BASIC 1-D KINEMATICS

A PHYSICS STORY

$$v = \frac{\Delta d}{\Delta t}$$

$$a = \frac{\Delta v}{\Delta t}$$

$$d = \frac{1}{2}at^2$$

Once again your wizard mentor has sent you off on a stupid quest he should have just done himself if he really wanted it done that badly but noooo it has to be done by you because how will you learn otherwise or something stupid like that. Not for the first time you're regretting ever taking on an eccentric wizard mentor. I mean, sure he has a cool hat and once defeated the dark sorcerer Grgxyx in the 700-day battle of Prplgrp.

But really, who hasn't? You could have done that, too, you just didn't want to wait in line. But nobody hires untrained adventurers these days. If you want to get anywhere in the world you have to be accredited by someone with a long beard, and this guy had one of the longest beards you've ever seen. Which he probably grew through the sheer power of being annoying to other people.

Begrudgingly, you sling your pack over your shoulder and trudge out of town, the cryptic set of instructions he scribbled on a discarded sandwich wrapper clenched in your hand.

There's a lot of nonsense on the paper, including what looks like his grocery list, a reminder to himself to look for his cat, and something mostly illegible that looks like "cheese rabbit," but some of it does look like directions:

#1 How far would you walk if you were walking at 12 m/s for 3 seconds?

#2 Don't actually do that. Instead, however many meters that would be, walk for that many seconds at 2 m/s. How far would that be?
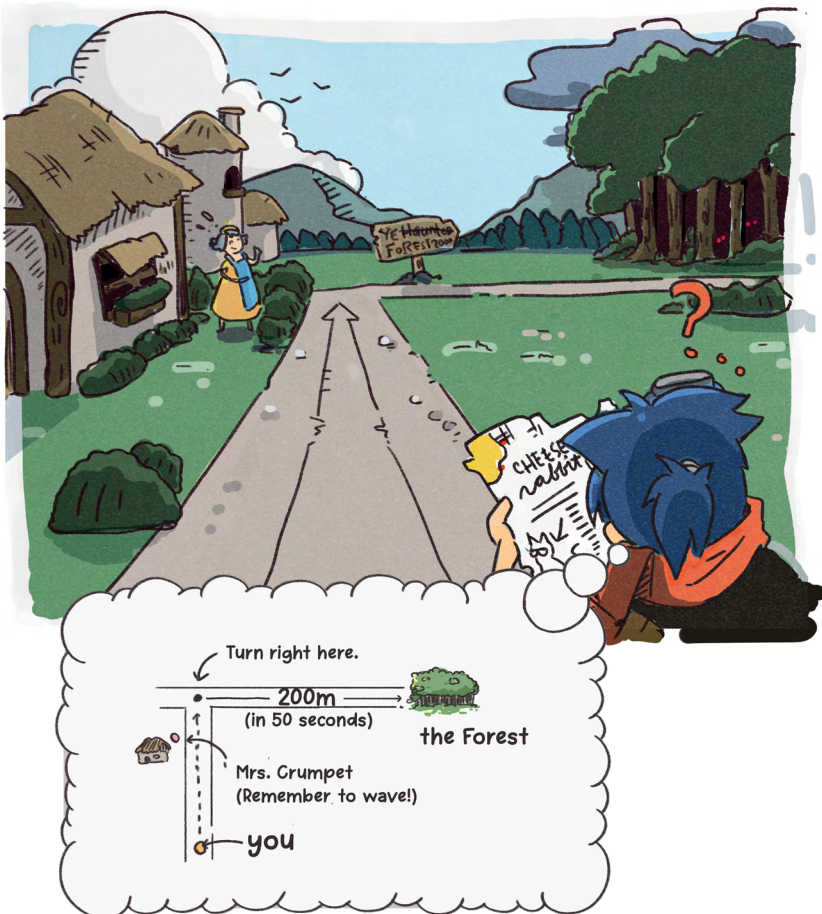
#3 Walk that distance down the road. Make sure you wave to Mrs. Crumpet as you go past. When you finish, turn right and walk 200 meters into the woods. Make sure that this takes you exactly 50 seconds. How fast do you need to be going in order for this to be the case?

#4 You'll see some disturbed earth there. Definitely **don't** dig there. Just... make sure it's all covered up still.

You reach the pile of dirt, sweating and swatting away angry bees, his instructions having sent you through two patches of nettles and a hive of hornets. You contemplate the dirt pile, wondering whether this is a test or if he's actually wanting you to check on something he buried. Knowing him, it's probably a shiny rock or something. Either way, you're too curious.

#5　You grab a sharp stick and get digging. You're able to dig 2 inches every second. How long does it take you to dig 24 inches down?

#6   After that amount of time has passed, your stick hits something solid, and you unearth a trapdoor. Yanking it open, you see a ladder extending down into a dark hole. You climb down the ladder at 4.5 m/s for a full three minutes. How deep is the hole?

#7   At the bottom of the hole, you squint into the dark, pulling out the tiny brass oil lamp you carry for this purpose. As your eyes adjust to the dark, you see a narrow tunnel. You walk at your usual 3.2 m/s pace, for what feels like 356 m. How long did that take you?


Pace: 3.2 m/s   = ?   356m

#8   The tunnel stretches on and on and on. You're wondering how it got here. Did the wizard dig this himself? If so, it's a surprising feat of engineering. You speed up, covering the next 1,050 m in 210 s. How fast were you going then?

#9   Up ahead, the ceiling rises, the walls stretch out away from you, and the light of your lantern is swallowed by the dark as you enter an enormous cavern. You sprint across it at a speed of 6 m/s, and it takes you 47 seconds to reach the other side. How wide is the cavern?

#10 As you sprint through the dark, lantern swinging, you barely miss a huge hole in the center. There is a safety rail around it, but only in parts and it's only a foot high. As you contemplate the hole, a bat swoops past, narrowly missing your head. The bat crosses the mouth of the hole, which appears to be 10 m in diameter, in half a second. How fast is the bat travelling?
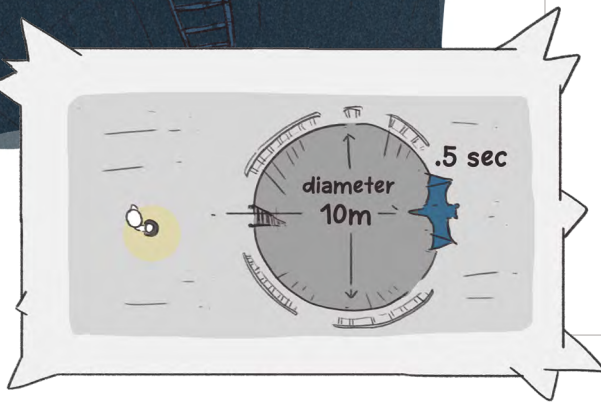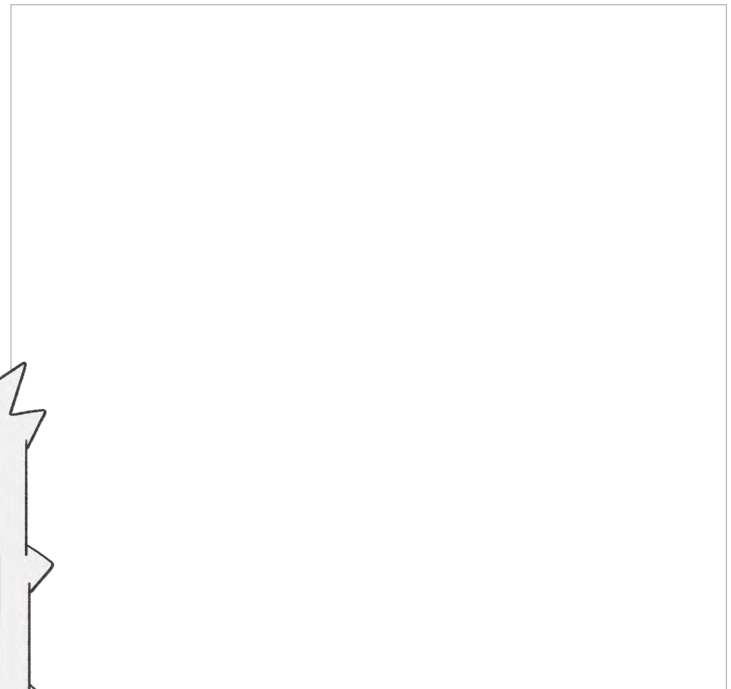
#11 You pick a bat skull off the ground and drop it into the hole, listening. 15 seconds pass before you hear it hit the bottom. How deep is the hole?
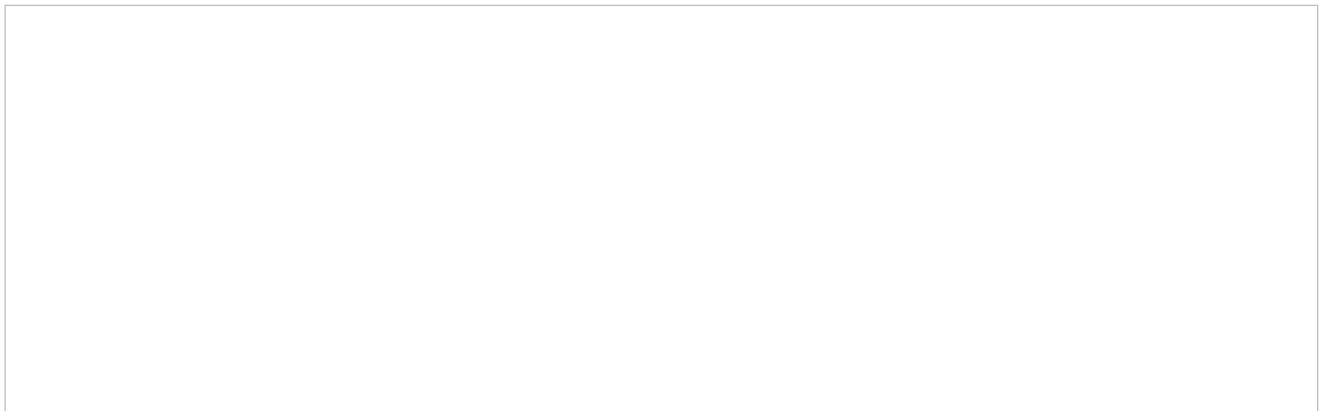
#12   You contemplate jumping down the hole. How fast would you be going when you landed, if you did that?

#13   Maybe better not, then. Luckily, you notice a ladder. Out of curiosity, before descending into the hole, you throw another bat skull up towards the ceiling. You throw it up, counting the seconds as it goes up and comes back down. You catch it after 8 seconds. How fast must you have thrown it?

#14   You throw it a little faster, so that you can hear it just barely graze the ceiling overhead. This time it took 24 seconds to go up and come back down. How fast must you have thrown it upwards?

#15   How high must the ceiling be?

#16   If you threw it up at 16 m/s, how fast would it be going when you caught it?

#17   You've been so delighted tossing skulls around that you've completely lost track of time. The wizard must be expecting you back by now, and you're still unsure whether he wanted you to explore this tunnel anyway, but you're too interested to give up now. You descend the ladder, finding yourself at last on a rocky ledge overlooking an even bigger chasm. This is illuminated with strange phosphorescent mushrooms clinging to the walls. You blow out your lantern to conserve fuel. Across the depths, you see another ledge. You pull out your crossbow and fire an arrow horizontally, just as an experiment. You count, and it takes 18 seconds before the arrow hits rock on the other side. You know that when you pull your crossbow bolt back a certain distance it fires arrows at 21 m/s. How wide is the chasm?
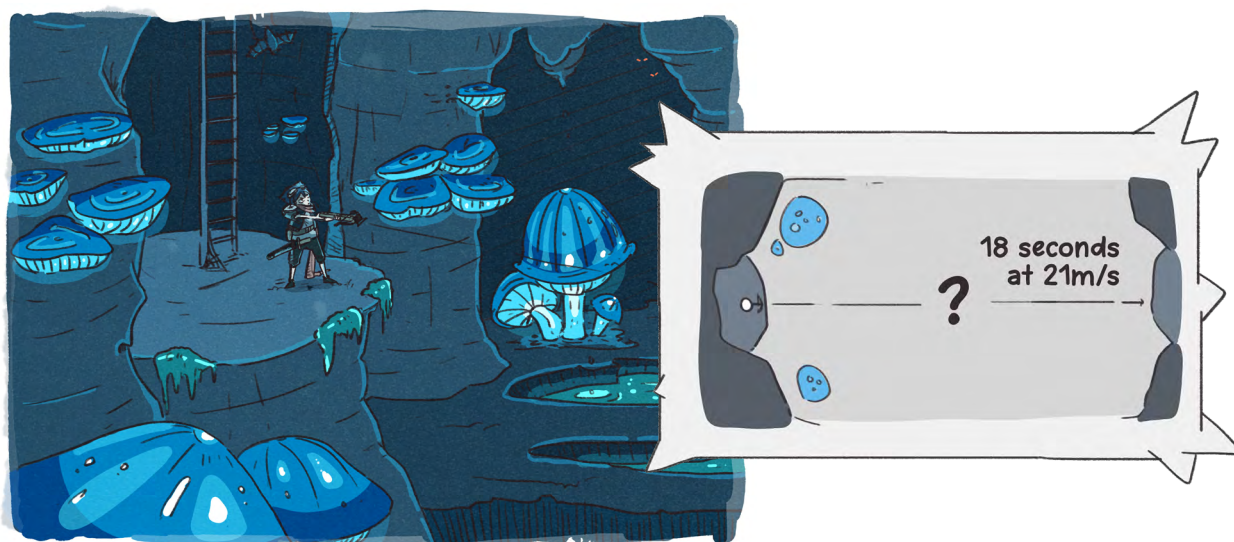
#18   The arrow that you fired fell quite a distance as it went, hitting the rock wall far below the ledge you can see. How far below the ledge must it have hit, assuming you correctly counted the time it took to cross the chasm, and also that you fired your arrow perfectly horizontally?

#19   You can see something else glowing on the other side of the chasm, giving off an intriguing golden light. You pull your rope from your bag, tie one end around an arrow and the other around a handy iron loop mounted on the wall behind you. You angle your shot upwards this time, watching as it arcs up into the dark and back down. You count the seconds, observing that your arrow goes upwards for 16 seconds before reaching its peak. How fast must it have been going vertically when you fired it?

#20   You aimed your shot perfectly; the arrow embeds in the wall behind the ledge, exactly across from you. Knowing that it took a full 27 seconds to cross the chasm (the same distance as before, unless this is a particularly strange chasm), how fast must your arrow have been travelling horizontally when you fired it?

#21   Excitedly, you tightrope walk across the chasm. You brought some bat skulls with you in your pocket, and you drop one when you reach the middle. You bounce a few times on the rope as you wait. It finally hits the bottom 135 seconds later. At least, you assume it was the bottom. You hear a soft ping, and an irritated growl. How deep is the bottom / terrifying monster you've just awoken?

#22   You shrug and bounce your way across the rest of the chasm, curious and excited to see where the golden light is coming from. The light gets brighter and brighter as you approach. You raise a hand, shielding your eyes from its brilliance. There is some more rumbling from down below, but you don't worry about it too much. At last, you step onto the ledge, feeling the warmth of the light on your skin. Your eyes adjust to the light, and you see there is a patch of floor here that is made of some kind of crystal that is glowing warmly. **On top of it sits a cat.**
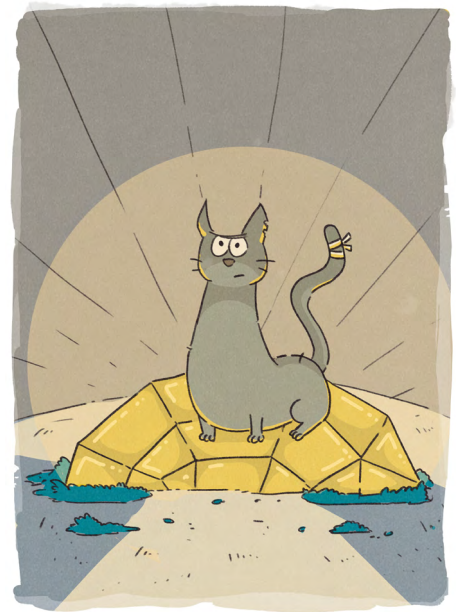
#23   Wait. You consult the paper with the instructions again. Maybe it wasn't a note to himself to find his cat? Was this whole trip just to get his cat for him? You scowl deeply, but then the cat speaks. "The dragon in the chasm behind you flies at a top speed of 7.4 m/s. I believe it is 6,970.8 m away from us, now. How much time do we have until it gets here?"

#24   The cat nods and continues. "It does take a while to get going, though. If it accelerates at 0.2 m/s^2, how long does it take it to reach its top speed?"

#25   The cat nods again. "Lastly, if the dragon did not have a top speed, and instead accelerated from rest at 0.2 m/s^2 for 450 seconds, how far would it travel?"
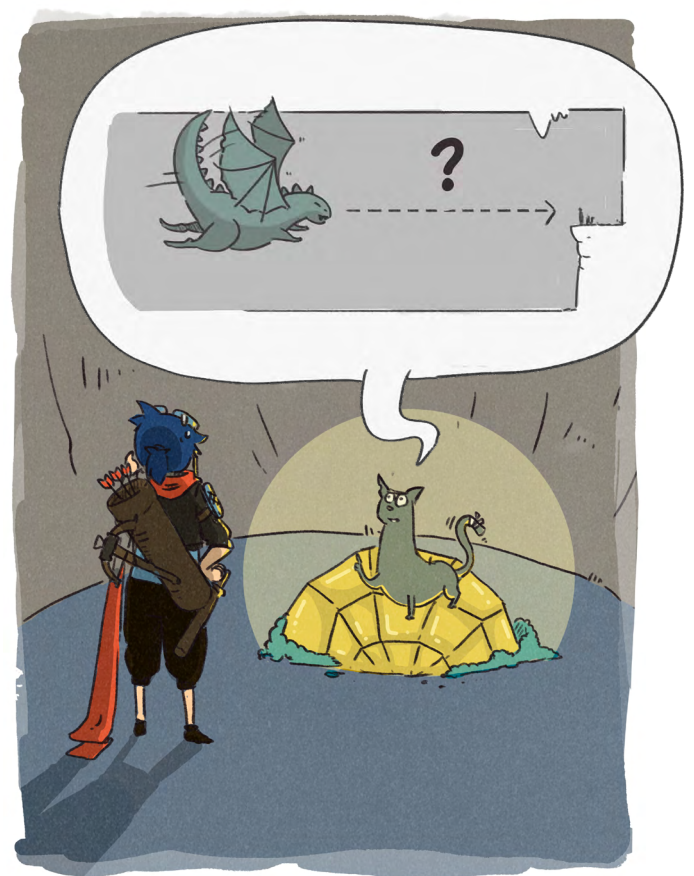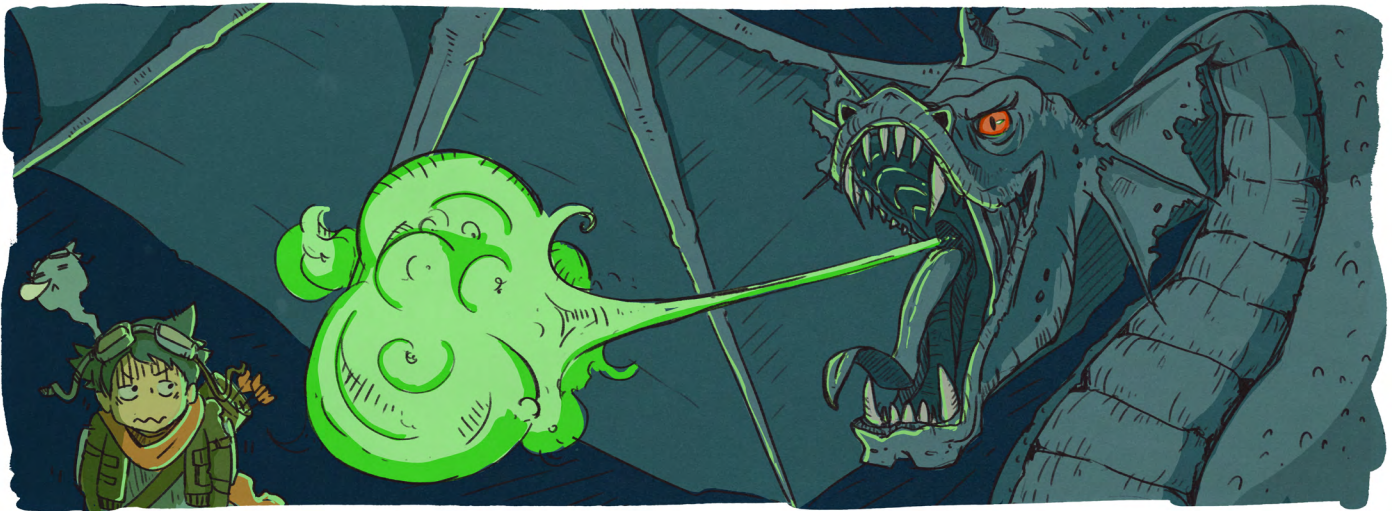
The cat licks its paw and contemplates you. "Very well. You have done well at the task I had my assistant set for you. I will accept you as my apprentice. You stare at the cat for several seconds as the rumbling increases behind you. You are still unsure what to ask when green flame erupts from the chasm. A scaly head with glowing red eyes and a cavernous mouth filled with sharp silver teeth like charred swords appears. The cat calmly approaches, leaping onto the top of its head, and looks back at you to see whether you are coming. You take a running leap onto the scaly face. You nearly fall off, but you just manage to grab a fistful of eyelid and haul yourself up. The dragon huffs as you settle yourself between the spikes on top of its head, next to the cat. Before you can ask the cat anything more, the dragon shoots off into the dark above.

ANSWER KEY

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1. 36 m

2. 72 m

3. 4 m/s

4. Correct! Or, not correct? Who knows what the right call was here, really.

5. 12 s

6. 810 m

7. 111.25 s

8. 5 m/s

9. 282 m

10. 20 m/s

11. 1,102.5 m if using 9.8 m/s^2 for g, 1125 m if using 10 m/s^2 for g

12. 147 m/s if using 9.8 m/s^2 for g, 150 m/s if using 10 m/s^2 for g

13. (Hint: the skull flies up for 4 seconds, and down for 4 seconds.) 39.2 m/s if using 9.8 m/s^2 for g, 40 m/s if using 10 m/s^2 for g 14. 117.6 m/s if using 9.8 m/s^2 for g, 120 m/s if using 10 m/s^2 for g 15. 705.6 m if using 9.8 m/s^2 for g, 720 m if using 10 m/s^2 for g 16. 16 m/s down

17. 378 m

18. 1,587.6 m if using 9.8 m/s^2 for g, 1620 m if using 10 m/s^2 for g

19. 156.8 m/s if using 9.8 m/s^2 for g, or 160 m/s if using 10 m/s^2 for g

20. 14 m/s

21. 89,302.5 m if using 9.8 m/s^2 for g, 91,125 m if using 10 m/s^2 for g

22. What? A cat? Well, it sort of makes sense. They do like sitting in warm places.

23. 942 s

24. 37 s

25. 20,250 m