space itself* is different for the man than it is for the woman. More accurately, that each of the two people is in a *different* space. In *reality.* They are in two *different* spaces.

SOCRATES: And *which* two different spaces would those be?

EINSTEIN: The space *inside* the elevator being one of them, and the space *outside* it being the other, of course.

SOCRATES: Then would you say that the space *inside* the elevator is curved – *really* curved – while the space *outside* the elevator is *not* at all curved?

EINSTEIN: Yes, I would!

SOCRATES: Just to be absolutely clear: the space *inside* the elevator would be bent, or curved, while the space *outside* the elevator would be totally straight – is *that* what you claim?

EINSTEIN: Yes – except that instead of calling that latter space "straight", I'd call it "flat".

SOCRATES: All right: "flat", then. But what *separates* the two different spaces – the curved one inside the elevator and the flat one outside it?

EINSTEIN: The elevator's walls, ceiling and floor, of course!

SOCRATES: Well, what if we were to imagine the ceiling and floor made out of some sort of *mesh*, so that the space *inside* and the space *outside* the elevator now become the *same* space? In this case, the elevator would be moving *through* the outside space, would it not; and as it moves, the outside space would *enter* the elevator through the top mesh, and *exit* it through the mesh at the bottom. Yes? Thus at all times the space *inside* the elevator would *be* the same space that's *outside* the elevator, and so be totally "flat", as you put it: right? Of course, now the man would also have to be dressed in a space-suit, just like the woman, but that's hardly a *relevant* issue, is it.

EINSTEIN: *(Thinking a bit).* You've got me there. I don't know what to say to that. It really does seem that space has got to be the same for both the woman *and* the man, and thus the floor of the elevator – at least if the elevator were made of a kind of mesh – *couldn't* be curved in *reality. (Brightening up a bit).* But what about *mathematical* proofs of curved space?

SOCRATES: Well, *are* there any?

EINSTEIN: *Personally* I don't know any, but I'm sure that mathematicians much more expert than I am have already come up with some … or at least *could* do so, if they haven't *yet!*

SOCRATES: Maybe. But *could* they come up with any such proofs with respect to *your* Theory? Let me remind you that yours is a Theory of *physics*, not of *mathematics.* Just because there are mathematical theorems which can, and admittedly do, deal *mathematically* with curved spaces – personally I don't see how *those* can be *proven* either, if we are to speak of rigorous logic as being the only (and strictest) criterion for "proof", but we'll ignore my doubts in that regard for the moment – that fact by itself doesn't mean that those mathematical theorems are necessarily applicable to *physics* – that is to say, to the *physical Universe as we know it …* does it now? Wouldn't the mathematicians have to prove, not only their *theorems* regarding curved space, but also *that* those theorems are

in fact applicable to *physics?* Or more to the point, do you *know* of a proof *that* these mathematical theorems *are* applicable to the physics of the known, *physical* Universe?

EINSTEIN: I confess I don't. But maybe *those* mathematicians do know of such a proof!

SOCRATES: Perhaps. But in *your* books and articles *you* certainly haven't *referred* to any such proof, have you.

EINSTEIN: You're right – I haven't.

SOCRATES: So as far as *your* Theory goes, strictly speaking you *yourself* don't have any such proof: right?

EINSTEIN: *(A bit despondently)* Once more you're right – *I* don't. *Strictly* speaking. *(Brightening up).* But I really don't *need* a proof: not in *science.* I was speaking to the philosopher Karl Popper a short while ago, and he convinced me that in science there simply *aren't* any proofs, there is only a preponderance of *evidence.* A scientific theory, according to him, can never be *verified*, or proved *true;* it can only be *falsified*, or in other words, proved *false.* (I don't mean to use the word "falsified" in the sense of "faked" or "tampered with", you understand – just in the sense of "the opposite of *verified"*. Admittedly the word is a bit ambiguous.) As long as there is plenty of evidence *for*, and absolutely none *against*, any theory, the theory stands; but if there is *any* evidence *against* a theory, it is "falsified" – which is to say, refuted. I totally agree with the good philosopher Popper. Besides, he is from Vienna, a city of which I thoroughly approve; but I agree, before you raise your objections, that that's a bit irrelevant here. But the pastries there … *(Wistfully trailing off).*

SOCRATES: So are you claiming that there is plenty of evidence *for* your Theory that space is curved by gravity, and none against, and so your Theory must stand until some evidence *against* it turns up?

EINSTEIN: Yes, that's *exactly* what I am claiming.

SOCRATES: Then would you be so kind as to point out the evidence *for* your Theory?

EINSTEIN: Certainly. One clear example of evidence for my General Theory of Relativity was the observation that gravity *could* bend light. My supporter Arthur Eddington organized an expedition to the island of Principe off the coast of West Africa during the total solar eclipse of May 29, 1919. Positions of star images within the field of vision near the eclipsed Sun were used to test my prediction of the bending of light around the Sun according to my General Theory of Relativity. The test was passed with flying colours!

SOCRATES: Well, as regards the Eddington expedition, I happen to have heard something about it, and I am not so certain that it constitutes a *clear* confirmation of your Theory. In fact I don't think it could have clearly confirmed *or* refuted your Theory. For one thing, the photographed starlight passed *very close* to the Sun on its way to the cameras, so how exactly can we be certain that the bending of the starlight was not due to the fact that the region of space close to the Sun isn't a *total* vacuum – immensely rich as it is in what is called "the Solar wind", which is in a sense the "atmosphere" of the Sun? After all, space near the Sun is neither homogeneous nor a complete vacuum, and we all *know* that light can bend in a non-homogeneous medium: in fact, that's our best explanation for mirages in the desert … isn't it? Besides, I have heard it claimed by some intelligent people who reviewed Eddington's work – such as the American astronomer Charles Lane Poor, a

professor of astronomy at Columbia University and a fellow of the Royal Society – that most of the data collected during the Eddington expedition – about 85% of it in fact – was arbitrarily discarded; and even worse, out of a total eclipse lasting 410 seconds, only 10 seconds were *actually* photographed: photographing the rest of of the eclipse, amounting to over 97 per cent of it, was not even possible, due to clouds and rain. I also understand that the margin of error of the instruments used for procuring the data was *far* below the level of precision required, as I said earlier, to either confirm *or* refute your theory. I am given to understand that the cameras used in the expedition were accurate to only 1/25th of a degree – which is something like 144 seconds of arc – while your prediction was that starlight would be bent by something like 1.75 seconds of arc. This would mean that just with regards to the camera data alone, the margin of error was over *eighty times* that required to confirm or refute your theory … and indeed, light from several stars was, as a result, "observed" to bend in a direction *transverse* to the expected direction, and from still others to bend in a direction *opposite* to that predicted by your Theory. … *(Pauses).* But be that as it may, I am not denying that *trajectories* can be bent by gravity, Professor Einstein! I quite *agree* that they can be. All that Eddington's expedition *could* have confirmed, even if it had been most *thoroughly* conducted, is that the *trajectories* of light – that is, of photons – can be bent by gravity … and I never doubted that for a second!

EINSTEIN: Then despite your reluctance to agree with the evidence collected by Eddington, you nevertheless do *agree* with me, don't you?

SOCRATES: As to *trajectories*, of *course* I do. People have known for *centuries* that the *trajectories* of moving bodies are bent – or more accurately, curved – by gravity: for example, all artillerymen know that! In fact, there isn't *any* trajectory of *anything* that moves in a *true* straight line, since there isn't *any* location in the entire Universe *completely* free from the force of gravity – or don't you agree?

EINSTEIN: Trajectories of *artillery shells* and *projectiles* can be curved by gravity, yes, but that's because such objects have *mass*. But *massless* things like photons are different!

SOCRATES: Are you claiming that photons don't have *any* mass – not even the most tiny amount?

EINSTEIN: Of *course* I am claiming that!

SOCRATES: Then how do you account for the fact that photons can *push* things – that being the principle behind "light sails" – and can also knock electrons out of atoms, as your own paper on the photoelectric effect argues?

EINSTEIN: Photons don't have *mass,* but they do have *energy*, and *that's* why they can push things and knock electrons out of atoms.

SOCRATES: Then, by the "most famous equation in the world" – as Professor Umberto Bartocci of the University of Perugia calls it, namely $E=Mc^2$, the equation you yourself made famous by inserting it in your paper 1905 paper – the photons' energy *does* have mass, doesn't it?

EINSTEIN: *(Thinking)* Again, *touché* … though as an aside, I have to admit that *I* didn't actually *first* come up with this equation. To be brutally honest – something I can afford to be now that I am dead – that credit to should go to the Italian industrialist Olinto De Pretto from Vicenza. He is now virtually unknown, but, in 1903 – two years before my 1905 paper in which I myself first came up with my Special Theory of Relativity – he did, I admit, publish the equation $E=Mc^2$ in an Italian scientific magazine, "Atte". Credit where credit is due*,*

and all that. But yes, to return to our discussion, when photons are *moving* they do have mass, as opposed to when they are at rest … and at rest they simply don't exist at all. So reluctantly I must admit that moving photons ought also to be affected by gravity. … *(Pauses in reflection).* In fact, come to think of it, that's exactly why black holes are *black*, isn't it: because photons can't escape their *gravity.* That couldn't *possibly* be the case *unless* photons *could* be attracted by gravity. Yes: I must admit that the trajectories of photons *must* be affected by gravity – just as trajectories of artillery shells and projectiles and planets and asteroids are affected by gravity. In fact, if I memory serves, someone came up with that idea even around Newton's time. So I have to admit that my Theory is *not* necessary to prove that the *trajectories* of photons can be affected by gravity. As a matter of fact, even if Eddington *had* actually proved that the Sun's gravity did bend light, it wouldn't have provided actual *evidence* for my Theory. Yes, again *touché*.

SOCRATES: So, as I said, there isn't *any* trajectory of *anything* that moves in a *true* straight line, since there isn't *any* part of the Universe *completely* free of gravity – or don't you agree?

EINSTEIN: Of course I do. That's *precisely* my point: space is bent – or, as you say, curved – *everywhere* in the Universe! The *entire* Universe exists in a bent, or curved, space.

SOCRATES: But if I may ask, then: how does the fact that *trajectories* of moving objects are curved in a gravitational field, show that *space itself* is curved in a gravitational field? Does the fact that, for instance, *artillery shells* move in curved trajectories after they are fired, show that *space itself* is curved?

EINSTEIN: No; but then, we're not talking about artillery shells, are we now. We're talking about *light,* than which nothing can move *faster!*

SOCRATES: Then if I may ask, what *exactly,* other than their speeds, is the *essential* difference between the trajectories of artillery shells and the trajectory of light?

EINSTEIN: Light is *much* faster, of course! *That's* the difference. *Thousands* of times faster. Tens of thousands, even hundreds of thousands of times faster!

SOCRATES: Yes, so it is; but so what? Doesn't that merely show that its trajectory is *more* straight than that of an artillery shell … but not *absolutely* straight? Just as the trajectory of a *fast-moving* artillery shell is *more* straight than a slow-moving one, but not *absolutely* straight?

EINSTEIN: Well, doesn't light always travel in *straight* lines? In fact, as you yourself pointed out earlier, don't we actually *use* light to *test* the straightness of a straight edge? We couldn't do so if light *didn't* travel in straight lines, could we now.

SOCRATES: I think we can do that only for *practical* purposes, because light is so *slightly* bent by the Earth's gravity that it might as well not be: the difference is too small to measure.

EINSTEIN: Quite. That's what I say too!

SOCRATES: But are you not *now* claiming that light *always* travels in straight lines? Isn't that the exact *opposite* of what you claimed earlier – that the paths in which light moves are *curved* by gravity? And isn't gravity *ubiquitous* in the Universe – in some places weaker and in some others, stronger, but *never altogether non-existent?*

EINSTEIN: Yes, but so what?

SOCRATES: Well, didn't you say earlier that light travels in a *curved* trajectory in the presence of a gravitational field?

EINSTEIN: Yes, but that curved trajectory *is* straight.

SOCRATES: Come again? Did you just say that a curved trajectory *is* straight? Am I to understand, in other words, that in your view a curved trajectory *isn't* a curved trajectory? Isn't that a veritable contradiction in terms?

EINSTEIN: Curved trajectories *can* be straight. Let me try to explain using an analogy. Consider a sphere. All the lines on the *surface* of the sphere would be curved, wouldn't they? But they would *also* be straight: if by "straight" we mean "the shortest distance between two points". You see, if you choose any two points on the surface of a sphere, the shortest line connecting them would be a "great circle" along the surface of the sphere, wouldn't it.

SOCRATES: But surely those lines are *curved:* indeed, doesn't your own definition of them, "great *circles"*, imply very clearly that they are *curved?*

EINSTEIN: Of course they are. They are curved *and* straight!

SOCRATES: That verily sounds like something right out of "Alice in Wonderland". If that is truly so, what might be the difference between *these* lines, which are curved *and* straight, and *really* straight lines connecting any two points on the surface of the sphere, but passing *through* the sphere: lines which are *not* curved at all?

EINSTEIN: Well, if we imagine the sphere to be *solid*, then lines *couldn't* pass through the sphere, now could they. So such lines couldn't even *exist.* Not in the *real* Universe!

SOCRATES: Well, I agree with that argument when it comes to *real* lines – and again, let's take the word "real" to mean "physical" in this context, at least for the sake of argument, even though I don't *totally* agree with such a definition – but since we are *imagining* the solid sphere, couldn't *imaginary* straight lines pass through such an *imaginary* sphere?

EINSTEIN: Okay, let's talk about *real* spheres, then. After all, we *are* talking about *reality* in my Theory, aren't we?

SOCRATES: Certainly. But then, do *real* lines and spheres exist in the *real* – or more accurately, the *physical* – world … irrespective of whether the physical world is real or merely apparent (given that the empiricist philosophers challenge all other philosophers in that regard)?

EINSTEIN: Of *course* real spheres exist in the real world! Consider a billiard ball, or a ball-bearing – or even a planet!

SOCRATES: But aren't they all, in reality, only *approximations* to spheres and not *true* spheres? If observed from *very* close, don't they all have *irregularities* which make them incapable of being *true* spheres? And as for lines, if we define a "line" as an entity having only *one* dimension, well then, *is* there any such thing *at all* in the *physical* world?

EINSTEIN: *(Thinking about it).* No, you're right; such things as *true* spheres and *true* lines don't exist in the physical world; but we were talking of *trajectories.* Surely you admit that *those* can exist in the real – or physical – world?

SOCRATES: Yes, of course. But then, a *curved* trajectory can't be *really* straight, can it? Because if we consider a curved *trajectory* between any two points, then we can always find a distance between *those* points which is *shorter* than the trajectory itself: can't we? After all, a trajectory exists in either an empty space, or in a space filled with a medium though which things can *move:* not in a *solid* space though which things *can't* move and in which things *can't* be located.

EINSTEIN: *(Thinking).* Yes, I suppose you are right.

SOCRATES: So you do agree that a curved *trajectory* can't be *really* straight?

EINSTEIN: *Maybe*. I'm not capitulating, mind you, it's just that I don't have a rebuttal to your argument right at this moment. But I shall think something up, I promise I will!

SOCRATES: *Indeed* you will, my dear Professor: I am confident of that. But *for the moment at least,* do you concede that a curved trajectory can't be straight?

EINSTEIN: *(Reluctantly)* Yes. *For the moment only,* mind you!

SOCRATES: So you do agree that the existence of a curved *trajectory* – even a trajectory of light itself – is absolutely *no* evidence of curved *space?* If I may remind you, you are under oath!

EINSTEIN: *(Even more reluctantly)* I don't know what to say. *(Sigh).* Yes, I suppose I do. For *now.*

SOCRATES: And aside from curved *trajectories,* do you know of anything *else* that provides *physical* evidence for your claim that space is bent, or curved?

EINSTEIN: No, I confess I don't. The problem is, you see, the effect is too small to detect in weak gravitational fields like that of the Earth, while we *just don't have the technology* to bring large rigid objects, like perfectly straight rods, close enough to strong gravitational fields – like that of the Sun, or of a black hole – and deep enough *into* those fields so that we can measure the bending of such straight rods in a manner that that could *definitively* show the bending of those rods by those fields alone, and by nothing else. *(Brightening up).* But I don't see you providing any evidence that space *can't* be curved, either. So I shall at least claim that my Theory still stands, because you haven't actually *falsified* it! At least, not yet. So my Theory *still stands!!!*

SOCRATES: Well, it's rather hard to prove a negative: "absence of evidence isn't evidence of absence", and all that! But perhaps it's not altogether *impossible.* However, I think we may be talking at cross purposes unless we can agree beforehand to a *criterion* for disproof – or "falsification" – of your Theory. Could you enunciate one?

EINSTEIN: *(Thinking hard and long).* Well, I would say my Theory would be disproved if you can provide evidence of something *in* a gravitational field that *isn't* curved … No, wait: something that *is* curved in the *absence* of a gravitational field *could* be *straight* in the *presence* of one. So no: scratch that. Let me try again. *(After a pause).* My Theory would be disproved if you can provide evidence for *something* – even if it be a merely *imaginary* or *theoretical* entity – that *isn't* curved in the *absence* of a gravitational field, which would also *not* be curved in the *presence* of one: so that that such a thing *remains* perfectly straight in the *absence* as *well* as in the *presence* of a gravitational field.

SOCRATES: You agree that the "something" you speak of need only be a *theoretical* or *imaginary* entity, such as a straight geometric line? Since, of course, there simply *isn't* any way, given our current state of technology, for us to test your claim *experimentally?*

EINSTEIN: Yes. I agree.

SOCRATES: For, as you just pointed out, we just don't *have* the technology to perform *actual* tests of your Theory, at least not yet – that is, an *experimental* test to either confirm *or* refute your theory simply *can't* be performed? At least, as you said, not with our *present* technology.

EINSTEIN: Yes, that's what I said. So then you'd admit that my Theory still *stands* … right?

SOCRATES: Well, I think it might be more appropriate to call it a "hypothesis" rather than a "theory", since there is, by your own admission, no *physical* evidence either for *or* against it; and from all our discussions so far, I think you will admit that all the *thought-experimental* arguments you have set forth in favour of it till now seem to be – shall we say – less than iron-clad: you have replied to *all* my counter-arguments by saying that you can't think of any rebuttals to them *yet*, and promise to come up with some rebuttals in *future* only. *(Pause).* But what if I could point out a *logical* contradiction within your Theory? Would you admit that your Theory would not survive *such* a test – a test of a "*P*otential *Lo*gical *F*alsifier", or *"FLOP"* to put it in terminology coined by the Cartesian philosopher Rocco Vittorio Macrì and his good friend, Prof. Umberto Bartocci of the University of Perugia?

EINSTEIN: *(Thinking a bit)* Why is it called a *"FLOP"* and not a *"PLOF"?*

SOCRATES: Well, these authors write in Italian, and their term for it in their original Italian papers is "*F*alsificatore *Lo*gico *P*otenziale" – hence *"FLOP".*

EINSTEIN: Ah, Italian! Lovely language. Of course you know that when I was a child my family had lived in Milan, and then in Pavia. It was during my time in Italy that I had written a short essay entitled "On the Investigation of the State of the Ether in a Magnetic Field." But the schooling there was awful. As a youth I hated my school's regimented teaching methods, and thought that the spirit of learning and creativity were destroyed by strict rote learning. Mind you, I got the same kind of rotten schooling later, when my family moved to Munich.

SOCRATES: Indeed you are quite right: such schooling is an abomination, and ought to be banned by law. But to return to our discussion: would you admit that if a "Potential Logical Falsifier" or *FLOP* – for example, a contradiction, or indeed any other logical flaw or fallacy – were to be revealed in your Theory, it would utterly collapse?

EINSTEIN: Yes – *provided* it's a *genuine* logical flaw, and not merely an *apparent* one!

SOCRATES: Shall we also agree upon a *criterion* for detecting *whether* the flaw is genuine or not?

EINSTEIN: Yes. If I may propose this criterion: a logical flaw or fallacy *is* genuine if its apparent nature *cannot* be pointed out. Would such a criterion satisfy you? I am assuming it would.

SOCRATES: Yes, it does. In fact, I can think of no better criterion … at least in *practice.* So shall we agree that a *logical* flaw or fallacy in your Theory would prove it false? Think about it *very* carefully now, because I wouldn't like you to backtrack if I found such thing.

EINSTEIN: *(Thinking very carefully and at great length).* Yes, all right: I agree.

SOCRATES: *(Shake!)*

EINSTEIN: *(Shake.)*

SOCRATES: Shall we also agree upon some definitions?

EINSTEIN: By all means.

SOCRATES: Shall we agree, then, that straight lines *cannot* be curved?

EINSTEIN: Why?

SOCRATES: Well, what sense would it make to say of a line that it is curved, if *every* line is curved?

EINSTEIN: Can't they be curved in different *degrees?*

SOCRATES: Yes; but then would you not agree that a line which is *not* curved to *any* degree, *is* actually *straight?*

EINSTEIN: Yes I would – *if* such a line existed. But what if it doesn't.

SOCRATES: Well, we have yet to *demonstrate* that it doesn't exist, and indeed *can't* exist – don't we.

EINSTEIN: Yes indeed; but I don't think *that* would be too hard for me to demonstrate to you.

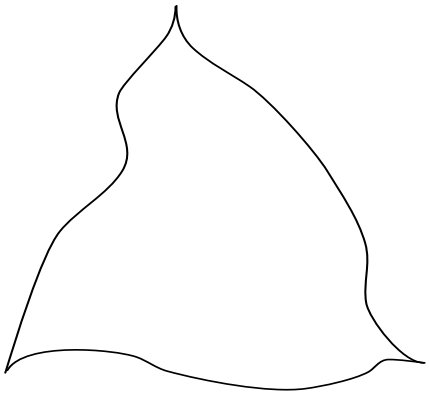
SOCRATES: We shall see. But let us finish coming to our agreements, shall we, before we come to such a demonstration?

EINSTEIN: Of course.

SOCRATES: Shall we also agree that geometrical figures such as "triangles", "squares", "rectangles", "circles", *etc*. can't even *exist* in the total *absence* of straight lines?

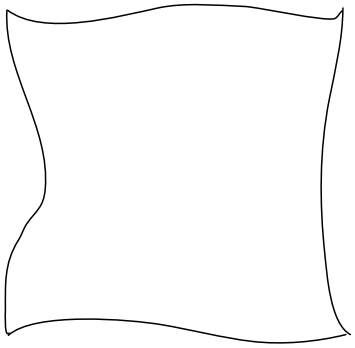
EINSTEIN: Come again?

SOCRATES: Well, let me put it to you another way. Is a three-sided figure possessing three angles, but whose sides are *not* straight, be *legitimately* called a "triangle"? For instance, can a figure like this *(draws in the sand with a stick)* be legitimately called a "triangle"?



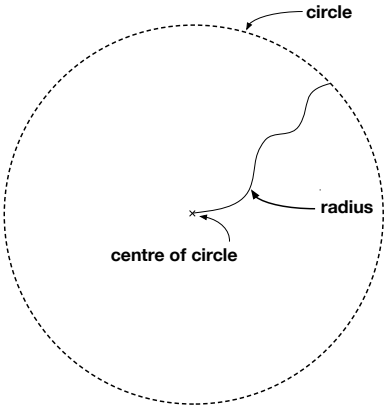
EINSTEIN: Of course not. That would be absurd.

SOCRATES: And likewise, a four-sided figure like this *(again draws in the sand)* can't legitimately be called a "square", or even a "rectangle" – agreed?



EINSTEIN: No, it can't: again, I do agree.

SOCRATES: And doesn't the *radius* of a circle have to be absolutely *straight*? Does it make any sense to have a circle, and call a line like this *(again draws in the sand)* its "radius"?



EINSTEIN: No, you're right; it makes no sense at all to do that.

SOCRATES: Indeed, doesn't the circumference of a circle *have* to be equidistant from its centre? And isn't distance measured with *straight* measuring rods?

EINSTEIN: Of course. The very *definition* of a "circle" is "a line equidistant from a single point".

SOCRATES: So *none* of the figures of geometry could even *exist* if no *straight* lines existed: would you not agree?

EINSTEIN: Yes of course; I admit *that*. But you're talking about figures in *Euclidean* geometry. However, the geometry *I* am proposing in *my* Theories is *non*-Euclidean, and indeed in General Relativity I am proposing a geometry of *curved* space, so it doesn't matter!

SOCRATES: Yes, let's discuss that. Would you agree for the two of us to construct a geometry of curved spaces "from scratch", as it were, so as to enable us to analyze its properties thoroughly?

EINSTEIN: Sure, I'd be happy to give it a try. I don't know if we can *succeed*, mind you, but I'm willing to give it a *try.*

SOCRATES: Well, would you agree that the simplest element of a curved space is a curved *line?*

EINSTEIN: No; the simplest element of a curved space – like of *any* space – is a *point,* in my opinion.

SOCRATES: Yes. True. Sorry: I misspoke. Let me re-phrase: isn't the simplest *curved* element of a curved space, a curved *line?*

EINSTEIN: Yes, I think we may safely say it is.

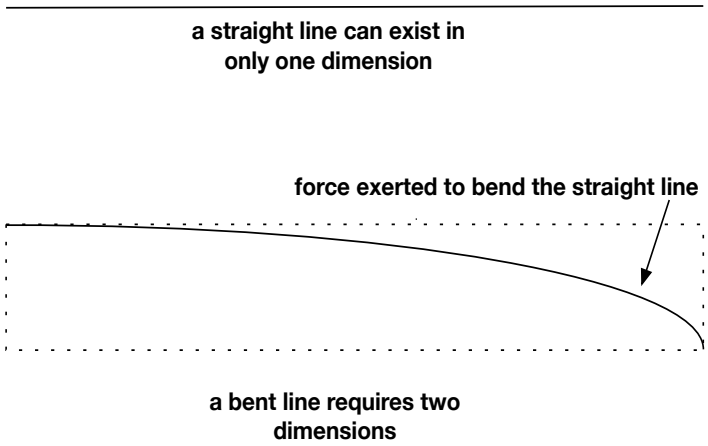
SOCRATES: Well, then. Do you also agree that although a *straight* line can exist in only *one* dimension, a *curved* line requires at least *two?*

EINSTEIN: Come again?

SOCRATES: Well, let me put it this way. Do you agree that in *order* to turn a straight line into a curved one, it has to be bent – or curved – *at an angle* to itself? Or in other words, bent in a direction which is *not* the direction in which the *original* straight line *itself* points?

EINSTEIN: *(Thinking about it).* Yes, I suppose so. I can, at all events, imagine a straight wire in my hands, and if I want to bend it, I must exert a force on it at *some angle* to its own direction. And I imagine the wire getting progressively thinner and thinner, so that it approaches the status of a true geometric line, that is, something having no thickness at all … *(Thinking hard)* Yes, when I imagine all this, I see that what you claim must be true.

SOCRATES: So you do admit that although a straight line itself can exist in only *one* dimension, a *bent* line requires at least *two,* because this *other* direction, in which one must "exert a force", as it were, to bend the straight line, is *not* the same direction as that to which the original straight line points, like this … or am I not making myself understood? What I mean is, do we not need something like this figure *(draws in the sand again)?*

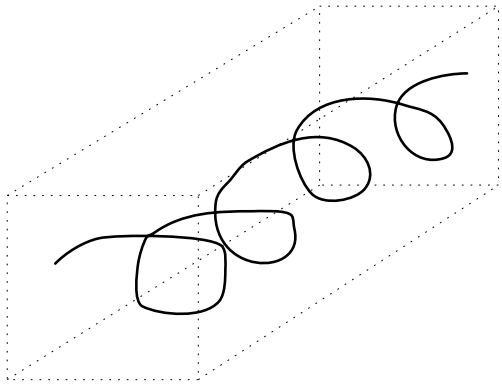


EINSTEIN: Yes. I agree. And yes, you *are* making yourself understood, thank you very much.

SOCRATES: So, to recapitulate: a *straight* line can exist in only *one* dimension, but for a *curved* line to exist, at least *two* dimensions must exist?

EINSTEIN: *(Thinking again)* Yes, I can see how that would be a necessity.

SOCRATES: In fact, would you agree that for a curved line to exist in the approximate form of, say, *a corkscrew*, a space of at least *three* dimensions must exist? That such a corkscrew-shaped line *cannot* exist in a space possessing only a *single* dimension – a single dimension which would be *defined*, in fact, by a *straight* line? *(Drawing in the sand):*



a corksrew-shaped line needs at least three dimensions to exist in

EINSTEIN: Yes. *(Concentrating again)* Yes, I see how this would have to be the case. Agreed.

SOCRATES: Good. Now extending this mode of thinking: if we were to *move* a curved line at an angle to itself, we'd describe a curved *surface,* would we not?

EINSTEIN: Yes, we would indeed.

SOCRATES: But such a curved *surface* must exist in at least *three* dimensions – right?

EINSTEIN: Now you've lost me.

SOCRATES: Well, let's consider the surface of a sphere, or of an ovoid – an egg-shaped object. That's a curved surface, wouldn't you agree?

EINSTEIN: Yes indeed it is!

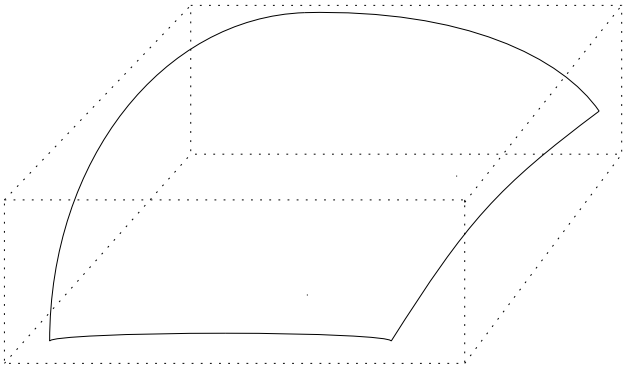
SOCRATES: But the *surface* of a sphere couldn't exist if the *sphere itself* didn't exist: am I not right? And likewise, the *surface* of an ovoid couldn't exist if the *ovoid itself* didn't exist. Right?

EINSTEIN: Of *course* not.

SOCRATES: And a *sphere* or an *ovoid* couldn't exist in only *two* dimensions: right?

EINSTEIN: No, of course not.

SOCRATES: And neither could a *part* of a sphere, nor *part* of an ovoid, or indeed *any* curved surface: right? Like this curved surface *(drawing):* it needs *three* dimensions to exist in, right?



a curved surface requires three dimensions to exist in

EINSTEIN: Right.

SOCRATES: Now don't we see a trend developing here?

EINSTEIN: Huh?

SOCRATES: For a curved *line* to exist we need at least *two* dimensions, and for a curved *surface* to exist, we need *three;* so how many dimensions would we need for a curved *volume* to exist? Would we not need at least *four?*

EINSTEIN: Why?

SOCRATES: Well, can *you* explain to me how a curved *volume* can exist in only *three* dimensions?

EINSTEIN: *(Thinking hard)* I can't. *(Brightening up)* But I can't explain how it can exist in *four* dimensions either! In fact, I can't even *imagine* four – or more – dimensions, although mathematicians assure me – rather vehemently – that they *do* exist.

SOCRATES: But do these mathematicians claim that four-dimensional objects *really* exist in a *physical* sense – that is, in the *physical* Universe? For example, can they actually *demonstrate* – that is to say, actually *show* us – a four-dimensional *physical* object?

EINSTEIN: Well, yes; they tell us that a *tesseract* – a four-dimensional analogue to a cube – has a three-dimensional representation that looks like a cube inside a cube with spokes connecting the corners of the two cubes together. It's all there on the *Wikipedia.*

SOCRATES: Indeed it is; but have you, or anyone else, ever *seen* a four-dimensional *physical* object like a *real* tesseract, and not merely a three-dimensional *representation* of one?

EINSTEIN: No, I confess I haven't; and I can't think of anyone else who has, either. Perhaps it isn't even *possible* to see it. However, very expert mathematicians assure me that according to my Theory, our entire *Universe* is a four-dimensional object … and we can see *that*.

SOCRATES: But we can't really *test* whether the Universe *is* what these mathematicians claim, can we now? Or, at least, can *you* devise a *foolproof experimental test* to check *definitively* whether their claim that the Universe is a four-dimensional object is *true* or not?

EINSTEIN: *(Thinking)* No, I admit I can't.

SOCRATES: And you don't have any *argument* to support such a claim yourself, do you?

EINSTEIN: Well, if we imagine an elevator being accelerated upwards at one "g" … oh, never mind. No, I don't have any such argument; not any more. You've poked holes in all my previous arguments in that regard: holes to which I don't *yet* have any rebuttals. *Yet*, mind you!

SOCRATES: So you do admit that at least as thing stand at *present,* we have *absolutely no physical evidence whatsoever* that four-dimensional objects can exist in the *physical* Universe? And we have no way to conduct any experimental test which would *confirm without any possibility of error* that the physical Universe *itself* is a four dimensional object?

EINSTEIN: I – reluctantly – admit that, yes.

SOCRATES: And you also admit that any claim that's not *experimentally testable* cannot be *scientific:* do you not?

EINSTEIN: Again, yes, I admit that: and this time, not reluctantly at all.

SOCRATES: So you would admit, would you not, that any claim made in the total absence of *any evidence whatsoever* – and one, moreover, which is not even *experimentally testable* – should not be given *any* credence from a *scientific* point of view?

EINSTEIN: True; but what about *mathematical* proofs for four – or more – dimensions, and of three-dimensional *curved* spaces, and so on and so forth?

SOCRATES: Oh, I am sure there are mathematical *formulae* in that regard which are self-consistent – that is, contain no *internal* inconsistencies; but since we are speaking of a theory of *physics* here, well then, in the absence of hard *physical* evidence for such mathematical entities, can we *really* accept such entities as being part of *physics* – or indeed, of *any* of the sciences of the *physical world?*

EINSTEIN: The way you have argued, I confess I am hard put to justify their acceptance in *physics.* Nevertheless I challenge you to explain how my Theory of Relativity can be *false*, given the *observable* fact that it has millions of experimental confirmations every year … ?

SOCRATES: Well, I am not at this juncture discussing your *entire* Theory of Relativity, you understand; only your "elevator" thought-experiment, and the notion of a "curved three-dimensional space" which it claims to support. I am not sure that *this* part of your Relativity Theory has "millions of confirmations every year" – indeed, I doubt that it has *any* experimental confirmation at all, since I doubt that any physical object "curved" in three-dimensional space has ever been actually *observed …* or for that matter, even *deduced* in a foolproof logical manner from actual observations. But even if such things *were* so observed or so deduced, all the same you do understand, I hope, that such observations or deductions would not amount to a confirmation of the *truth* of your Theory …?

EINSTEIN: Why in heaven's name not?

SOCRATES: Well, it would be the result of a simple logical error, which even Galileo had made – as explained by Prof. Owen Gingerich, Professor Emeritus of Astronomy and History of Science at Harvard University, in an article called "The Galileo Affair" in *Scientific American*. Galileo argued that the solar system is heliocentric by using the following fallacious reasoning: *(1)* If the solar system were heliocentric, Venus would exhibit phases; *(2)* Venus exhibits phases; *(3)* Therefore the solar system must be heliocentric. This is such a simple error that, as the Cartesian philosopher Rocco Vittorio Macrì points out, even medieval logic was able to discern it. It's an example of an erroneous form of *modus ponens*, which goes thus: **[if *p* were true, then *q* would be true] *implies that* [*q* is true, therefore *p* is true].** As Macrì points out, nothing could be more wrong! The *correct* form of reasoning in this regard, called in medieval terms *modus tollens,* is as follows: **[if *p* were true, then *q* would be true] *implies that* ['*not q*' is true, therefore '*not p*' is true]** … or, a little less formally, **[if *p* were true, then *q* would be true] *implies that* [*q* is *not* true, therefore *p* is *not* true].** Or, to put it in even simpler terms, as our good friend Popper puts it, it's not the *truth* of a theory that can *ever* be established by observations, but only its *falsehood.* For example, he says, no number of confirming observations can confirm the *truth* of a universal generalization, such as "All swans are white"; and yet it is logically possible to *refute* or *disprove* it – to "falsify" it – if even a *single* black swan is observed.

EINSTEIN: Yes, Popper and I had a long talk about this subject. I like the fellow; he's from Vienna *(the pastries there are amazing … ! Did you ever try the Sachertorte at Hotel Sacher? Invented for Prince Metternich himself, no less. The most famous cake in the world since 1832. The original recipe remains a well-kept secret of their hotel. Pardon me for drooling).* And yes, I agree with your conclusion too, regarding Popper's argument.

SOCRATES: So you do agree that even a totally *false*, and even *unscientific*, theory can provide accurate predictions, and be confirmed millions of times?

EINSTEIN: Yes, I think so – even though it seems *utterly* contrary to common sense.

SOCRATES: Well, consider the Mayans. Their incredibly accurate astronomical calculations and sophisticated mathematics were steeped in religion and omens, their priests discerning the very will of the gods behind the occurrences of astronomical phenomena. The *theories* behind these amazingly accurate predictions were no better than astrology – that is to say, they were utterly *unscientific;* and yet their *predictions* were *highly* accurate.

EINSTEIN: When you explain it like this, yes, I get it. Theories that are completely "bunkum" – as Americans call them – can nevertheless be predictive: even highly so. Even though it seems utterly counterintuitive to say so, it is nevertheless quite true.

SOCRATES: My point exactly. So your theory of curved three-dimensional space is, as far as I can tell, utterly *unscientific*, given that, by your own admission, there is *no* evidence for it, and moreover, it can't even be *tested;* you admit that? Thus, the fact that it gives accurate predictions can't have *any* bearing on its scientificity, any more than the fact that the Mayan theories of astrology gave highly accurate predictions!

EINSTEIN: Most reluctantly I must agree with you. *Most* reluctantly. Logically I have no rebuttal. Yet I still claim that you haven't yet *disproved* – what Popper would call "falsified" – my Theory.

SOCRATES: Admittedly not *yet*. But shall we continue? I recognize that it's getting to be a very long conversation, but I'm game if you are.

EINSTEIN: By all means; I'm game. As I have said about myself, "It's not that I'm smart, it's just that I stay with problems longer." And, my dear Socrates, you too seem to do the same.

SOCRATES: Yes, I'm not too smart either. Indeed I think I'm one of the dumbest people alive – or more correctly, dead *or* alive! I believe the "*Xxx* For Dummies" books were written just for me.

EINSTEIN: *(Smiling)* Well, that makes two of us.

SOCRATES: "Dumb & dumberer", eh?

EINSTEIN: Yep! *(Fist bump).* But we won't specify who is which – I mean, we won't specify which of us is the dumb one and which the "dumberer". Let's leave *that* decision up to posterity!

SOCRATES: *(Laughing aloud)* Yes, let's do that! But to return to our discussion: would you agree that at every point on a *curved* line there must be a *tangent?* Or at least the *possibility* of one?

EINSTEIN: Yes, I think I can agree to this … *(thinking)* mmm. Yes.

SOCRATES: And that *any* tangent *must* be a straight line?

EINSTEIN: Not necessarily. "Tangent" simply means "touching". Or more correctly, the tangent to a curve at a given point is the line that "just touches" the curve at that point. Nothing is said about that line needing to be *straight!*

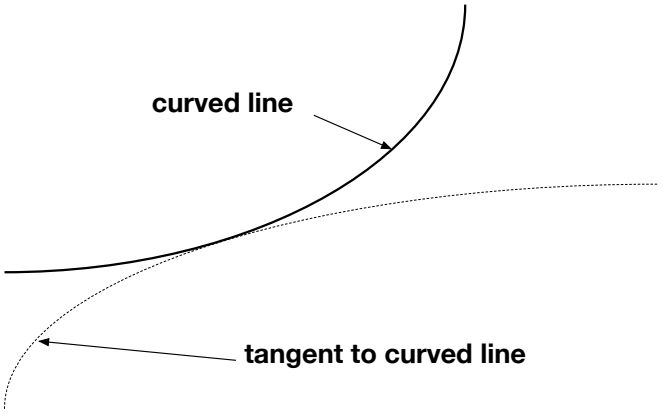
SOCRATES: It's not *said*, I admit that – at least not *always;* nevertheless, *sometimes* it *is* actually said, too – check out the *Wikipedia* in that regard. And in any case, even when it's not explicitly spelled out, isn't it always at least heavily *implied* that a tangent *must* be a straight line?

EINSTEIN: *"Heavily"* implied?

SOCRATES: Well, *strongly* implied, then … although I do understand that these days, "heavily implied" is also acceptable terminology.

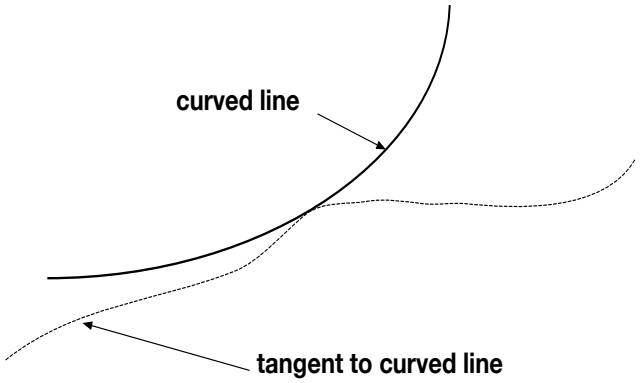
EINSTEIN: How is it implied at all?

SOCRATES: Well, isn't it implied from all the drawings explaining the concept of "tangent"? Have you *ever* seen "tangent" explained like this: *(draws in the sand)?*



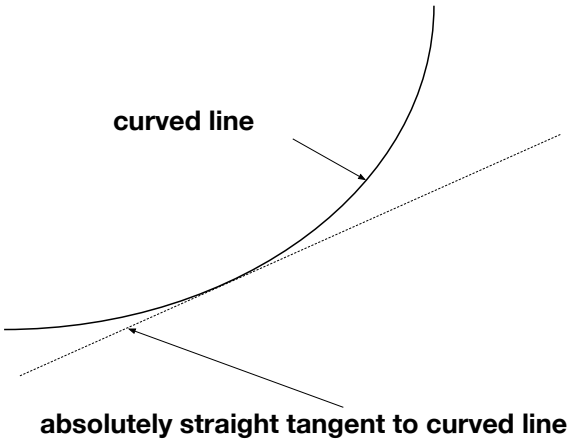
EINSTEIN: Er. No, I confess I haven't.

SOCRATES: Or like this: *(again draws in the sand)?*



EINSTEIN: No. No, I haven't. Okay. I agree; you're right.

SOCRATES: In fact, aren't tangents always illustrated thus, implying that tangents *must* be straight? *(drawing in the sand again):*



EINSTEIN: Yes. I agree.

SOCRATES: And are we also agreed that to an absolutely *straight* line there *is* no tangent, and can never even *be* one? *Ever?* Because even if we hypothesize that there *is* one, it would touch the straight line *all* along the latter's length, and not just at *one* single point … and therefore would not *be* a tangent at all?

EINSTEIN: *(After thinking for a long time)* Yes, we are. To an absolutely *straight* line there can *be* no tangent. *Ever.* True enough.

SOCRATES: So it's *not* possible for a tangent to be anything *but* a truly straight line … do you agree?

EINSTEIN: All right; I guess I do have to agree to that. But what if mathematicians can *prove* that tangent's *don't* have to be straight lines?

SOCRATES: Well, I'd have two counter-arguments against that. The first is that even if they do have such a proof, that *by itself* would not be sufficient to establish that their proof applies to the *physical* Universe, would it now. Wouldn't they also need to have *another* proof, or at the very least a *demonstration,* namely that their proof about tangents not needing to be straight lines actually *applies* to the Universe we know (and love)? Do you *know* that they have *such* a proof or demonstration?

EINSTEIN: I confess I don't.

SOCRATES: So in the *absence* of any such proof or demonstration, what they claim would not be applicable to *your Theory:* right?

EINSTEIN: Yes.

SOCRATES: And my second counter-argument is, that even if they do have a proof that tangents could be curved lines, would that not also mean, *ipso fatso*, that there could be *straight* lines that are tangents *to* those curved "tangents"?

EINSTEIN: *"Ipso fatso"?*

SOCRATES: Pardon me: I got into the habit of using that silly phrase after watching Archie Bunker in the hilarious TV show "All in the Family". I meant to say *ipso facto*. Would that not also mean, *ipso facto*, that there could be straight lines that are tangents *to* those curved tangents? And if so, would that not contradict our agreement that to a straight line itself – that is, to a tangent itself – there can *be* no tangent?

EINSTEIN: Yes, I suppose so.

SOCRATES: Thus, even in a space that is curved *everywhere* – and as a result, would *appear* to contain no straight lines – even in *such* a space, at *every* point along *every* curved line there must exist at least the *possibility* of a tangent to that curved line?

EINSTEIN: Yes …

SOCRATES: And that every tangent *must* be an absolutely *straight* line? We did agree to *that* earlier, didn't we?

EINSTEIN: Yes, I confess we did.

SOCRATES: So then, even if a space is curved – and, therefore, all the lines in it are also curved – even so there must exist at least the *possibility* of *absolutely, really, actually, perfectly* straight lines? Indeed, a *limitless number* of absolutely straight lines … namely, all the limitless number of *tangents* at all the points on all the curved lines?

EINSTEIN: *(Thinking hard).* Yes. I do have to admit it. Yes.

SOCRATES: Just to be clear that we *are* in agreement. You *do* agree, don't you, that even though on – say – the surface of a sphere, or on a part thereof, there are are no *absolutely* straight lines whatsoever, nevertheless at *every* point along *every* line on the surface of a sphere, there can exist a *tangent,* which *is* – and *must* be – an *absolutely* straight line? Admittedly these straight lines would not lie along the *surface* of the sphere, but *outside* the sphere; but that's not to say they don't, or can't, *exist at all.* Right?

EINSTEIN: Yes, I agree.

SOCRATES: And if the surface of a sphere – or part thereof – were somehow to be "flattened out" (and we won't specify exactly *how* we'd flatten it out, and in fact we shall consider it irrelevant), so that the curved lines which *were* on it, now get straightened out also, that *per se* would not affect *any* of the *actually, really, absolutely, perfectly, totally* straight lines which were *tangents* to the curved lines which used to exist on its surface before that surface was "flattened out" – am I not right?

EINSTEIN: *(Thinking hard for a long while)* Yes, I agree.

SOCRATES: So have I not, in that case, met your criterion for a disproof – or a refutation – of your Theory's claim that space can be curved by gravity?

EINSTEIN: *Huh?* How so?

SOCRATES: Well, your Theory is that space is curved in the presence of a gravitational field, isn't it?

EINSTEIN: Yes, of course.

SOCRATES: And we agreed, did we not, that your Theory would be disproved – or "falsified", to use Popper's terminology – if I can provide evidence for something, even something entirely imaginary like a straight geometric line, that *isn't* curved in the *absence* of a gravitational field, which would also *not* be curved in the *presence* of one? So that that such a thing would *remain* perfectly and absolutely *straight* in the *absence* as *well* as in the *presence* of a gravitational field? In fact, wasn't that your *own* criteria for disproof of your Theory?

EINSTEIN: Yes; so it was.

SOCRATES: We even shook on it, if I remember.

EINSTEIN: Yes we did … . *hmm.* Yes. Yes, we did. I remember that too.

SOCRATES: *Indeed* we did. So have I not now established that *tangents* to *any* curved lines, whether in a flat space *or* a curved one, must *remain* straight whether space *itself* is curved or not? At least in the *physical* Universe … whatever may be the case in *pure* mathematics; that is to say, mathematics that have *not* been shown to apply to the *physical* Universe.

EINSTEIN: *(Thinking very, very hard).* Yes, you do seem to have established it; I do admit that … *(trailing off).*

SOCRATES: And since you claim that space is curved in the *presence* of a gravitational field, while in the *absence* of one, space is totally *flat,* then these tangents would remain *absolutely,*

actually, really, perfectly straight in the *absence* as *well* as in the *presence* of a gravitational field – would you admit that? Remember, you are under oath! *(Smiles).*

EINSTEIN: *(In a whisper)* Er … yes.

SOCRATES: Was that a "Yes"?

EINSTEIN: Yes. *(Ahem)* Yes.

SOCRATES: And can you discern any flaw in my logic?

EINSTEIN: *I* certainly can't discern one – at least, not *yet*. But that doesn't mean I won't think up a rebuttal to your argument, I *promise* I will!

SOCRATES: I look forward to discussing the matter further when you do!

EINSTEIN: *(Thinking about it)* What I were to *repudiate* my earlier agreement with you, and claim that the criterion for falsifiability I gave earlier isn't really a good *enough* criterion?

SOCRATES: Well, I would say you are reneging on a solemn agreement, then! *(Smiles).*

EINSTEIN: Aren't scientists allowed to change their minds, then?

SOCRATES: Indeed they are. I was just joking. By all means change your mind.

EINSTEIN: So. I *have* changed my mind: the criterion I earlier gave for disproof of my Theory *isn't* really a valid one.

SOCRATES: Then can you give me any *other* criterion for disproof of your Theory? A *valid* one?

EINSTEIN: No, I can't … and I shan't.

SOCRATES: Then by Popper's argument, isn't your theory unscientific?

EINSTEIN: *(Thinking)* Yes. *(Thinking some more).* Okay, then I shall claim that the only such criterion must be an *experimentally testable* criterion, not a merely *theoretical* one.

SOCRATES: And exactly how would an experiment be devised, then, to test your Theory – given that you yourself claim our technology to be incapable of testing your Theory *experimentally?*

EINSTEIN: Since such a test *can't* be devised, I claim that my Theory still stands!

SOCRATES: *(Smiling)* Well, before I tackle *this* argument, shall we check to see just *how much* of your Theory still stands, by *summarizing* and *stating again* the *main points* of our discussion?

EINSTEIN: *(Reluctantly)* Well … all right then.

SOCRATES: In the first place, we did establish, didn't we, that your claimed "equality of gravitational and inertial mass" does not, *strictly speaking*, exist in *the physical Universe?* Or if it does at all, it exists only for infinitesimally small volumes of space only? And that for all larger volumes – even volumes like those of a room or an elevator – there is only a strong *similarity* between the two, but not actual *equivalence*, strictly speaking?

EINSTEIN: *Strictly speaking.* Yes, but only *strictly speaking.* Only if we're "splitting hairs", as it were.

SOCRATES: Indeed. However, if you remember, we also agreed that "splitting hairs" was *necessary* in order to check your Theory, since – by your own admission – at our present stage of technology we just don't have sufficiently accurate instruments to *experimentally* test your Theory, and that your Theory discusses very *tiny* amounts of curvature of space, at least in normal circumstances? Did we not, as a consequence, *agree* to "splitting hairs"?

EINSTEIN: Yes, we did. Yes.

SOCRATES: But then, *strictly speaking,* and if we *are* to split hairs – which as you admit is necessary, and eminently valid, in the context of your thought-experiment – you *haven't* established, have you, that *gravity* can bend space, even if *acceleration* could do so?

EINSTEIN: *(Reluctantly)* No, I haven't. I haven't *established* it. No.

SOCRATES: Now coming to the issue of acceleration by itself: you claimed that acceleration could bend a beam of light, not merely *apparently* but also *in reality,* because according to you – and also according to the empiricist philosophers – appearance *is* reality: right?

EINSTEIN: Indeed.

SOCRATES: But later you admitted that you don't hold the empiricist view to be a *hard and fast rule*, and that sometimes appearances *are* mere appearances, and *not* reality – right?

EINSTEIN: Right.

SOCRATES: So, and I'm repeating just to be clear: you *do* agree that sometimes appearances *can* be mere appearances, and *not* reality at all?

EINSTEIN: Yes: I just said that, didn't I.

SOCRATES: And when I introduced another observer *outside* the elevator, to whom – as per your own admission – all trajectories of photons would appear perfectly *straight*, you claimed that reality *itself* could be different for these two different observers: am I not correct?

EINSTEIN: I did. Yes, you're right.

SOCRATES: But then you changed your mind about that, didn't you, because postulating multiple *real* "realities" would result in a manifest contradiction, and wouldn't even fit your Theory?

EINSTEIN: I did change my mind. Yes. In fact, I admit that my Theory is about *the* – that is to say, the *one* and *only* – reality, for I claim that space is bent in *all* gravitational fields; and bent *in actual reality …* and not that it is bent in *some* realities or in *some* gravitational fields, while it is *not* bent in *other* realities or in *other* gravitational fields.

SOCRATES: Right. And you also agreed that if we were to imagine the floor and ceiling of our elevator made out of some sort of mesh, so that the space inside the elevator were the *same* as the space outside it, then that *single* space would be "flat" for both the hypothetical man *inside* the elevator and the hypothetical woman *outside* it. Am I not right?

EINSTEIN: You are right, yes: I reluctantly agree.

SOCRATES: So you *agree* that your Theory *is* about just *one* reality, namely that of the physical Universe, and not multiple realities: or in other words, that reality is *not* relative?

EINSTEIN: *(Reluctantly)* Yes.

SOCRATES: We also agreed that *trajectories* of such things as pistol bullets would appear *curved* to the man inside the elevator, but perfectly *straight* to the woman outside the elevator: did we not?

EINSTEIN: We did.

SOCRATES: Then we also agreed that if, before setting the elevator in acceleration, an *absolutely rigid and straight ruler* were stretched from the laser pointer to the opposite wall of the elevator, the ruler would *remain* straight no matter who was observing it, both before *and* after the elevator were accelerated? And thus your thought-experiment would collapse; for in a *bent* space, a ruler which *was* perfectly straight and rigid in *unbent* space, ought to become bent *itself* as well?

EINSTEIN: Well, that's not *exactly* the case. We agreed that *if* such a perfectly straight and rigid ruler – one which *was* perfectly straight before the elevator were accelerated – appears straight even when the elevator is accelerating, *then* my though-experiment *would* collapse; but after thinking about it, I said that I could not be *certain* that such a ruler *would* in fact appear absolutely straight in the accelerating elevator. Indeed, I claimed later, after due reflection, that it would be *bent* in an accelerating elevator in exactly the same manner and to the same degree as the light beam becomes bent.

SOCRATES: You did indeed. But then I pointed out that if that were the case, the spot where the light shone on the wall of the elevator opposite the laser pointer would *not* be slightly below the spot on the wall where the laser pointer itself was affixed, didn't I? Or in other words, that one of the very assumptions of your thought experiment would not hold, so that your thought-experiment would amount to a *reductio ad absurdum,* thereby refuting itself?

EINSTEIN: Yes, true; but then I said, "Let's follow this trend of thought to the end", and you agreed.

SOCRATES: I did indeed. But you did agree that *if* the ruler were to *remain* straight, your Theory would collapse: am I right?

EINSTEIN: Yes. *If*.

SOCRATES: And then you added that the floor of the elevator would *also* be bent in the same manner and to the same degree as the light beam, and *that* would account for it.

EINSTEIN: Yes, I did say that, didn't I. Thanks for reminding me.

SOCRATES: But then I pointed out that your assuming the floor of the elevator to be curved in this manner would be a logical *fallacy,* since it would be assuming that which is yet to be demonstrated.

EINSTEIN: Remind me why.

SOCRATES: Well your thought-experiment is designed to show – or in other words, to *demonstrate* – that space *can be* bent due to acceleration; and in *such* a demonstration, you can't validly

assume that space is bent due to acceleration, for that is precisely what you are *trying* to demonstrate *using* the thought-experiment! At least, not if you want to be rational.

EINSTEIN: Ah. Yes. I remember now. Yes: in a thought-experiment designed to *show* that space *can* be bent, it can't logically be assumed *ahead of time* that space *is* bent. I agree.

SOCRATES: So you agree that *logically* speaking, the floor of the elevator *can't* be assumed to be bent in your thought-experiment?

EINSTEIN: *(Reluctantly again)* Yes.

SOCRATES: So then: if I may continue?

EINSTEIN: By all means.

SOCRATES: You claimed also that there are *mathematical* proofs that space is bent.

EINSTEIN: I did indeed, didn't I.

SOCRATES: Yes you did. And I countered this claim by saying that mathematicians may well have mathematical proofs of theorems which *assume ahead of time* that space is curved; but they don't seem to have *any* proof, mathematical or otherwise, or even a mere demonstration, that space – the space of the *physical Universe – can* be curved. At least you weren't able to tell me that *you* knew of such a proof or demonstration; and the General Theory of Relativity being *your* Theory, then I claimed that in its absence there is no *reason* to believe that *your* Theory applies to *the physics of the known Universe.*

EINSTEIN: You did say something like that, I do admit it.

SOCRATES: So then, have I not clearly shown you that your Theory *hasn't* been demonstrated to apply to the *physical* Universe? May I remind you again that you are under oath.

EINSTEIN: *(Very, very reluctantly)* Yes, I suppose so. But still … I don't know. I'm not sure you're right, but I can't come up with a rebuttal right at this moment. But I shall work at it, I promise you! I am *very* persistent.

SOCRATES: I welcome every chance to learn from you in future, I assure you, my dear Professor Einstein. But let's continue our recapitulation. If I remember aright, you then claimed that you need not come up with a *proof* to establish your theory, but only *evidence;* because according to most modern philosophers of science, including our good friend Popper, there *are* no proofs in science.

EINSTEIN: I did, didn't I. Yes I did. Indeed. Good point, if I say so myself.

SOCRATES: And you wished to point out the Eddington expedition as one source of such evidence*,* to show that space can be curved by gravity.

EINSTEIN: So I did.

SOCRATES: Not by *acceleration*, mind you, but by *gravity.*

EINSTEIN: Yes, that's the *goal* of my thought-experiment, isn't it. The "acceleration" part is just an *intermediate* argument, to *get* to the goal.

SOCRATES: But the thought-experiment itself tries to establish *first* that space is bent due to *acceleration,* does it not?

EINSTEIN: Indeed it does. As I said, it's an *intermediate* argument.

SOCRATES: And it would only be able to conclude that space is bent due to gravity if an exact *equivalence* between gravity and acceleration could be established – something you failed to do, right?

EINSTEIN: *(Cheering up)* Not entirely *failed*, you understand. I came pretty darn close; I just didn't establish it *strictly speaking*.

SOCRATES: Well, even if you *had* established it *perfectly,* Eddington's expedition – even if it had been conducted absolutely thoroughly, a matter regarding which doubts have been expressed – could only have established that the *trajectory of light* could be curved by gravity; right? To which I replied that no one has ever doubted that *trajectories* of things that can be *attracted* by gravity can be *curved* by gravity, but that this fact *per se* doesn't establish that *space* is bent – or curved – by gravity. Right?

EINSTEIN: Right. On both counts.

SOCRATES: And I also showed – and you yourself agreed – that light *is* attracted by gravity, for, as you yourself pointed out, if it weren't, black holes, for example, wouldn't *be* black: right?

EINSTEIN: Right.

SOCRATES: So you do agree that you *haven't* yet demonstrated that space *can* be bent – or curved – by gravity?

EINSTEIN: *(Reluctantly)* Yes.

SOCRATES: Then at this juncture you tried to say that a trajectory can be curved *and* straight simultaneously, by arguing that the shortest lines between any two points on a curved surface can themselves be curved if they run *along* the curved surface, so that if we define "straight lines" to mean the shortest lines between any two points, those lines would be curved *and* straight. Right?

EINSTEIN: Right. I did. The mathematics of curved spaces proves that.

SOCRATES: But then I pointed out that such lines aren't *really* the absolutely *shortest* possible lines between those points, because *really* straight lines between those *same* two points – lines which *don't* run *along* the curved surface – would be even *shorter,* didn't I?

EINSTEIN: You did. Yes.

SOCRATES: Which means that there *is* a real difference between any *really* straight line and any *really* curved line – yes? Did you not admit that I was right?

EINSTEIN: *(Reluctantly)* Yes … . Mmm. Yes.

SOCRATES: Just to be *absolutely* clear: you *do* agree now that straight lines *can't* be curved?

EINSTEIN: *(Reluctantly)* Yes.

SOCRATES: And then, at one point you also claimed that your Theory has "millions of confirmations every year", so the *likelihood* that it's correct must be very high: did you not?

EINSTEIN: I did indeed. And so it has! Millions of confirmations every year.

SOCRATES: But it was clear to both of us, from a consideration of *other* theories – such as those of Mayan astrology – which *also* have lots of confirmations, and which are *highly* predictive, that this fact *per se* is *absolutely* no guarantee of any theory's *correctness:* right?

EINSTEIN: Yes, I admitted the logic of this reasoning, though it *is* highly counter-intuitive. Most people, I imagine, wouldn't even *get* the argument. But *I* do. Yes.

SOCRATES: So the *number* of confirmations of your Theory is *no* guarantee of its correctness, is it?

EINSTEIN: *(Reluctantly)* No, it isn't.

SOCRATES: And we then spoke of finding a way to "falsify" – which is to say, in unambiguous words, to refute, or disprove, or render false – your Theory, didn't we?

EINSTEIN: Yes, we did. Yes.

SOCRATES: And when we spoke about that, you claimed that I had not been able to "falsify" your Theory with any of the counter-arguments I had presented *up to then:* right?

EINSTEIN: Yes, I remember that quite well.

SOCRATES: And you admitted that there *is* no *experimental* way to "falsify" – or refute, or render false – your Theory, at least with our *present* technology … right?

EINSTEIN: Right again.

SOCRATES: And we both agreed that *unless* there *is* a way to "falsify" a theory, it is not *scientific:* right?

EINSTEIN: Yes: by Popper's criterion – with which I quite agree – an *unfalsifiable* theory is absolutely *unscientific.*

SOCRATES: But you did agree that even though with our present technology there is no *experimental* way to "falsify" your Theory, there has *got* be a *theoretical* or *logical* way to do so: right?

EINSTEIN: Yes, I agreed to that, Yes. Because unless there is *some* way to falsify it, it can't be scientific; and since my Theory *is* a Theory of science, I *must* have *some* way to falsify it!

SOCRATES: And when I asked you to give me a *criterion* for falsifiability of your Theory, you said that it *would* be falsified if I could illustrate the existence of something – even something entirely imaginary like a geometrical line – which is straight in the *presence* of a gravitational field which "curves" space, and which *also remains straight* in the *absence* of a gravitational field, so that space *isn't* curved there? Didn't you *yourself* come up with this criterion?

EINSTEIN: I did indeed.

SOCRATES: And then I pointed out to you that *tangents* to curved lines must be *straight no matter what,* because the very notion of a "curved tangent" is fraught with internal contradictions, did I not? So that tangents would have to be *straight* no matter whether the space in which they existed were curved or not by gravitational fields … or, indeed, curved for *any* reason whatsoever?

EINSTEIN: You did.

SOCRATES: And I also pointed out that this argument *met* your criterion for a *theoretical* falsification of your Theory, did I not? Which means that your Theory stood clearly "falsified", didn't it?

EINSTEIN: Yes, you did say that. At which point I *repudiated* that criterion for falsifiability. Only on second thoughts, you understand; but as you yourself admitted, a scientist must be *allowed* to change his mind!

SOCRATES: *Indeed* he should: and so should a philosopher. But when I asked you to give some *other* criterion for falsification of your Theory, you said something like this: "The only such criterion must be an *experimentally testable* criterion, not a merely *theoretical* one."

EINSTEIN: *(Brightly). Yes* I did.

SOCRATES: And when I asked along the following lines – "Exactly *how* would an experiment be devised to test your Theory, since you yourself claim, and rightly so, that our technology doesn't allow us to test your Theory *experimentally?",* you answered something like this: "Since such a thing *can't* be devised, I claim that my Theory still *stands!"*

EINSTEIN: I did, didn't I. *(Proud of himself).*

SOCRATES: But then are you not claiming that your theory isn't "falsifiable"?

EINSTEIN: Not *experimentally*, no: it sure *isn't!*

SOCRATES: And you claim that experimental falsifiability is the *only* criterion for its falsifiability – yes?

EINSTEIN: Yes, of course – didn't I say so less than a minute ago?

SOCRATES: You did indeed.

EINSTEIN: So then!

SOCRATES: So then, you claim it isn't falsifiable *at all*, don't you?

EINSTEIN: Yes! *(Raising his voice a bit)* So my Theory *still stands!*

SOCRATES: *Indeed* it does … but *(raising his voice in turn)* not as a *scientific* Theory, right?

EINSTEIN: *(Flummoxed).* Yes, okay; I admit it. *Either* I come up with a falsifiability criterion – one which would *have* to be entirely *theoretical,* since *experimental* tests are impossible under our present level of technology – or else my Theory becomes unscientific. And the

only *theoretical* criterion I have been *able* to come up with *can* be met, thereby *actually* falsifying my Theory. I am caught between a rock and a hard place now!

SOCRATES: *(Smiling)* Well, isn't that just too bad?

EINSTEIN: *Gottverdammt!* Well, never mind. I am sure I shall find my way out of this conundrum in the future, though I can't right now. But in the past I *have* been able to find my way out of a paper bag, both literally and figuratively – literally was at a party, and I was drunk, but never mind that – so I strongly suspect that I can find my way out of this problem too.

SOCRATES: I shall be *most* happy to resume our discussions when you *do* find your way out of it!

EINSTEIN: I should all the same like to point out that my Theory is *widely* accepted. Indeed, there is not a *single* Nobel Prize winner in physics – at least after the 1920s – who *doesn't* accept it. Over 99.99% of all physics professors – who have studied it all throughout their lives – accept it, all over the world. I can't believe they would be doing so if the Theory wasn't *demonstrably* correct. I just *can't* believe that 99.99% of all the *best* physicists in the entire world – graduates of the *best* universities in the world – and *all* Nobel Laureates in physics since the 1920s, can *all* be wrong … *it just doesn't make any sense!*

SOCRATES: When you put it like this, I confess I am as mystified as you are.

EINSTEIN: So what are we *missing* in our discussions?

SOCRATES: *I* don't know – *you* tell me! After all, it's *your* Theory, isn't it.

EINSTEIN: *Indeed* it is. And I have the support of pretty much *all* the best physicists in the world … and I have had that support for almost a century! Indeed, some of these fellows are *much* smarter than I am. As I said earlier, I am not really *smart;* I'm just *persistent* – I *stay* with problems till I finally solve them, or else am satisfied that they are not solvable. But *these* fellows *are* smart. *Really* smart. With high IQs. They're not *dumb* like *me!*

SOCRATES: I know what you mean. I too am myself not very smart; in fact I always considered myself as not knowing anything – though it was pointed out to me a while ago, here in these Elysian Fields, that if I had *really* not known anything, I could not have known *that* I didn't know anything … and so, after my death, I've had to actually *deny* not knowing *anything*. Besides, I must admit that I do know how to walk, talk, think, argue and such; so I must know *something*. But I know *very little*. Most people are *much* smarter than I am. Even now that I'm dead, let alone when I was alive. I'm quite dumb dead *or* alive, in actual fact.

EINSTEIN: Yep. That, as I said earlier, makes two of us! *(Smiling).*

SOCRATES: Indeed it does. And yet, the problem you are facing – of highly intelligent people believing things that turn out to be, upon closer examination, quite untrue – is not altogether unfamiliar to me. You see, when I was alive, I used to accost people in the streets of Athens and ask them probing questions; and among these people were some who were highly intelligent, learned and honoured. Among them were prestigious politicians, judges, military men, experts – people who had achieved much more in life than I ever did, or even dreamed of. Yet I could never understand *why* they were so well regarded, since after close questioning, none of them were able to convince me that they were *actually* right, even though in their fields they were widely *considered* to be right!

EINSTEIN: *(Smiling)* Yes, I read quite a few of Plato's "Socratic Dialogues" when I was young, and I saw how you made mincemeat out of many of these so-called "intelligent" people, who clearly weren't so intelligent after all.

SOCRATES: Well, "mincemeat" is not quite *le mot juste;* my intent was always to *learn* something form our conversations, seeing as these people were so well regarded. I never intended to "make mincemeat" out of them – no, *never*. And I was always willing to change my mind … which, in fact, was never made up in the first place. In *any* subject.

EINSTEIN: Ah. How wise of you!

SOCRATES: "Wise"? Oh no, my dear Professor, not wise! I was just *dumb* … if not even "dumberer". I still am, as a matter of fact!

EINSTEIN: *(Smiling)* Yes, I understand you perfectly. I myself was just a patent office clerk in Zürich when I wrote my very first paper on Relativity. I didn't even have the qualifications to get a better-paying job!

SOCRATES: Yes: I heard about that. But then surely you have asked yourself the question, *Why* do so many highly intelligent people believe in your Theory of gravity "bending" space, given that upon close examination, it has *no* evidence *whatsoever* in its favour, and, except in a theoretical way, *can't* be falsified? And that, in fact, *when* a theoretical criterion of falsifiability is actually enunciated, the criterion can *actually* be *met*, thus *actually* falsifying your Theory?

EINSTEIN: I must confess that our conversation has now forced me to ask myself that very question.

SOCRATES: And what do you think is the answer?

EINSTEIN: Well, either all these people know something we don't, or else they are not *really* as intelligent as they are made out to be!

SOCRATES: And which of the two alternatives is the more likely?

EINSTEIN: The former, I think. They *must* know something we don't. For surely it's *very* unlikely that 99.99% of the most highly educated and smartest people in the world are so *very* wrong!

SOCRATES: But hasn't that happened before – indeed, quite often? Like in the middle ages, when pretty much *everybody* believed what Aristotle wrote, such as that women had fewer teeth than men (for he never bothered to actually check by counting women's teeth)? Or that lighter bodies fell at a slower rate than heavier ones (for he never bothered to figure out that it was the air that made feathers, for instance, fall slower than rocks)?

EINSTEIN: Yes, but that was the middle ages. No bloody wonder they didn't make much progress! Once the Renaissance came around, though, all that nonsense was quickly overthrown. Well, *relatively* quickly. See – Relativity applies to *everything!* … Just joking, just joking.

SOCRATES: But even *today* most physicists believe Galileo's claim that *all* bodies must fall to Earth at the same rate, don't they? In fact, haven't they believed that for several *centuries?*

EINSTEIN: Of *course* they have – and *rightly* so!

SOCRATES: Oh really? And if I may make so bold as to ask, do *you* believe that too?

EINSTEIN: Of *course* I do, my dear Socrates! *Everybody* believes that nowadays. It's a well-known and well-established *fact*. It's even been *tested* on the Moon, in the absence of air! A feather and a hammer were dropped by astronaut David Scott of Apollo 15, and both objects fell at the same rate.

SOCRATES: But could the very tiny differences in their rates of fall have been *perceived?* I suspect not. But more to the point, do you believe that all bodies fall at the same rate because everybody believes it, or do you believe it because of some logical *reason?*

EINSTEIN: For a *very* logical reason. The thought-experiment to prove it was devised by Galileo himself. He argued thus: "*Suppose* a heavy cannonball and a light musket ball were to be dropped from the same height; and *suppose* the cannon ball did indeed fall to the ground in less time than the musket ball. Then if they were both *fixed* together – say by means of welding – then the two *together* would have to fall both faster *and* slower than the cannon ball by itself: *faster,* because the two together weigh more than the cannon ball by itself, and *slower,* because the lighter musket ball, which falls at a slower rate than the cannon ball, would have to exert some *drag* on the cannon ball as they both fall together! But it's utterly impossible for the two together to fall both faster *and* slower than the cannon ball, so they must *all* fall at the same rate." A cast-iron, knock-down argument, isn't it?

SOCRATES: *(Thinking)* Yes, I see how this argument might be considered both valid and sound. It certainly *seems* to be sound, at all events.

EINSTEIN: So I'm *right* in thinking that *all* objects, *regardless* of their weight, would fall to Earth at the same rate, am I not?

SOCRATES: Yes, I agree … for any objects that exist *on Earth*. In fact, even if you were to drop an entire *mountain* like Mount Olympus onto the Earth, it wouldn't fall any faster than a musket ball. If it *could* be done, of course … but let's consider that irrelevant for now.

EINSTEIN: So you *do* agree with me?

SOCRATES: Yes, of course: regarding cannon balls, musket balls and mountains, or indeed anything that was already part of the Earth before it was picked up and then dropped. You see, the *reason* I so believe is that the gravitational attraction between any two bodies like the mountain and the Earth – and thus their rate of fall from any given height, or more correctly the rate at which the body and the Earth approach each other – is *proportional to the sum of their masses;* and the sum of the masses of the Earth and the mountain taken separately is *absolutely no different* than their combined mass when they were together! And the same applies to the sum of the masses of the cannon ball and the Earth, and of the musket ball and the Earth.

EINSTEIN: Exactly so! What did I say? Mount Olympus too, as you pointed out, would fall to Earth no faster than a musket ball. *If* it could be dropped. Which it can't, but that's irrelevant.

SOCRATES: I am indeed convinced that you *are* right about Mount Olympus, the cannon ball and the musket ball. Shall we consider, however, a *modification* to Galileo's thought-experiment?

EINSTEIN: Certainly! *(Rubbing his hands with glee in anticipation).*

SOCRATES: Let's consider the planet Jupiter.

EINSTEIN: Yes. What of it?

SOCRATES: And let's also consider that, according to our best theories, it's made of atoms.

EINSTEIN: Indeed it is – but so what?

SOCRATES: And let's agree that the atomic theory of matter is *correct:* namely, that in every atom there is a "cloud" of electrons – from one to 92 (or more, in artificially-created atoms) – around a tiny nucleus, and that *most* of the mass of the atom is concentrated in the nucleus, not in the electron "cloud".

EINSTEIN: Yes, I quite agree to all that: but shall we get to your point?

SOCRATES: I'm coming to that. You agree, don't you, that the diameter of the nucleus of an atom is smaller than one-ten-thousandth the diameter of the atom itself?

EINSTEIN: Actually, I believe it is *considerably* smaller, depending on the atom. If I remember aright, even in Uranium – the heaviest of all the natural elements – the diameter of the nucleus is around 1/23,000th of the diameter of the atom; and with the lighter elements the diameter of the nucleus gets progressively even smaller when compared with the diameter of the atom itself. In hydrogen the ratio of their diameters is about 1:140,000.

SOCRATES: But *even* if we assume the ratios of diameter of the nucleus and the diameter of an atom to be as little as 1:10,000, the *volume* of the atom would at the very *least* be ten-thousand times ten-thousand times ten-thousand times larger than that of the nucleus?

EINSTEIN: Hmm. *(Thinking for a while)* Yes. Yes, I guess so.

SOCRATES: And that's – let's see – 1,000,000,000,000 times? Namely, a "one" with twelve zeroes after it? A trillion times, in other words?

EINSTEIN: Hmm. Let me think about it. *(Thinking in his head).* Yes, I think that's correct. The actual figure is likely to be even larger, indeed *much* larger, seeing that Jupiter is made of much lighter atoms than uranium; but it would be at *least* that large.

SOCRATES: Indeed. But then, if it were somehow possible to shrink Jupiter down to a spherical object with the *mass* of Jupiter but with the *volume* of only the *nuclei* of its atoms, such an object would be at least *one trillion* times smaller in volume than Jupiter is now?

EINSTEIN: Yes – and more likely, even smaller.

SOCRATES: And Jupiter is, roughly speaking, about a thousand times larger in *diameter* than Earth. Right?

EINSTEIN: I don't know. Is it?

SOCRATES: Well, I looked it up on the *Wikipedia* a short time ago. Of course the *Wikipedia* could be wrong, but in this particular case I rather doubt it.

EINSTEIN: I'll take your word for it, then. I never bother to memorize facts which I can readily look up. A waste of brain-power, I say!

SOCRATES: Indeed. Well, since the ratio of the *diameters* of Jupiter and Earth is about a thousand to one, the ratio of their *volumes* must be the *cube* of that, or about a *billion* to one – right?

EINSTEIN: Again, I'll take your word for it! But let me tell you, all this mathematics is giving me quite a headache.

SOCRATES: I'm almost finished.

EINSTEIN: Go on then!

SOCRATES: So it means that the volume of a spherical object of the mass of Jupiter, but composed only of the *nuclei* of Jupiter's atoms, would be less than a trillionth times one-thousandth of the volume of the Earth?

EINSTEIN: I suppose so. *(Thinking)* Yes. Actually, even smaller.

SOCRATES: And that, in other words, would be at least *one billionth* the volume of the Earth?

EINSTEIN: Yes, I suppose so …

SOCRATES: Or in other words, it would be like a sphere with a *diameter* less than *one-thousandth* the diameter of the Earth? So, since the Earth is about 1,300 kilometres in diameter – and yes, I *have* looked it up on the *Wikipedia* – this sphere with the mass of Jupiter would be just *a few kilometres* in diameter?

EINSTEIN: Er. Yes. Or rather, I'll take your word for it that the figures are correct. Of course you understand that we couldn't actually *make* a spherical object the mass of Jupiter with a diameter of just a few kilometres, but as you say, that's irrelevant here.

SOCRATES: Right. And such a sphere would be roughly the size of a mountain like Olympus, yes? *Roughly,* of course. And maybe even smaller.

EINSTEIN: Yes, *around* that size. Roughly speaking. Of course mountains aren't spherical, you understand … but yes, I get what you mean. *Roughly*.

SOCRATES: So by your argument, such a sphere, with the mass as great as Jupiter's but just a few kilometres in diameter, should fall to Earth at the *same* rate as Mount Olympus, or even a musket ball, shouldn't it?

EINSTEIN: Yes! That's what I said, didn't I.

SOCRATES: But the *force of gravitational attraction* between this sphere and the Earth, at any given distance between them, would be proportional to the *sum* of their masses, wouldn't it be?

EINSTEIN: Of course. "Elementary, my dear Watson!" … Er – sorry. I just *like* saying that phrase.

SOCRATES: And the mass of Jupiter is over *three hundred times* the mass of the Earth, isn't it?

EINSTEIN: I don't know, but again I'll take your word for it …

SOCRATES: Well, we could both of us take the word of the *Wikipedia* – shall we do that?

EINSTEIN: Okay!

SOCRATES: If so, wouldn't the force of gravitational attraction between the Earth and this sphere – which has the mass of Jupiter but is just a few kilometres in diameter – be over *three hundred times* the force of gravitational attraction between the musket ball and the Earth?

EINSTEIN: Er … yes, I suppose it would be.

SOCRATES: So wouldn't this sphere with the mass of Jupiter fall to Earth at a much *faster* rate than the musket ball, or even Mount Olympus? Supposing, naturally, that they all *start* falling from the same height. Of course I'm using the word "falling" here in the sense of both this sphere and the Earth *mutually coming together* – but strictly speaking, isn't that what *all* cases of "falling" are? In this case it would be more like the Earth "falling" towards this massive sphere, at least *technically*. But essentially, *every* case of "falling" is *two* bodies coming together, *mutually*. It's not like one of them is stationary while the other is "falling": they are *both* falling *towards* each other, even in the case of the musket ball and the Earth. Am I not right about that?

EINSTEIN: Yes, true enough. *(Looks worried).*

SOCRATES: But then – to return to our thought-experiment – wouldn't the Earth and this sphere the mass of Jupiter "fall" towards each other *much* faster than the musket ball and the Earth, or even Mount Olympus and the Earth? And that, because the force of gravitational attraction between this *massive* sphere and the Earth would be over three *hundred* times stronger than the force of gravitational attraction between Mount Olympus and the Earth?

EINSTEIN: *(Perplexed in the extreme)* I don't know what to say. What you said all sounds very, *very* correct, logically and rationally! Yes, I suppose they would. The Earth and this sphere of the mass of Jupiter would "fall", as you say, mutually towards each other at a much faster rate than the Earth and Mount Olympus would. *Much* faster. Yes. True enough …

SOCRATES: So isn't your earlier claim – and Galileo's claim – that *all* bodies must fall to Earth at the same rate, demonstrably *false?*

EINSTEIN: *(Thinking for a long time).* Yes, I suppose it is.

SOCRATES: Shall we analyze the *reasons* for the error?

EINSTEIN: Yes, let's do that. I confess I am still mystified.

SOCRATES: We approached this, didn't we, using the physical law that the gravitational attraction between bodies at any given distance is proportional to the *sum of their masses?*

EINSTEIN: Yes we did.

SOCRATES: So that the lesser the *sum of the masses* of the falling body and the Earth, the lesser the *force* of gravitational attraction between them?

EINSTEIN: Yes, of course.

SOCRATES: So if the falling body originates on the *Earth itself,* the sum of the masses of the Earth and that body is *the same at all times;* while if the body originates in *outer space*, then the sum of the masses of the Earth and *that* body is *greater* than of the Earth alone, before the body started falling towards it – am I not right?

EINSTEIN: Yes, you are.

SOCRATES: So even a small *meteorite* would fall faster towards the Earth than Mount Olympus itself? Because the sum of the masses of the Earth and the meteorite would be *greater* than the sum of the masses of the Earth-minus-Mount-Olympus, plus Mount Olympus itself?

EINSTEIN: *Yes! Yes!!!* I see now what you mean. You are *quite* right! It's not that *heavier* bodies fall faster than lighter ones, but that from any given height, the rate of fall of *any* body to the Earth is proportional to the *sum* of the masses of the Earth and that particular falling body, taken together. *Period.*

SOCRATES: And yet *most* physicists, even at NASA, *still* believe that *all* bodies fall to Earth at the same rate, don't they? From any given height, at all events.

EINSTEIN: I confess they do.

SOCRATES: Yet they are *wrong?*

EINSTEIN: Er. Yes.

SOCRATES: *All* of them?

EINSTEIN: Well, perhaps not *all* of them believe that all bodies fall to Earth at the same rate, but *most* of them do.

SOCRATES: Maybe as many as 99.99% of them?

EINSTEIN: Possibly. *Very* possibly.

SOCRATES: With even Nobel Laureates among them?

EINSTEIN: Again, *very* possibly.

SOCRATES: And yet every single one of those who believe it would be believing something that's *demonstrably false:* right?

EINSTEIN: Dear me. Dear, dear me. Me oh my. I can't believe it! How on *Earth* – how in *heaven's name* – could I have been *so stupid* all these years? I must *kick* myself … *(Sighs).* I had better go and tell Galileo about this right away.

SOCRATES: He already knows. I talked to him a short while ago …

EINSTEIN: My goodness! Even Galileo knows, and *I* didn't till now … and he's, like, from the bloody *sixteenth century!* Awful situation. *Absolutely awful.*

SOCRATES: Well, my dear Professor, at least you – and Galileo, too – are both open-minded enough to admit it when you've been demonstrated wrong!

EINSTEIN: Yes, thankfully. I was always against believing something simply because some *authority* said so. Indeed I once quipped that to punish me for my contempt of authority, fate made me an authority myself! *(Wry smile).*

SOCRATES: Maybe it did! *(Smiles).* But *most* physicists aren't so open-minded … or are they?

EINSTEIN: I can't speak for most physicists, really I can't. And shouldn't. But *I* am definitely willing to change my mind if I am demonstrated to be in error.

SOCRATES: But you *would* admit, wouldn't you, that just because 99.99% of physicists believe something, it doesn't mean that what they believe must be *true?*

EINSTEIN: Er. Yes, I suppose so.

SOCRATES: So the 99.99% of physicists, absolutely *brilliant* physicists with *astronomically* high IQs, who believe in *your* Theory that space can be bent by gravity could *also* be wrong – yes?

EINSTEIN: The way you have put it … I don't know what to say … Dear me. Dear, dear, dear me. *(Trailing off)*

SOCRATES: May I remind you once again that you are under oath? *(Smiling).*

EINSTEIN: Yes, I am. And yes, you are right. Clearly the fact that my Theory has millions – literally – of unbelievably intelligent supporters all over the world is no better evidence for its truth than the millions – literally – of confirmations it has every year.

SOCRATES: I am glad you understand that. Most people, in my experience, just don't get it.

EINSTEIN: Weird. *Most* weird.

SOCRATES: What is?

EINSTEIN: That I could have been *so* wrong all throughout my life. *Throughout my entire life!* And not just me. *Lots* of people! *Brilliant* people. *Weird.*

SOCRATES: *(Silent).*

EINSTEIN: Fuck! *Fuck!!!*

SOCRATES: I didn't know you swore, Professor Einstein … ?

EINSTEIN: I *don't,* normally. But *this* occasion calls for it!

SOCRATES: Maybe you are being too hard on yourself. You see, since you repudiated your criterion for "falsifiability", I haven't yet rendered your Theory actually *false*: I have only rendered it *unscientific.*

EINSTEIN: Isn't that bad *enough?*

SOCRATES: Well, that's just a *temporary* situation, isn't it? If you can come up with *some* criterion for falsifiability – *any* criterion – your Theory wouldn't be unscientific any more … and it wouldn't yet be *falsified* either!

EINSTEIN: *(Cheering up)* You're *right!* So now what?

SOCRATES: Shall we discuss your thought-experiment a bit more, then?

EINSTEIN: Yes, let's do that! *(Happy again).*

SOCRATES: Shall we get back to the *simplest* kind of your thought-experiment? The one in which all we have is the elevator, the man inside it, the laser pointer and the beam of light?

EINSTEIN: Yes, let's do that. Make things as simple as possible … but not *simpler*, I always say!

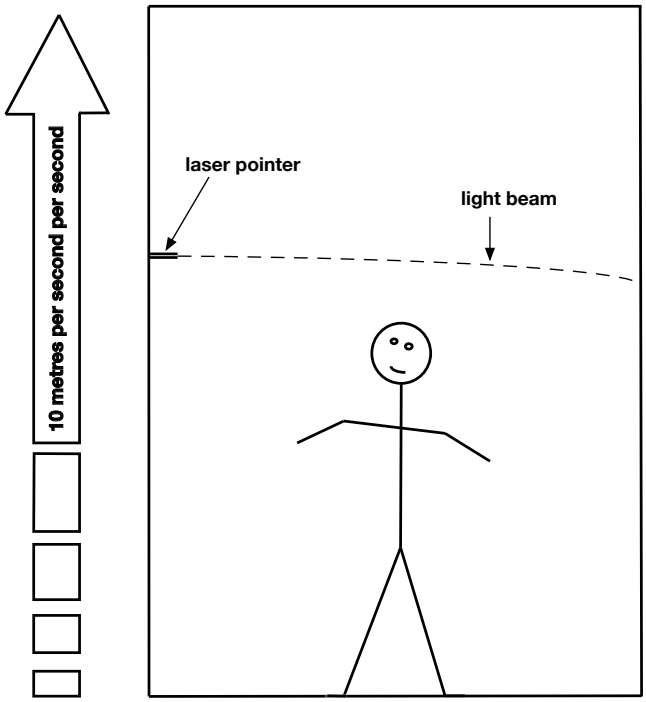
SOCRATES: Right. So we are both agreed that to the man the beam of light would *appear* curved, aren't we?

EINSTEIN: Yes we are.

SOCRATES: Except, of course, that the curvature in any decent-sized elevator would be too small to discern with the naked eye; but we'll ignore that for the moment and consider it irrelevant.

EINSTEIN: As I did myself in my original thought-experiment. Yes. Let's do that.

SOCRATES: Like this, right? *(draws in the sand again):*



EINSTEIN: Right.

SOCRATES: Now may I ask you, once again: what is the *exact* shape of the curved light beam?

EINSTEIN: I beg your pardon?

SOCRATES: I mean, yes, we know it's *curved*, but what is the *nature* of this curvature? Is it a part of a circle, or a part of an ellipse, or a part of a parabola, or a part of a hyperbola, or some other type of curve?

EINSTEIN: *(Thinking for a while)* Well, I should say it's part of a *parabola*, because we are talking about a *trajectory*, aren't we … and in a gravitational field, all trajectories of things that are caused to move horizontally are *parabolic*.

SOCRATES: Yes. Exactly so. Or rather, if I wanted to quibble, I might say that in a *gravitational field* trajectories of objects are actually parts of *ellipses* – at least according to Kepler – with one of the foci of each ellipse at the centre of gravity of the planet over which the object whose trajectory is under consideration is moving; but since in your case the elevator is under *acceleration*, and there *is* no centre of gravity, you are *quite* correct to call it a parabola. Or rather, a *part* of a parabola.

EINSTEIN: Thank you.

SOCRATES: And you would agree, I hope, that a parabola, or even a part thereof, is not curved *uniformly* all along its length, but that it's *degree* of curvature *differs* depending on where exactly along its entire length one is talking about?

EINSTEIN: Yes, of course. That, in fact, applies to *all* curves except circles. Only a *circe,* of a part thereof – that is to say, an *arc* – is curved to the *same* degree along its entire length.

SOCRATES: Indeed. But now, shall we suppose that *another* laser pointer is affixed to the *opposite* wall of the elevator, at the same height above the floor as the first?

EINSTEIN: Okay …

SOCRATES: And shall we suppose that this *second* laser pointer is set to shine a light beam at the wall on which the *original* laser pointer is fixed, so that when the elevator is *not* being accelerated, the spot of light from the *second* laser pointer shines at the *same* height above the floor of the elevator as the spot of light from the *first* laser pointer, except that it's shining on the *opposite* wall.

EINSTEIN: *(Thinking about it)* Yes. Okay.

SOCRATES: So that when the elevator is *not* under acceleration, *both* laser pointers shine their light beams in perfectly horizontal, and parallel, lines, both beams being *exactly* the same height above the floor of the elevator along their *entire* lengths.

EINSTEIN: Yes.

SOCRATES: So that once the elevator is accelerated, both the light beams from both the laser pointers now become curved, but each light beams shines in the opposite direction to the other?

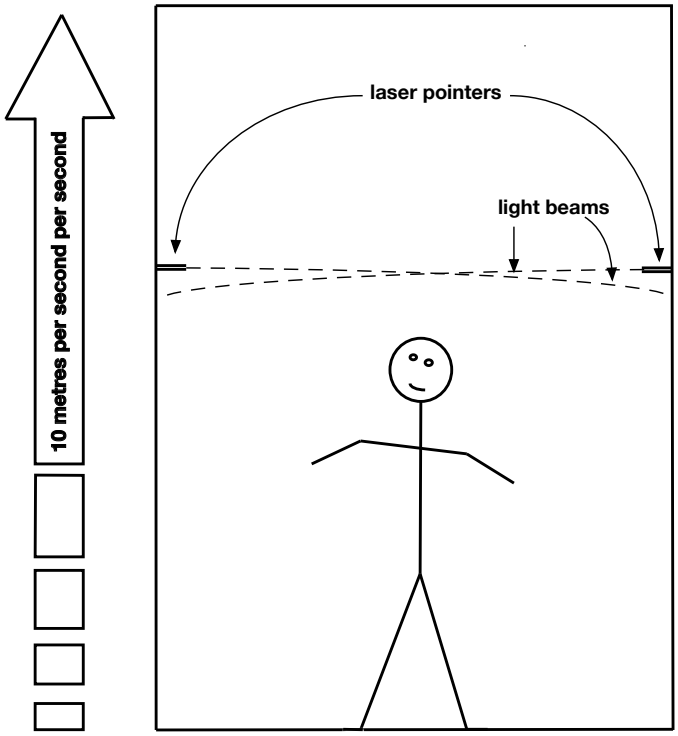
EINSTEIN: Yes, yes; I got it the first time.

SOCRATES: *Did* you indeed?

EINSTEIN: Yes of course I did! What do you take me for: a dummy? *(Pauses).* Oops! I guess I put my foot in it this time, didn't I? *(Smiles).*

SOCRATES: *Heh-heh!*

EINSTEIN: Anyway, to *show* you that I got it, let *me* draw the picture in the sand this time *(draws):*



SOCRATES: Yes, that's right: you *did* get it.

EINSTEIN: Thank you!

SOCRATES: Now let's consider the two light beams from the two laser pointers. They would *both* be parabolic in shape, right?

EINSTEIN: Of course.

SOCRATES: And both would be *equally* parabolic in shape, right?

EINSTEIN: Indeed they would be.

SOCRATES: Nevertheless there *would be* a difference between them, wouldn't there be?

EINSTEIN: In what way?

SOCRATES: Well, doesn't one of them consist of the *right* part of a parabola, and the other beam, the *left* part of a parabola? In other words, would they not be *mirror images* of each other?

EINSTEIN: *(Thinking)* Yes. *(Thinking some more)*. Yes, you're right. Each would be the *exact* mirror image of the other.

SOCRATES: And it would *not* be possible to put the two mirror images together simply by *moving* one of them towards the other so as to form one *single* curve, would it?

EINSTEIN: Come again?

SOCRATES: Well, if we *move* the two curved lines traced by these two light beams, so as to try to cause *both* of them to lie *exactly* along the same path – so that instead of them being *two* curved lines, they become a *single* curved line – well then, doing such a thing becomes quite *impossible,* doesn't it?

EINSTEIN: I *still* don't get it.

SOCRATES: All right, let me put it another way. Consider the two curved lines traced out by these two light beams.

EINSTEIN: Yes.

SOCRATES: They are *two* curved lines, aren't they?

EINSTEIN: *(Testily)* Of course they are.

SOCRATES: Pardon me for proceeding step by step. Now, is there *any* way to *move* one of these lines towards the other, so as to cause them to both line up *all throughout their lengths,* so that they *both* end up along the *same path?* So that they *both* form a *single* curved line?

EINSTEIN: Well, yes: we can flip one of the two lines over, and then move it towards the other, so that they both line up and form one single curved line.

SOCRATES: Exactly so: we'd have to *flip* one of them over to do it. But *without* flipping one of the two lines over, we *couldn't* do it, could we?

EINSTEIN: *(Thinking)* No, we couldn't. But so what?

SOCRATES: Well, according to your Theory, space would be curved in *exactly the same manner and to the same degree* as the light beams are curved, wouldn't it?

EINSTEIN: Yes, that's my Theory!

SOCRATES: But the two light beams are curved *differently*, aren't they? Not in *degree*, admittedly, but in *manner.* That is to say, in the *way* they are curved.

EINSTEIN: I'm not quite sure I follow. Could you elaborate upon that, please.

SOCRATES: Certainly. Let's consider each beam in turn. The beam emerging from the laser pointer affixed to *one* of the walls of the elevator is *more* curved along *one* half of its length than along the *other* half of its length, right?

EINSTEIN: Yes …

SOCRATES: So according to your Theory, space must be *more* curved in the half of the elevator in which the light beam is more curved, than it is in the *other* half, right? And *vice versa,*

space must be *less* curved in the half of the elevator in which the light beam is less curved, than in the other half? Yes?

EINSTEIN: Yes.

SOCRATES: And the beam emerging from the laser pointer affixed to the *other* wall is *also* more curved along *one* half of its length than along the *other* half of its length: yes?

EINSTEIN: Yes, true.

SOCRATES: But in each of the two beams, the half that is *more* curved is on *opposite sides of the elevator,* isn't it?

EINSTEIN: *(Thinking a bit).* Yes, that's right.

SOCRATES: So space must be *more* curved in one half of the elevator than it is in the other half, *and also* more curved in the other half than in the first half … is that not so?

EINSTEIN: Umm, yes … *(trailing off)*

SOCRATES: So my question to you is: is that even *possible?* I mean, *logically* and *rationally* only; for although Jesus did say "with God all things are possible", here we're discussing *physics.*

EINSTEIN: *(Deep in thought now)* Umm. Hmm. *(Muttering under his breath). Gottverdammt!*

SOCRATES: No need to be profane, Professor. But if I may insist: *is* it possible, or *isn't* it?

EINSTEIN: No, I guess it *isn't* possible.

SOCRATES: So would you agree, or would you not, that your thought-experiment has a fatal *flaw* in it … in Macrì's terminology, a *FLOP?* May I remind you, one last time, you are under oath.

EINSTEIN: *(Thinking very, very hard)* Yes, I have to admit it, I do. Intellectual honesty doesn't allow me to do any less. Well, back to the drawing board! Luckily, now that I am dead I have an entire eternity to come up with a better theory; but all the same I had better get cracking on it right away.

SOCRATES: When you've come up with it, let me know! I shall be *most* interested in discussing it.

EINSTEIN: Thank you. It's been a – well, I won't say "a pleasure", but a very *interesting* talk! And believe me, I am not *personally* offended. I should *love* to resume our debates later.

SOCRATES: C u l8r!

EINSTEIN: How do you *do* that? I mean, speak like you're texting?

SOCRATES: *G o o o o o o d* question! *(Smiles, and walks away.)*

EINSTEIN: *(Muttering under his breath)* Effing cool, that is.

(His iPhone *dings, indicating the receipt of a text message. It's from Socrates:*

"Fifteen hundred years ago, everybody 'knew' that the Earth was the center of the universe. Five hundred years ago, everybody 'knew' that the Earth was flat. And 15 minutes ago, you 'knew' that humans were alone on this planet. Imagine what you'll ' k n o w ' tomorrow. ~ Agent K [Tommy Lee Jones], 'Men in Black'.")