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Problems for Self-Study

1. Time t equals zero

A is on a train traveling due west along the x-axis at a constant velocity of seventy kilometers per hour (70 km/h). He stands at the rear of the train, looking back with some fondness at town M (6,3). The location of the university, his few friends. His point of departure. He is carrying a suitcase (30 kg) and a small bound volume (his thesis: 0.7 kg; 7 years).

   Using the information given, calculate A's final position.

2. Assume A is lonely. Assume A is leaving M (6,3) in order to find someone who could possibly equal his love of pure theory. A says to himself, No one in a town like M (6,3) could possibly equal my love of pure theory. Not even P, his esteemed advisor and mentor.

   A suspects P is a closet empiricist, checking his theory against the world instead of the other way around.

   A once barged in and caught P, hunched over his desk, with a guilty but pleasured look on his face, *approximating*, right there in his office.

3. Relative motion

Across the train car, A spots B. Assume B is lovely.

   (a) A immediately recognizes that B is not a physicist.
   (b) Still, he calculates his approach.
   (c) A wonders, into what formula do I plug the various quantitative values of B? Could B, A wonders, though she clearly lacks formal training in mechanics, could she ever be taught, in some rudimentary sense, to understand the world as I do?
   (d) A notes her inconsistent postulates. Her wasted assumptions. Her lovely inexactness.
   (e) He decides to give her a test.
   (f) A says: If a projectile is launched at a 30 degree angle to the earth, with an initial velocity of 100 m/s, how far does it travel?

(g) *B* notes his nervous and strange confidence, his razor-nicked chin, his tie too short by an inch. An uncombed tuft of hair. She is charmed.

(h) *B* humors *A*.

(i) *B* says, Well, doesn't it depend on how windy it is?

(j) Ignore the wind, says *A*.

(k) *B* says, But how can I ignore the wind?

(l) Ignore the wind, says *A*.

(m) Are you saying there is no wind?

(n) *A* says, The wind is *negligible*. He says this with a certain pleasure. The other passengers roll their eyes.

(o) *A* says, It does not matter for the purposes of the problem. Besides, *A* says, it makes the math too hard.

(p) *A* looks at *B*'s dumb, expectant, beautiful face. He feels pity for her meager understanding of physics. How can he explain to her what must be ignored: wind, elephants, cookies, air resistance. And: the morning dew, almost everything in newspapers, almost everything owing to random heat dissipation, the taste of papaya. And: the mass of the projectile, the shape of the projectile, what other people think, statistical noise, the capital of Luxembourg.

(q) *A* wonders: can I be with a woman who, however lovely, does not understand how to hold all else constant? How to isolate a variable? *A* thinks:

    i. she will see it my way;
    ii. she will change for me;
    iii. I will educate her.

B thinks:

    iv. he is lonely;
    v. I can make him less so;
    vi. I will help him.

4. *A* spent seven years (2557 days, 4191 cups of coffee) in town M (6,3). He was writing his thesis (79 pages, 841 separate equations).

A's thesis is on nonlinear dynamic equations.

(a) In it, he discovers a tiny truth.

(b) When he had written the last step in his proof, *A* smiled.

(c) *A*'s tiny truth is about a tiny part of a tiny sliver of a tiny subset

of all possible outcomes of the world.

(d) When *A* brought it to his advisor and mentor, the esteemed *P*, *P* smiled. *A*'s heart leapt.

(e) *P* said: "What it lacks in elegance, it makes up for in rigor."

(f) *P* also said: "What a wonderful *minor* result."

5. *A* and *B* are sliding down a frictionless inclined plane. They are accelerating towards the inevitable. Domesticity. Some marriages are driven by love, some by gravity.

6. The three-body problem

Things continue to get more complicated for *A*, now traveling in an elliptical path around *B*. *B* remains fixed, giving birth to their first child, *C*. Doctors and nurses orbit *B* periodically.

(a) Given the mass of *A* (now 80 kg) and the mass of *B* (now 55 kg), calculate the gravitational force between the two bodies of *A* and *B* using Newton's universal gravitational formula:
$F_g = \dfrac{G(m_A)(m_B)}{r^2}$, where *G* is the gravitational constant.

(b) Imagine the situation from the stationary perspective of *B*. As bodies whirl around you, you focus on the pain, the quiet place, the baby, of course, the baby.

(c) Now imagine the situation from *A*'s perspective. You wonder: what if the child turns out like its mother? What if the child does not understand theory? You've spent so many nights, lying awake with *B*, for hours, trying to teach her how to see the world, its governing principles, the functions lying under it all. Hours spent with *B* as she cries, frustrated, uncomprehending.

(d) This is what is well-known in the field of celestial dynamics as the *three-body problem.*

(e) Put simply, this is the problem of computing the mutual gravitational interaction of three separate and different masses.

(f) Astronomers since the time of Kepler have known that this problem is surprisingly difficult to solve.

(g) With two bodies, the problem is trivial. With two bodies, we can simplify the universe, empty it of everything but, say, the moon and the earth, an *A* and a *B*, the sun and a speck of dust. The equations are solved analytically.

(h) Unfortunately, when we add a third body to our equations of motion, the equations become intractable. It turns out the

mathematics gets very complicated, very fast.

(i) *A* has only recently begun to feel comfortable with his predictions   of *B*'s path, *B*'s behavior, her perturbations and eccentricity   of orbit. And now this, he thinks. Another body.

(j) *B* screams with the agony of childbirth.

(k) *A* looks into *B*'s eyes. *A* wonders if it is necessary for her to scream so loudly.

(l) *A* thinks generally about the concept of pain. *A* has a witty thought and would like to write it down.

7. Moment of inertia

(a) *A* and *B* are not moving ($v_A = v_B = 0$). *A* is in his study, hidden in the corner. He is talking in a low voice.

(b) *B*, across the house, is watching television.

(c) *A* is talking to *J*, who is married to *S*. *S* is a good friend of *A*.

(d) *J* is thinner than *B*. *S* is older than *A*.

(e) *B* is listening to *A*. *S* is listening to *J*.

(f) Also listening: the neighborhood. *Theta* and *Sigma*, *Delta* and *Phi*.

(g) Also listening: the social circle: *Phi*, *Chi* and *Psi*. *Eta*, *Zeta* and *Nu*. Even *Lambda* has been known to listen.

(h) Others, just speculating, say that *A* and *J* would make a *good-looking couple*. *A* says no, thinks yes. *J* blushes.

(i) *S* exerts a force on *J*. *A* exerts a force on *B*. *A* wants to exert a force on *J*, and *J* would like it if *A* would exert a considerable force on her.

(j) *B* is walking down the hall. *A* can hear *B*. *B* can hear *A*'s voice growing softer with each step she takes. *A* freezes in anticipation, ready to hang up the phone.

(k) *B* turns and goes into the kitchen, pretending not to hear.

(l) *A* does not move. *B* does not move. The forces cancel out. Everyone remains at rest.

8. Partial solutions

(i)   make renovations to the kitchen;

(ii) make renovations to themselves;

(iii) go on safari;

(iv) go to a "seminar";

(v)   make large purchases of luxury durable consumer goods;

(vi) make small overtures to an object of lust at work;

(vii) take up golf;
(viii) find a disorder and self-diagnose;
(ix) get a purebred dog;
(x) get religion;
(xi) landscape the backyard;
(xii) have another child.

9. *Gedanken* experiment

   (a) Imagine *A* is building a spaceship. He is tired of being pushed, pulled, torqued, accelerated. Collided with on a daily basis. Losing momentum. He is tired of his thesis failing, time and again. Every day an exception to *A*'s Theorem. Every day he recognizes it a little less—once a shiny, unused tool, a slender, immaculate volume. Now riddled with holes, supported with makeshift, untenable assumptions. *A*'s Theorem has not so much predicted the future with success as it has recorded a history of its own exceptions.

   (b) It is simplest to approach the problem of satellite motion from the point of view of energy.

   (c) Every night for a year, *A* and *B* eat dinner in silence. Every night for a year, *A* lights a cigarette, opens a beer, goes to the garage to work on his imaginary spaceship. Sometimes, he has doubts. Sometimes, he gets frustrated, wondering if it is worth all the imaginary trouble.

   (d) And then, one day, *A* finishes his spaceship. Even imaginary work pays off.

   (e) *A* turns on his imaginary vehicle, listens to it roar. It makes a lot of imaginary noise. *B* tries to talk over it, but the engine is deafeningly loud.

   (f) *B* shouts at *A*, right in front of his face. *A* sees *B* moving, gesturing wildly. Why is she acting so crazy?

   (g) The energy of a body in satellite motion is the sum of its kinetic and potential energies. It is given by the following:

   $$E = K + U = \frac{1}{2}mv^2 - \frac{GmM}{r^2}.$$

   (h) *A* watches *B* moving frantically around the garage. *A* notes that *B* looks rather desperate, as if she is trying to stop him, trying to hold him, trying to keep him from leaving Earth.

   (i) *A*'s spaceship is heating up. It is time, he thinks. He holds the imaginary levers and calculates his trajectory. He enjoys for a

minute the low frequency hum as it vibrates through his whole body. His future opens up in front of him.

(j) He is moving now. His past sealing itself off, trailing further and further behind him.

(k) The escape velocity, v_{esc}, of a projectile launched from the surface of the earth is the minimum speed with which the projectile must launch from the surface in order to leave the vicinity of the earth forever.

(l) His imperfect theorem, his imperfect credit, his imperfect house, his imperfect bladder, his imperfect gums, his imperfect career, his imperfect penis: gone. Also gone: the history of his interactions, his past collisions, his past. *A* has finally achieved his major result. He is free from the unceasing pull of gravitational memory.

10. *A* is in deep space. The solar wind is at his back, pushing him along at a rate of 0.000000001 m/s.

At this rate, it will take his entire lifetime to travel a distance of just over eight feet.

B is on a space rock, watching *A* drift by glacially. Imagine you are *B*.

(a) You are 20 m from *A*. Close enough to see his face. Close enough to know his shape. Close enough to imagine contact.

(b) You have a rope. If you can throw it just right, you may be able to tie yourself to *A*, turn his course, affect his trajectory. You will not be able to stop him, but you may be able to make sure that, wherever it is he is drifting to, you end up there as well.

(c) Assume you are of average strength. Assume you are of above average compassion, patience, will, and determination.

(d) If you throw the rope and miss, what happens? If you never throw the rope, what happens?

(e) Imagine you will spend a period of eighty years within a few meters of this astronaut, a man in an insulated space suit. Imagine it is possible to drift by this man, staring at him, as he makes his way into the infinite ocean of space.

(f) You will never know any other points, other problems, the mysteries of biochemistry, the magic of literature, the pleasures of topology. You will only know physics.

(g) You will never know what it feels like inside his suit.

(h) You will never know why you are on this rock.

11. Initial Conditions

A is on a train traveling due west along the *x*-axis at a constant velocity of seventy kilometers per hour (70 km/h). He is carrying a suitcase (30 kg) and a small bound volume (his thesis: 0.7 kg; 7 years).

He stands at the rear of the train, looking back at town *M* (6,3). A point full of sadness, an origin of vectors, a locus of desire. A point like any other point.