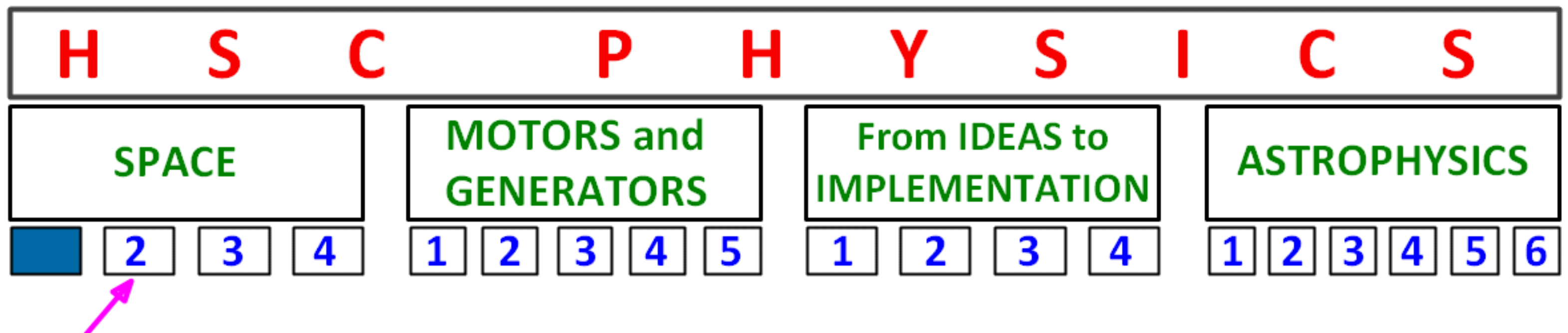


SPACE

1st Quarter; Module 1

PERIOD 11

Effects of Earth Motion on Rocket Launch &
Rocket motion



SPACE 2

Many factors have to be taken into account to achieve a successful rocket launch, maintain a stable orbit and return to Earth

Students learn to:

- describe the trajectory of an object undergoing projectile motion within the Earth's gravitational field in terms of horizontal and vertical components
- describe Galileo's analysis of projectile motion
- explain the concept of escape velocity in terms of the:
 - gravitational constant
 - mass and radius of the planet
- outline Newton's concept of escape velocity
- identify why the term 'g forces' is used to explain the forces acting on an astronaut during launch
- discuss the effect of the Earth's orbital motion and its rotational motion on the launch of a rocket
- analyse the changing acceleration of a rocket during launch in terms of the:
 - Law of Conservation of Momentum
 - forces experienced by astronauts
- analyse the forces involved in uniform circular motion for a range of objects, including satellites orbiting the Earth
- compare qualitatively low Earth and geo-stationary orbits
- define the term orbital velocity and the quantitative and qualitative relationship between orbital velocity, the gravitational constant, mass of the central body, mass of the satellite and the radius of the orbit using Kepler's Law of Periods
- account for the orbital decay of satellites in low Earth orbit
- discuss issues associated with safe re-entry into the Earth's atmosphere and landing on the Earth's surface
- identify that there is an optimum angle for safe re-entry for a manned spacecraft into the Earth's atmosphere and the consequences of failing to achieve this angle

SPACE 2

Many factors have to be taken into account to achieve a successful rocket launch, maintain a stable orbit and return to Earth

Students:

- solve problems and analyse information to calculate the actual velocity of a projectile from its horizontal and vertical components using:

$$v_x^2 = u_x^2$$

$$v = u + at$$

$$v_y^2 = u_y^2 + 2a_y\Delta y$$

$$\Delta x = u_x t$$

$$\Delta y = u_y t + \frac{1}{2} a_y t^2$$

- perform a first-hand investigation, gather information and analyse data to calculate initial and final velocity, maximum height reached, range and time of flight of a projectile for a range of situations by using simulations, data loggers and computer analysis
- identify data sources, gather, analyse and present information on the contribution of one of the following to the development of space exploration: Tsiolkovsky, Oberth, Goddard, Esnault-Pelterie, O'Neill or von Braun
- solve problems and analyse information to calculate the centripetal force acting on a satellite undergoing uniform circular motion about the Earth using

$$F = \frac{mv^2}{r}$$

- solve problems and analyse information using:

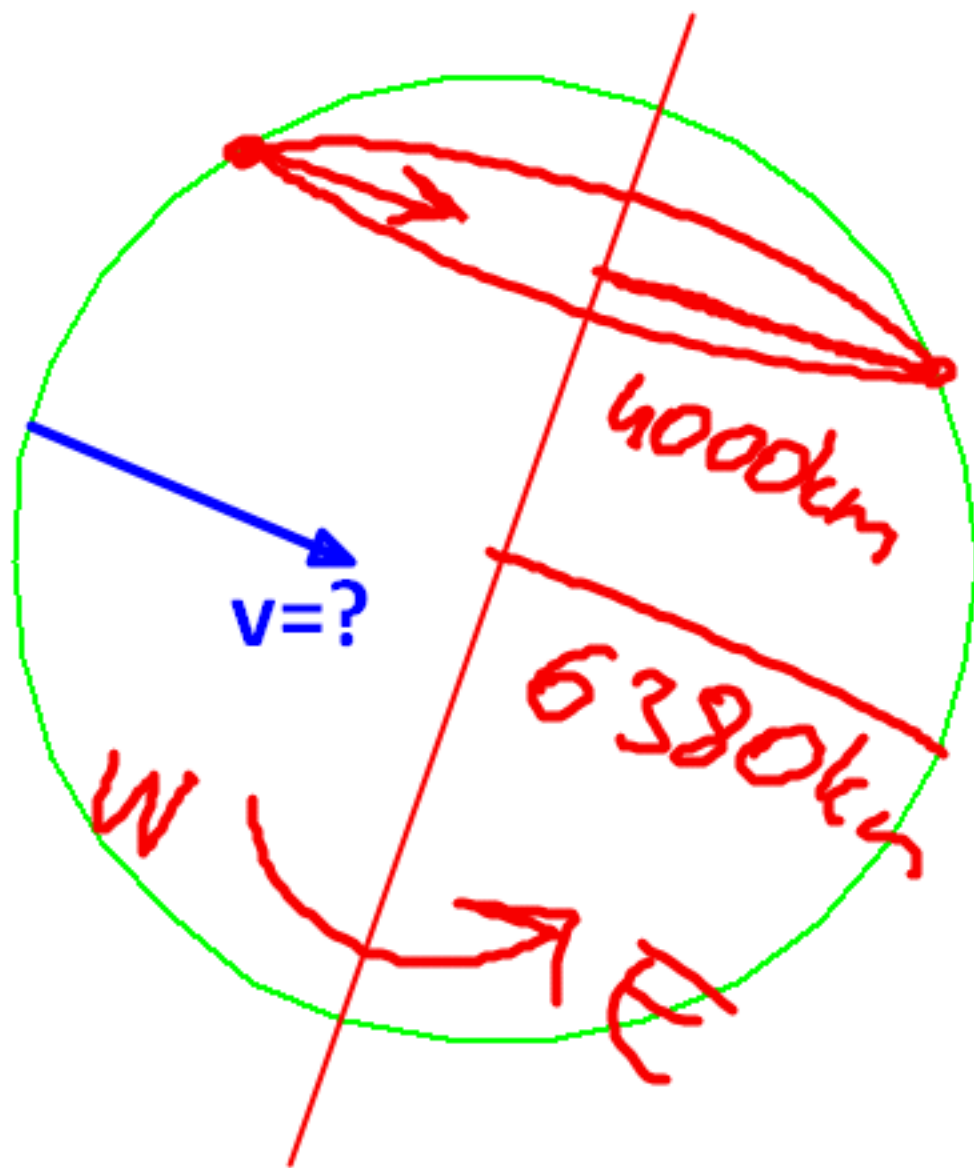
$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

EFFECTS OF EARTH'S MOTION ON THE LAUNCH OF ROCKETS

EARTH HAS TWO TYPES OF MOTION

1. ROTATIONAL; ROTATING ON ITS OWN AXIS

What is the speed of a point on the equator due to Earth's rotation on its axis?



$$v = \frac{2\pi R}{24 \text{ hours}} = \frac{2\pi 6380}{24 \text{ h}} \approx 1700 \text{ km/h}$$

R

2. ORBITAL; ORBITTING AROUND THE SUN

1. ROTATIONAL; ROTATING ON ITS OWN AXIS

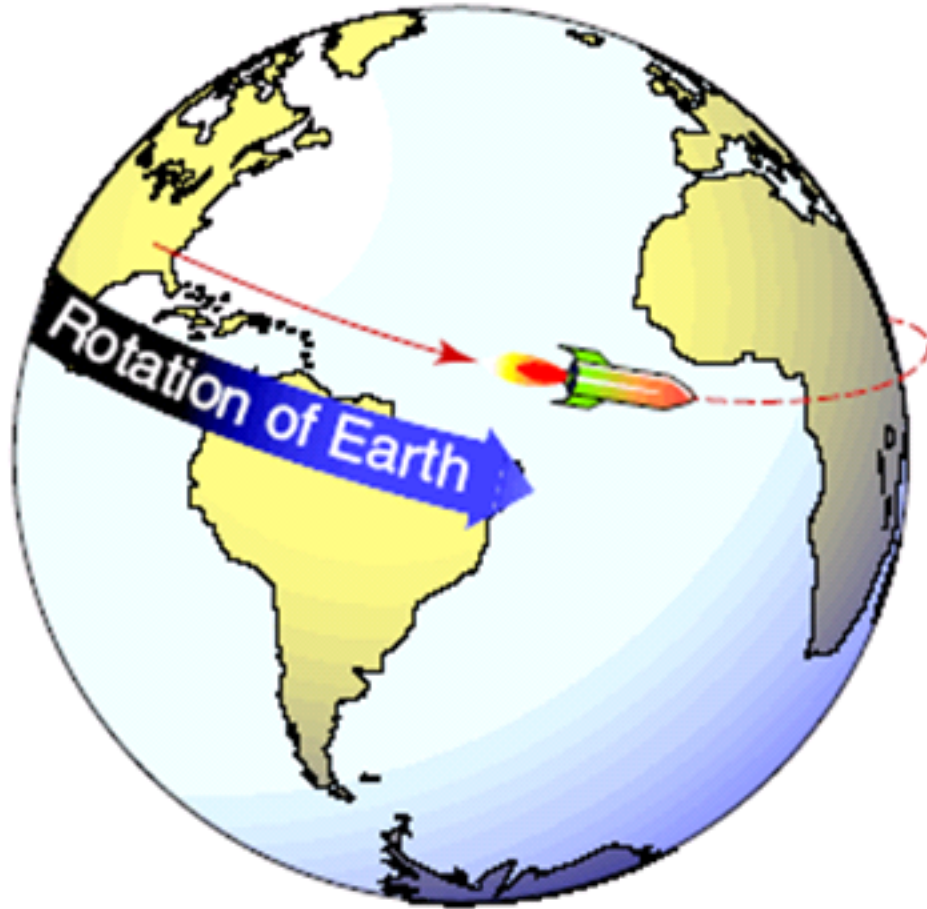


Figure 2.23 *A rocket heading into orbit is launched to the east to receive a velocity boost from the Earth's rotational motion.*

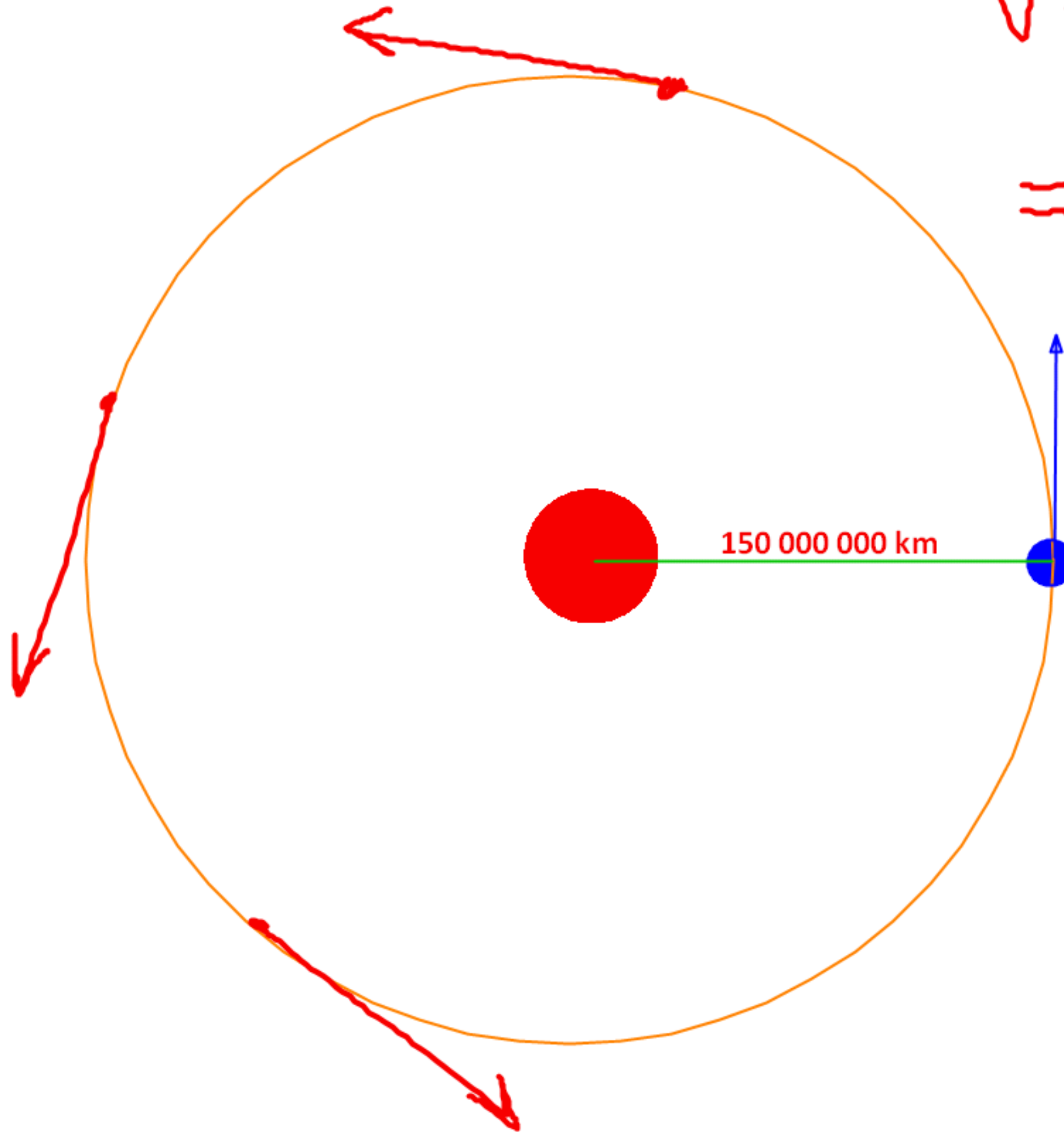
Engineers planning to launch a rocket into orbit can exploit the Earth's rotation in order to achieve the velocity needed for a stable orbit.

This is done by launching in the direction of the Earth's rotation; that is, by launching toward the east.

In this way, the rotational velocity of the launch site relative to the Sun will add to the orbital velocity of the rocket relative to the Earth, to produce a higher orbital velocity achieved by the rocket relative to the Sun.

2. ORBITAL; ORBITTING AROUND THE SUN

What is the Earth's speed due to its orbit around the Sun?



$$v = \frac{2\pi R}{T}$$
$$= \frac{2\pi \cdot 150 \times 10^6 \text{ km}}{365 \times 24 \text{ h}}$$

$$= 108\,000 \text{ km/h}$$

$$\approx 100\,000 \text{ km/h}$$

$$\approx 30\,000 \text{ m/s}$$

2. ORBITAL; ORBITTING AROUND THE SUN

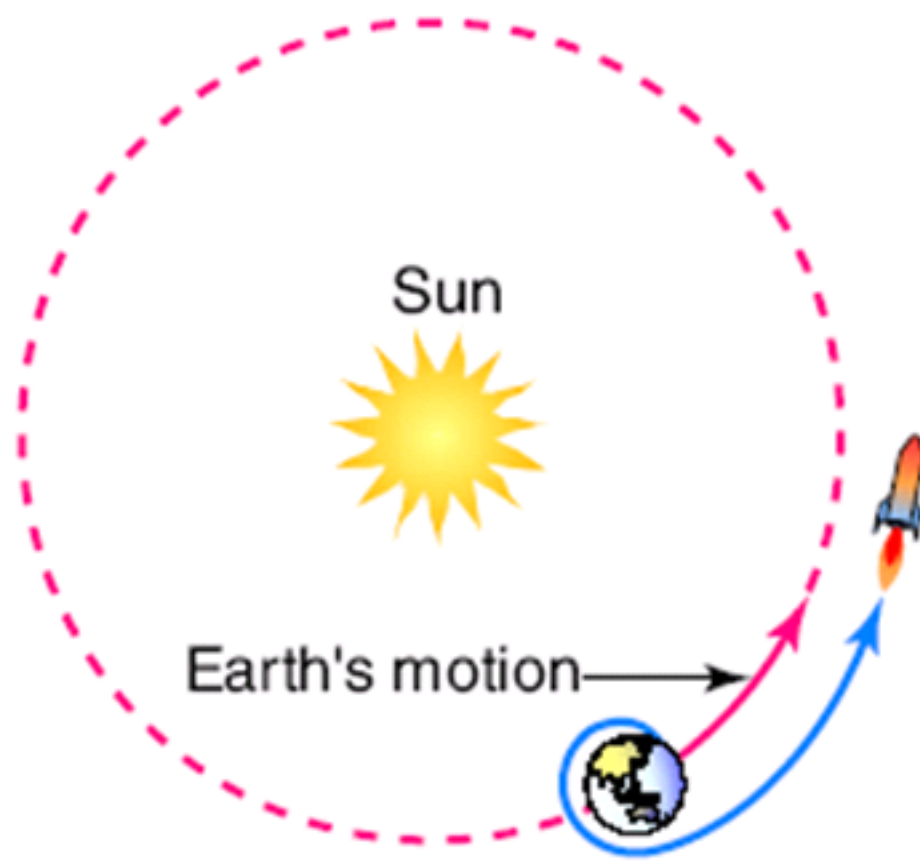


Figure 2.24 *The flight of a rocket heading into space is timed so that it can head out in the direction of the Earth's motion and thereby receive an extra boost.*

Engineers planning a rocket mission heading further into space can exploit the Earth's revolution around the Sun by planning the launch for a time of year when the direction of the Earth's orbital velocity corresponds to the desired heading.

Only then is the rocket launched up into orbit.

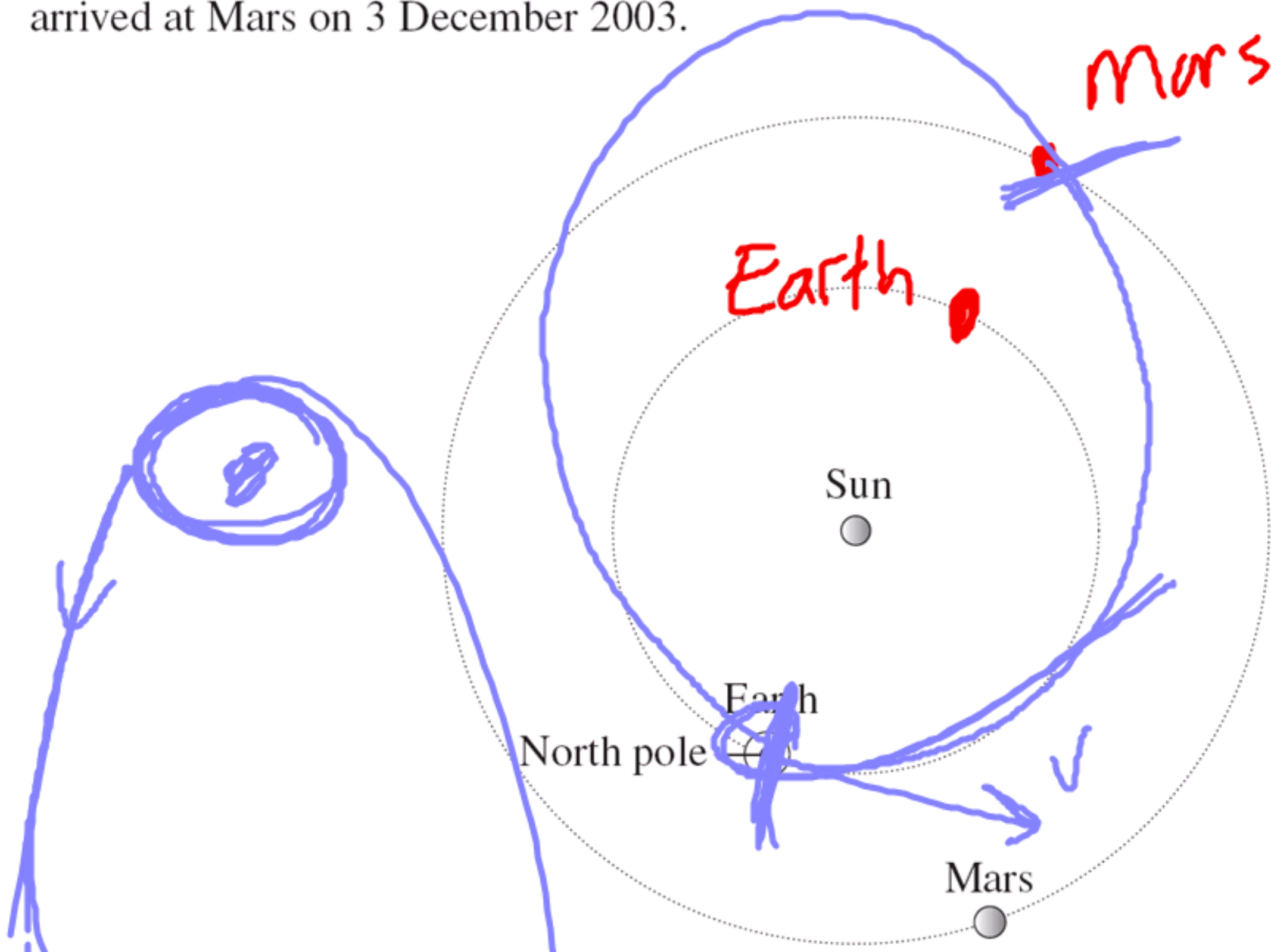
The rocket is allowed to proceed around its orbit until the direction of its orbital velocity corresponds with the Earth's, and then its engines are fired to push it out of orbit and further into space.

In this way the Earth's orbital velocity relative to the Sun adds to the rocket's orbital velocity relative to the Earth, to produce a higher velocity achieved by the rocket relative to the Sun.

2004 HSC PAPER

Question 19 (6 marks)

On 11 June 2003 the Mars Rover called Spirit was launched on a satellite from Earth when the planets were in the positions shown in the diagram below. The satellite arrived at Mars on 3 December 2003.

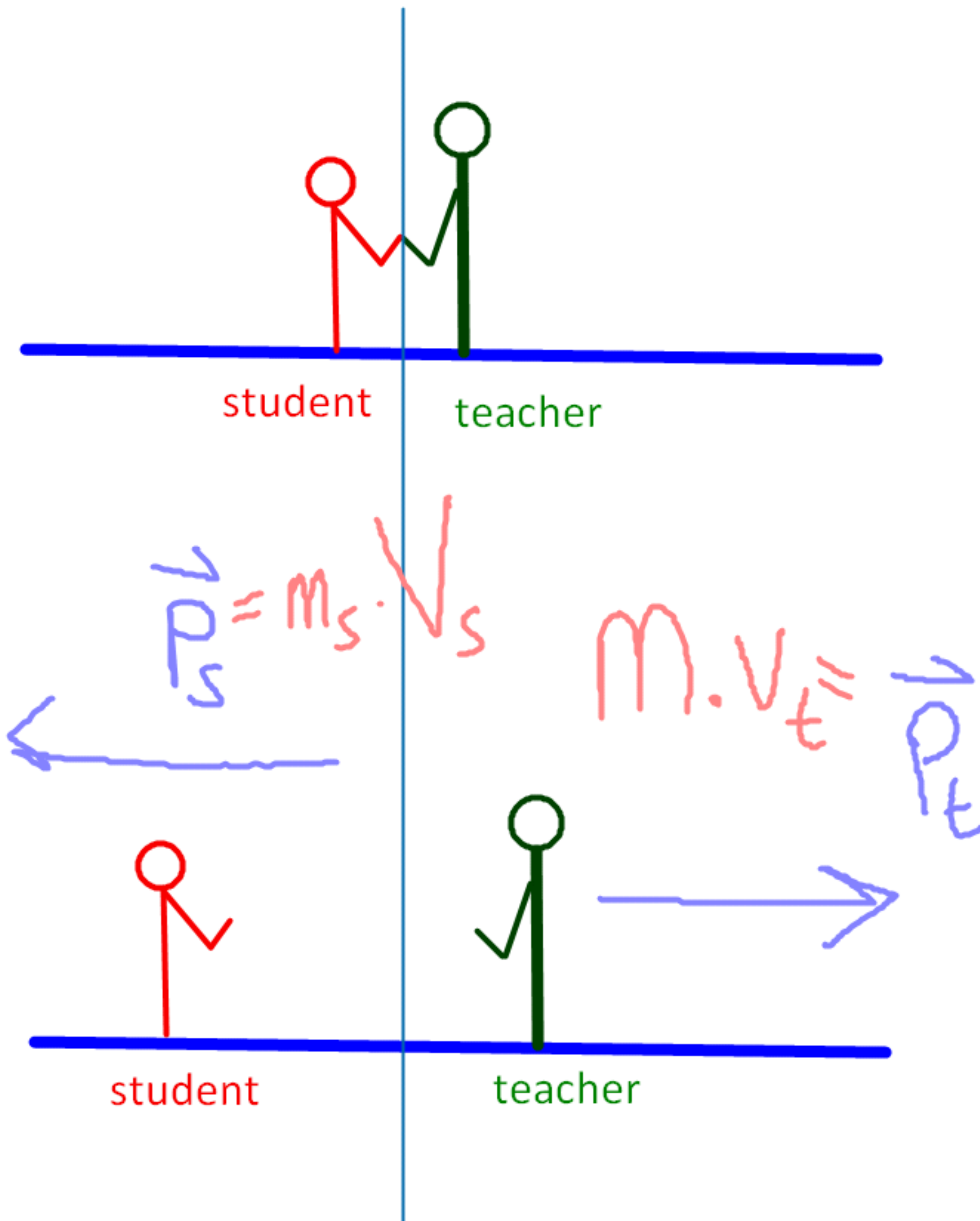


- (a) Indicate on the diagram the approximate positions of Earth and Mars on 3 December 2003 and show the satellite's trajectory to Mars. 3
- (b) Discuss the effect of Earth's motion on the launch and trajectory to Mars of this satellite. 3

HOW DO ROCKETS MOVE IN SPACE (OR NEAR EARTH'S SURFACE) ?

THERE ARE TWO COMMON METHODS OF GOING SPACE

Imagine a teacher (90 kg) and a student (50 kg) pushing each other on ice as shown below. what would you say for the momentum and velocities of both as they leave each other?



$$\vec{p}_i = 0 = \vec{p}_f$$

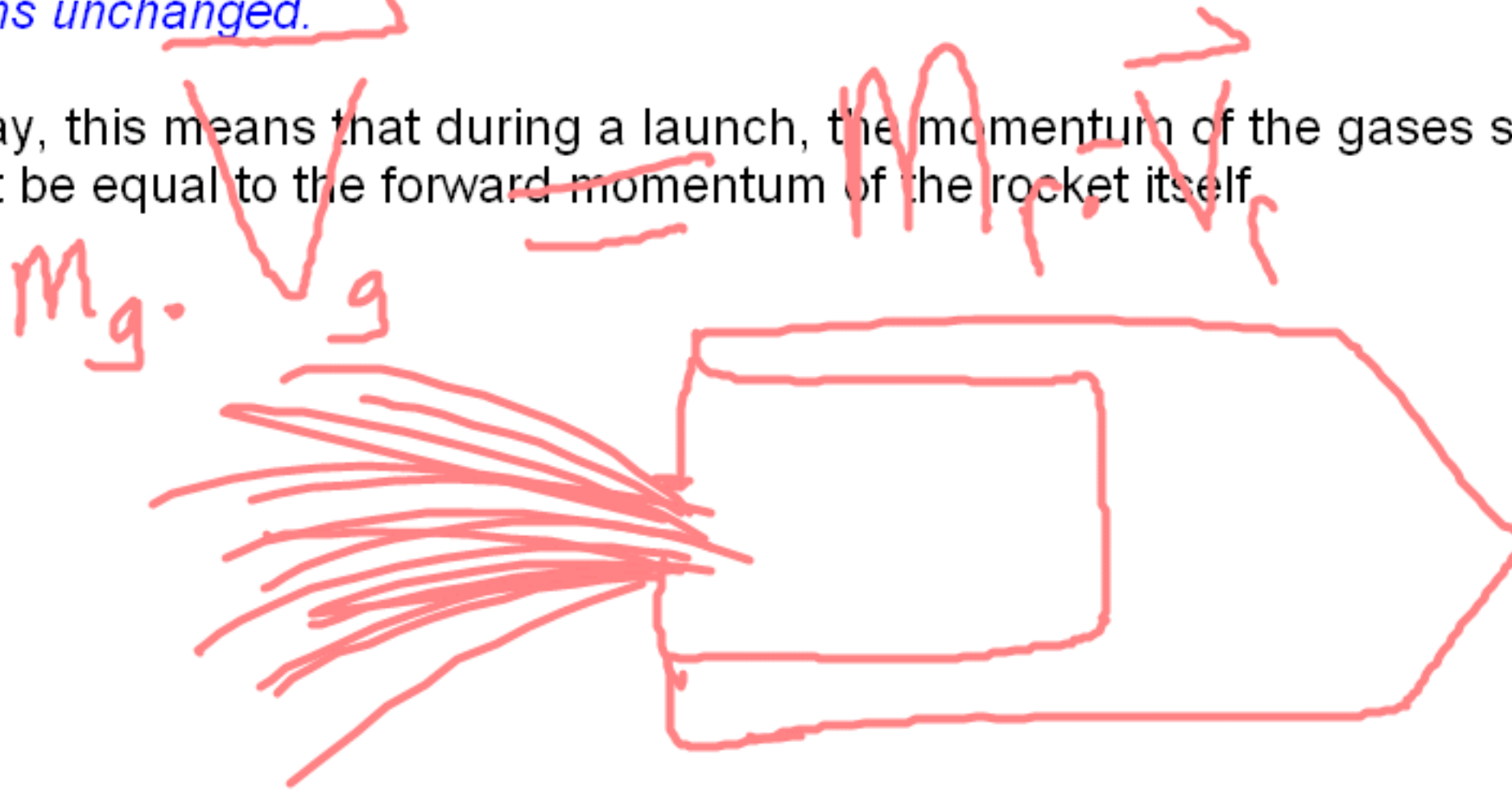
$$\vec{p}_f = 0 \Rightarrow \vec{p}_s = -\vec{p}_t$$

$$m_s \cdot \vec{v}_s = m_t \cdot -\vec{v}_t$$

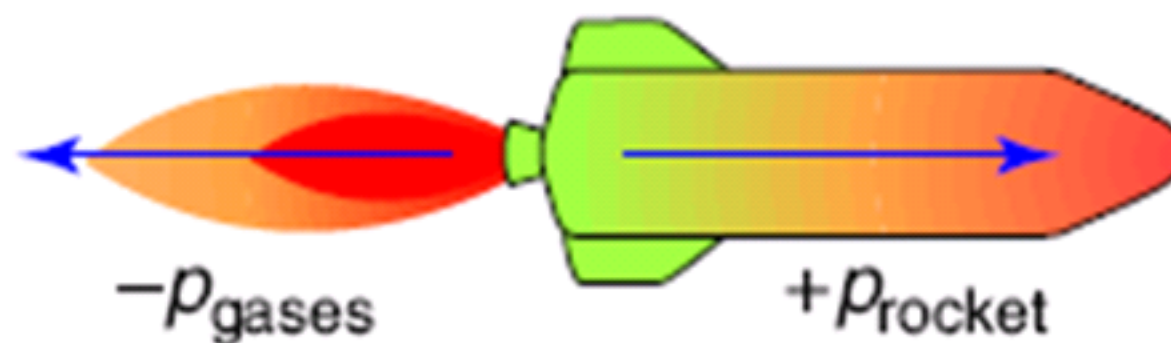
CONSERVATION OF MOMENTUM

The Law of Conservation of Momentum: During any interaction in a closed system the total momentum of the system remains unchanged.

Stated another way, this means that during a launch, the momentum of the gases shooting out of the rear of the rocket must be equal to the forward momentum of the rocket itself.



This means that the backward momentum of the gases is exactly equal in magnitude to the forward momentum of the rocket, endowing the rocket with forward velocity.



It is important to note that, while the mass of the gases during any given second is less than the mass of the rocket, their velocity is much greater, so that their momenta are equal but opposite.

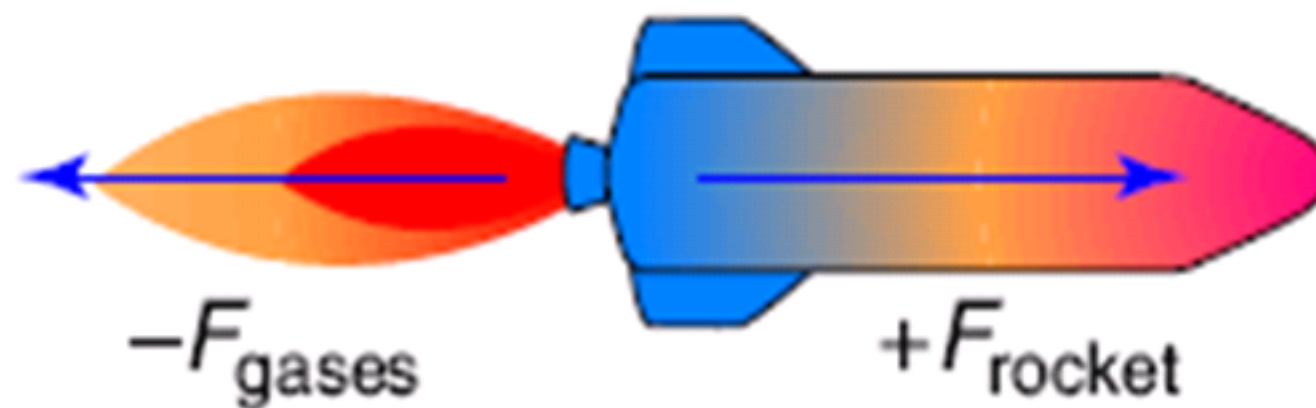
FORCES EXPERIENCED BY BOTH

Newton's Third Law of Motion. This law says that for every force there is an equal but opposite force. And this is also the case here.

How?

$$\overleftarrow{F_{\text{on gas by rocket}}} = - \overrightarrow{F_{\text{on rocket by gas}}}$$

The rocket is forcing a large volume of gases backward behind it, and the gases, in turn, force the rocket forward.



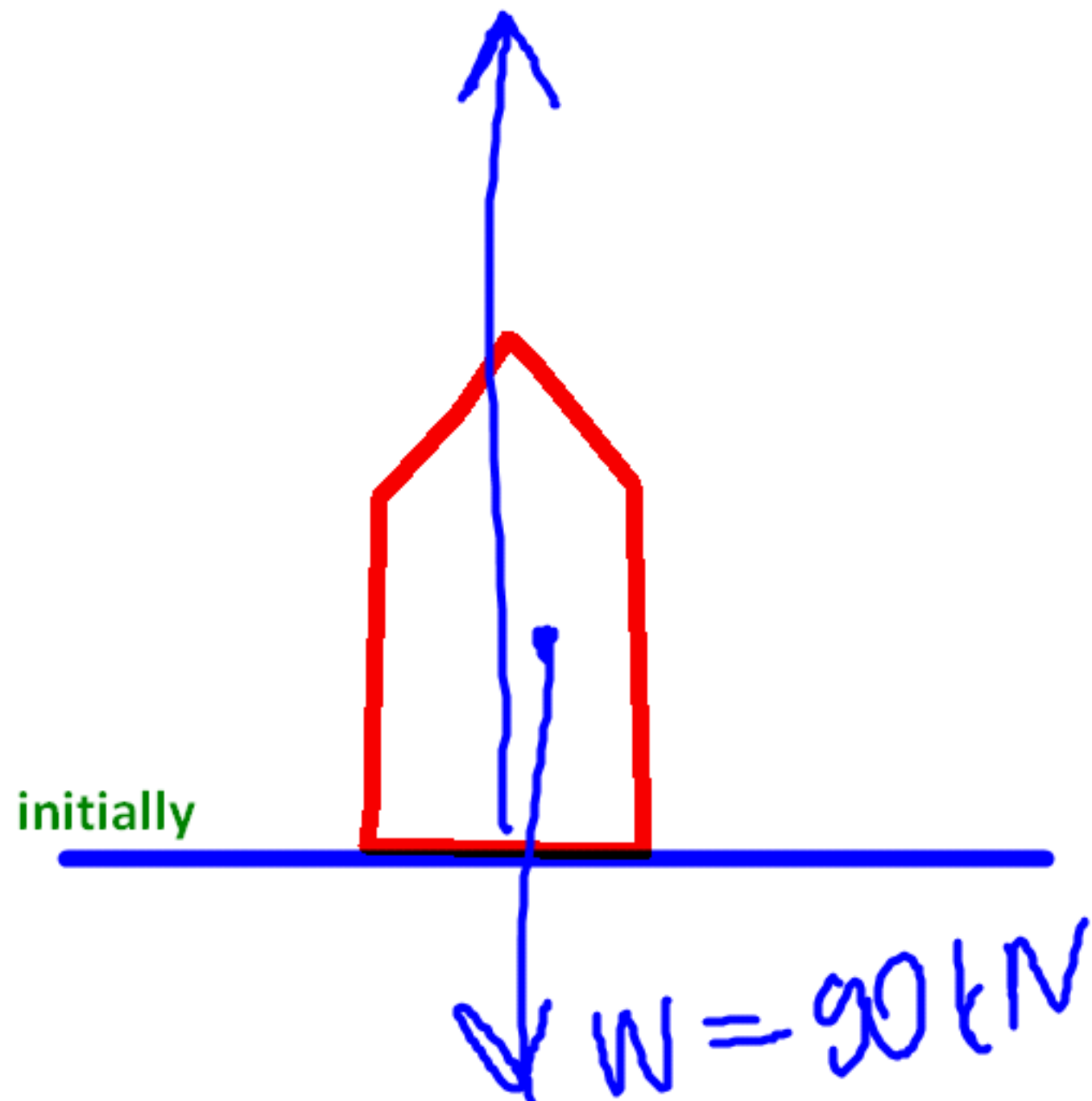
Although the two forces are equal and opposite, the rocket experiences just one of them — the forward push that we call thrust.

Calculating the g force on a rocket > The test rocket has a pre-launch mass of 9000 kg, of which 3000 kg is solid propellant. It is able to deliver a thrust of 120 000 N for a period of 5s. (take g as 10 m/s^2 and assume it stays constant) Assuming that the rocket is fired directly up, determine:
(a) the initial rate of acceleration and g force
(b) the final rate of acceleration and g force just prior to exhaustion of the fuel.

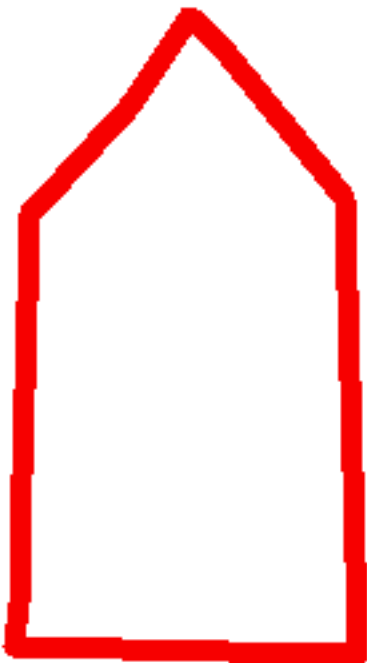
$$F_{\text{net}} = 30 \text{ kN}$$

$$T = 120 \text{ kN} \quad a = \frac{30000}{9000} \approx 3.5 \text{ m/s}^2$$

$$g\text{-f} = \frac{g+a}{g} \approx 1.5$$



Calculating the *g* force on a rocket > The test rocket has a pre-launch mass of 9000 kg, of which 3000 kg is solid propellant. It is able to deliver a thrust of 120 000 N for a period of 5s. (take *g* as 10 m/s² and assume it stays constant) Assuming that the rocket is fired directly up, determine:
(a) the initial rate of acceleration and *g* force
(b) the final rate of acceleration and *g* force just prior to exhaustion of the fuel.



at the
exhaustion
of the fuel



HOMEWORK

- ✦ Homework is an integral part of your "Learning Curve", take it seriously!
- ✦ Target minimum 1 hour of Physics everyday
- ✦ Divide your physics home study in three segments;
 - ✓ Revision (past)
 - ✓ Homework (present)
 - ✓ Tomorrow (future)
- ✦ Homework is due next period, unless otherwise stated
- ✦ If you cannot do all, at least do a few from each piece

*Apart from **reading the relevant pages from the textbook and solving the rest of the questions in this booklet** your homework is:*

1. New Booklet (8 page)
2. Chapter 2 Questions 1-20

Also

PM Practice Booklet

All Questions in Period 7 & 8 Booklets

Experiment 4 Report

NEXT PERIOD >

CIRCULAR MOTION