CHAPTER ONE

SPEED AND VELOCITY. COMPOSITION OF MOTIONS

HOW FAST DO WE MOVE?

A good athlete can run 1.5 km in about 3 min 50 sec—the 1958 world record was 3 min 36.8 sec. Any ordinary person usually does, when walking, about 1.5 metres a second. Reducing the athlete's rate to a common denominator, we see that he covers seven metres every second. These speeds are not absolutely comparable though. Walking, you can keep on for hours on end at the rate of 5 km. p.h. But the runner will keep up his speed for only a short while. On quick march, infantry move at a speed which is but a third of the athlete's, doing 2 m/sec, or 7 odd km.p.h. But they can cover a much greater distance.

I daresay you would find it of interest to compare your normal walking pace with the "speed" of the proverbially slow snail or tortoise. The snail well lives up to its reputation, doing 1.5 mm/sec, or 5.4 metres p.h.—exactly one thousand times less than your rate. The other classically slow animal, the tortoise, is not very much faster, doing usually 70 metres p.h.

Nimble compared to the snail and the tortoise, you would find yourself greatly outraced when comparing your own motion with other motions—even not very fast ones—that we see all around us. True, you will easily outpace the current of most rivers in the plains and be a pretty good second to a moderate wind. But you will successfully vie with a fly, which does 5 m/sec, only if you don skis. You won't overtake a hare or a hunting dog even when riding a fast horse and you can rival the eagle only aboard a plane.

Still the machines man has invented make him second to none for speed. Some time ago a passenger hydrofoil ship, capable of 60-70 km. p.h., was launched in the U.S.S.R. (*Fig. 1*). On land you can move faster

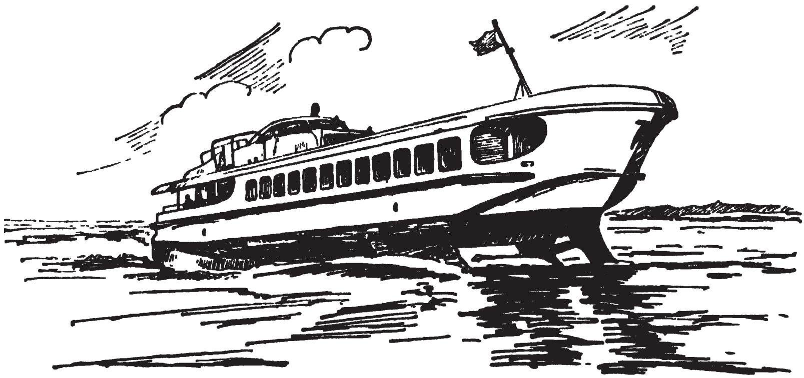

Fig. 1. Fast passenger hydrofoil ship

than on water by riding trains or motor cars—which can do up to 200 km. p.h. and more (*Fig. 2*). Modern aircraft greatly exceed even these speeds. Many Soviet air routes are serviced by the large TU-104

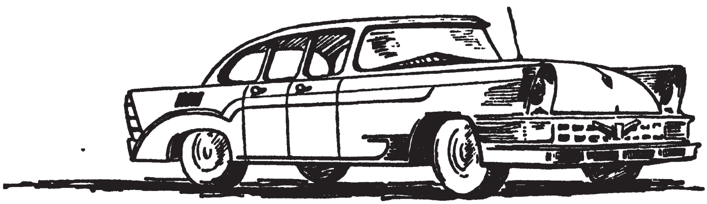

Fig. 2. New Soviet ZIL-111 motor car

(*Fig. 3*) and TU-114 jet liners, which do about 800 km. p.h. It was not so long ago that aircraft designers sought to overcome the "sound barrier", to attain speeds faster than that of sound, which is 330 m/sec, or 1,200 km. p.h. Today this has been achieved. We have some small but very fast supersonic jet aircraft that can do as much as 2,000 km.p.h.

There are man-made vehicles that can work up still greater speeds. The initial launching speed of the first Soviet sputnik was about

Fig. 3. TU-104 jet airliner

8 km/sec. Later Soviet space rockets exceeded the so-called "escape" velocity, which is 11.2 km/sec at ground level.

The following table gives some interesting speed data.

A snail	1.5 mm/sec	or	5.4 metres p.h.
A tortoise	20 "	or	70 "
A fish	1 m/sec	or	3.5 km. p.h
A pedestrian	1.4 "	or	5 "
Cavalry, pacing	1.7 "	or	6 "
" trotting	3.5 "	or	12.6 "
A fly	5 "	or	18 "
A skier	5 "	or	18 "
Cavalry, galloping	8.5 "	or	30 "
A hydrofoil ship	16 "	or	58 "
A hare	18 "	or	65 "
An eagle	24 "	or	86 "
A hunting dog	25 "	or	90 "
A train	28 "	or	100 "
A ZIL-111 passenger car	50 "	or	170 "
A racing car (record)	174 "	or	633 "
A TU-104 jet airliner	220 "	or	800 "
Sound in air	330 "	or	1,200 "
Supersonic jet aircraft	550 "	or	2,000 "
The earth's orbital velocity	30,000 "	or	108,000 "

RACING AGAINST TIME

Could one leave Vladivostok by air at 8 a.m. and land in Moscow at 8 a.m. on the same day?

I'm not talking through my hat. We can really do that. The answer lies in the 9-hour difference in Vladivostok and Moscow zonal times. If our plane covers the distance between the two cities in these 9 hours, it will land in Moscow at the very same time at which it took off from Vladivostok. Considering that the distance is roughly 9,000 kilometres, we must fly at a speed of 9,000:9=1,000 km. p.h., which is quite possible today.

To "outrace the Sun" (or rather the earth) in Arctic latitudes, one can go much more slowly. Above Novaya Zemlya, on the 77th parallel, a plane doing about 450 km. p.h. would cover as much as a definite point on the surface of the globe would cover in an identical space of time in the process of the earth's axial rotation. If you were flying in such a plane you would see the sun suspended in immobility. It would never set, provided, of course, that your plane was moving in the proper direction.

It is still easier to "outrace the Moon" in its revolution around the earth. It takes the moon 29 times longer to spin round the earth than it takes the earth to complete one rotation (we are comparing, naturally, the so-called "angular", and not linear, velocities). So any ordinary steamer making 15-18 knots could "outrace the Moon" even in the moderate latitudes.

Mark Twain mentions this in his *Innocents Abroad*. When sailing across the Atlantic, from New York to the Azores "... we had balmy summer weather, and nights that were even finer than the days. We had the phenomenon of a full moon located just in the same spot in the heavens at the same hour every night. The reason for this singular conduct on the part of the moon did not occur to us at first, but it did afterward when we reflected that we were gaining about twenty minutes every day, because we were going east so fast—we gained just enough every day to keep along with the moon."

THE THOUSANDTH OF A SECOND

For us humans, the thousandth of a second is nothing from the angle of time. Time intervals of this order have only started to crop up in some of our practical work. When people used to reckon the time according to the sun's position in the sky, or to the length of a shadow (*Fig. 4*), they paid no heed to minutes, considering them even unworthy

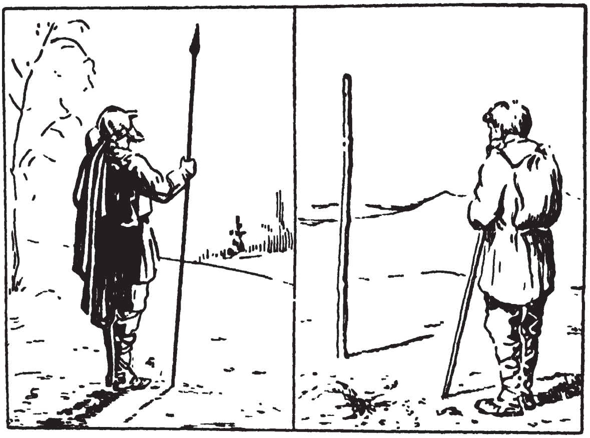

Fig. 4. How to reckon the time according to the position of the sun (left), and by the length of a shadow (right)

of measurement. The tenor of life in ancient times was so unhurried that the timepieces of the day—the sun-dials, sand-glasses and the like—had no special divisions for minutes (*Fig. 5*). The minute hand first appeared only in the early 18th century, while the second sweep came into use a mere 150 years ago.

But back to our thousandth of a second. What do you think could happen in this space of time? Very much, indeed! True, an ordinary train would cover only some 3 cm. But sound would already fly 33 cm and a plane half a metre. In its orbital movement around the sun, the earth would travel 30 metres. Light would cover the great distance of 300 km. The minute organisms around us wouldn't think the thousandth of a second so negligible an amount of time—if they could think of course. For insects it is quite a tangible interval. In the space of a second a mosquito flaps its wings 500 to 600 times. Consequently in the space of a thousandth of a second, it would manage either to raise its wings or lower them.

We can't move our limbs as fast as insects. The fastest thing we can do is to blink our eyelids. This takes place so quickly that we fail even to notice the transient obscurement of our field of vision. Few know, though, that this movement, "in the twinkling of an eye"—which has

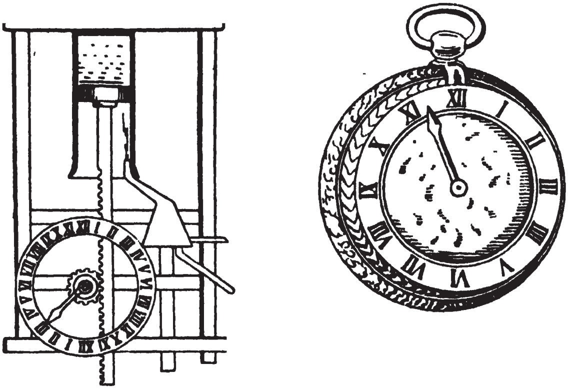

Fig. 5. An ancient water clock (left) and an old pocket-watch (right). Note that neither has the minute hand

become synonymous for incredible rapidity—is quite slow if measured in thousandths of a second. A full "twinkling of an eye" averages—as exact measurement has disclosed—two-fifths of a second, which gives us 400 thousandths of a second. This process can be divided into the following stages: firstly, the dropping of the eyelid which takes 75-90 thousandths of a second; secondly, the closed eyelid in a state of rest, which takes up 130-170 thousandths; and, thirdly, the raising of the eyelid, which takes about 170 thousandths.

As you see, this one "twinkling of an eye" is quite a considerable time interval, during which the eyelid even manages to take a rest. If we could photograph mentally impressions lasting the thousandth of a second, we would catch in the "twinkling of an eye" two smooth motions of the eyelid, separated by a period during which the eyelid would be at rest.

Generally speaking, the ability to do such a thing would completely transform the picture we get of the world around us and we would see the odd and curious things that H. G. Wells described in his *New Accelerator*. This story relates of a man who drank a queer mixture which caused him to see rapid motions as a series of separate static phenomena. Here are a few extracts.

"'Have you ever seen a curtain before a window fixed in that way before?'

"I followed his eyes, and there was the end of the curtain, frozen, as it were, corner high, in the act of flapping briskly in the breeze.

"'No,' said I, 'that's odd.'

"'And here,' he said, and opened the hand that held the glass. Naturally I winced, expecting the glass to smash. But so far from smashing it did not even seem to stir; it hung in mid-air—motionless. 'Roughly speaking,' said Gibberne, 'an object in these latitudes falls 16 feet in a second. This glass is falling 16 feet in a second now. Only you see, it hasn't been falling yet for the hundredth part of a second. [Note also that in the first hundredth of the first second of its downward flight a body, the glass in this case, covers not the hundredth part of the distance, but the 10,000th part (according to the formula $S=1/2\ gt^2$). This is only 0.5 mm and in the first thousandth of the second it would be only 0.01 mm.]

"'That gives you some idea of the pace of my Accelerator.' And he waved his hand round and round, over and under the slowly sinking glass.

"Finally he took it by the bottom, pulled it down and placed it very carefully on the table. 'Eh?' he said to me, and laughed....

"I looked out of the window. An immovable cyclist, head down and with a frozen puff of dust behind his driving-wheel, scorched to overtake a galloping *char-à-banc* that did not stir....

"We went out by his gate into the road, and there we made a minute examination of the statuesque passing traffic. The top of the wheels and some of the legs of the horses of this *char-à-banc*, the end of the whip lash and the lower jaw of the conductor—who was just beginning to yawn—were perceptibly in motion, but all the rest of the lumbering conveyance seemed still. And quite noiseless except for a faint rattling that came from one man's throat! And as parts of this frozen edifice there were a driver, you know, and a conductor, and eleven people!...

"A purple-faced little gentleman was frozen in the midst of a violent struggle to refold his newspaper against the wind; there were many evidences that all these people in their sluggish way were exposed to a considerable breeze, a breeze that had no existence so far as our sensations went....

"All that I had said, and thought, and done since the stuff had begun to work in my veins had happened, so far as those people, so far as the world in general went, in the twinkling of an eye...."

Would you like to know the shortest stretch of time that scientists can measure today? Whereas at the beginning of this century it was only the 10,000th of a second, today the physicist can measure the 100,000 millionth of a second; this is about as many times less than a second as a second is less than 3,000 years!

THE SLOW-MOTION CAMERA

When H. G. Wells was writing his story, scarcely could he have ever thought he would see anything of the like. However he did live to see the pictures he had once imagined, thanks to what has been called the slow-motion camera. Instead of 24 shots a second—as ordinary motion-picture cameras do—this camera makes many times more. When a film shot in this way is projected onto the screen with the usual speed of 24 frames a second, you see things taking place much more slowly than normally—high jumps, for instance, seem unusually smooth. The more complex types of slow-motion cameras will almost simula H. G. Wells's world of fantasy.