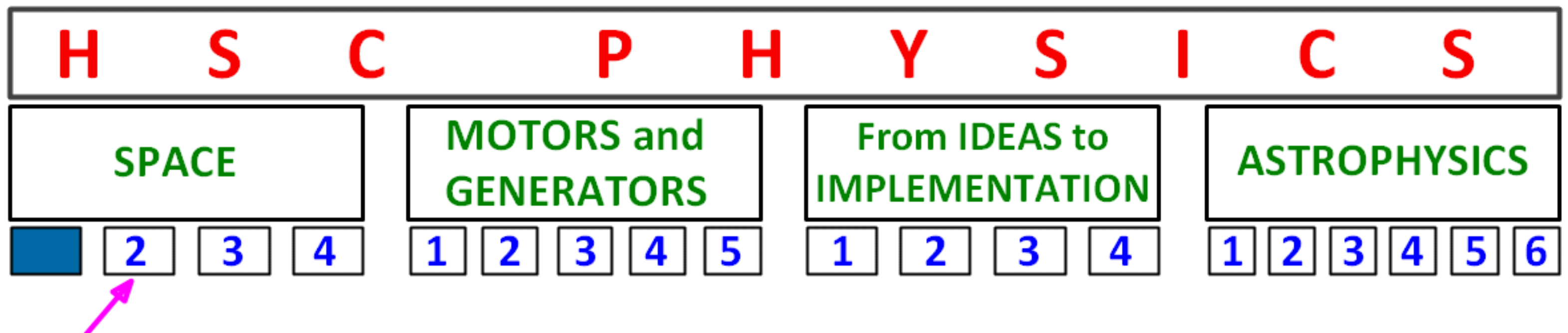


SPACE

1st Quarter; Module 1

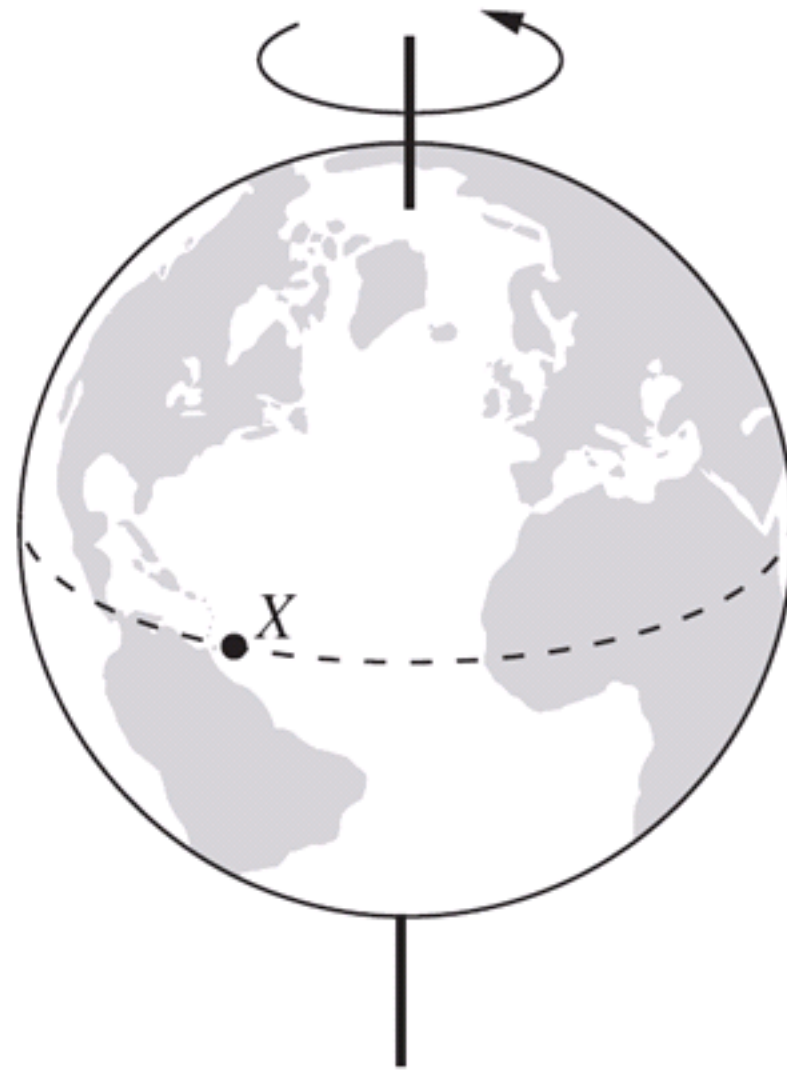
PERIOD 12

Circular Motion - Satellites



Question 17 (4 marks)

The diagram shows the position X on Earth's surface from which a satellite is to be launched into a geostationary orbit.



- (a) On the diagram, draw an arrow to show the direction of launch from X , and justify your choice.

1

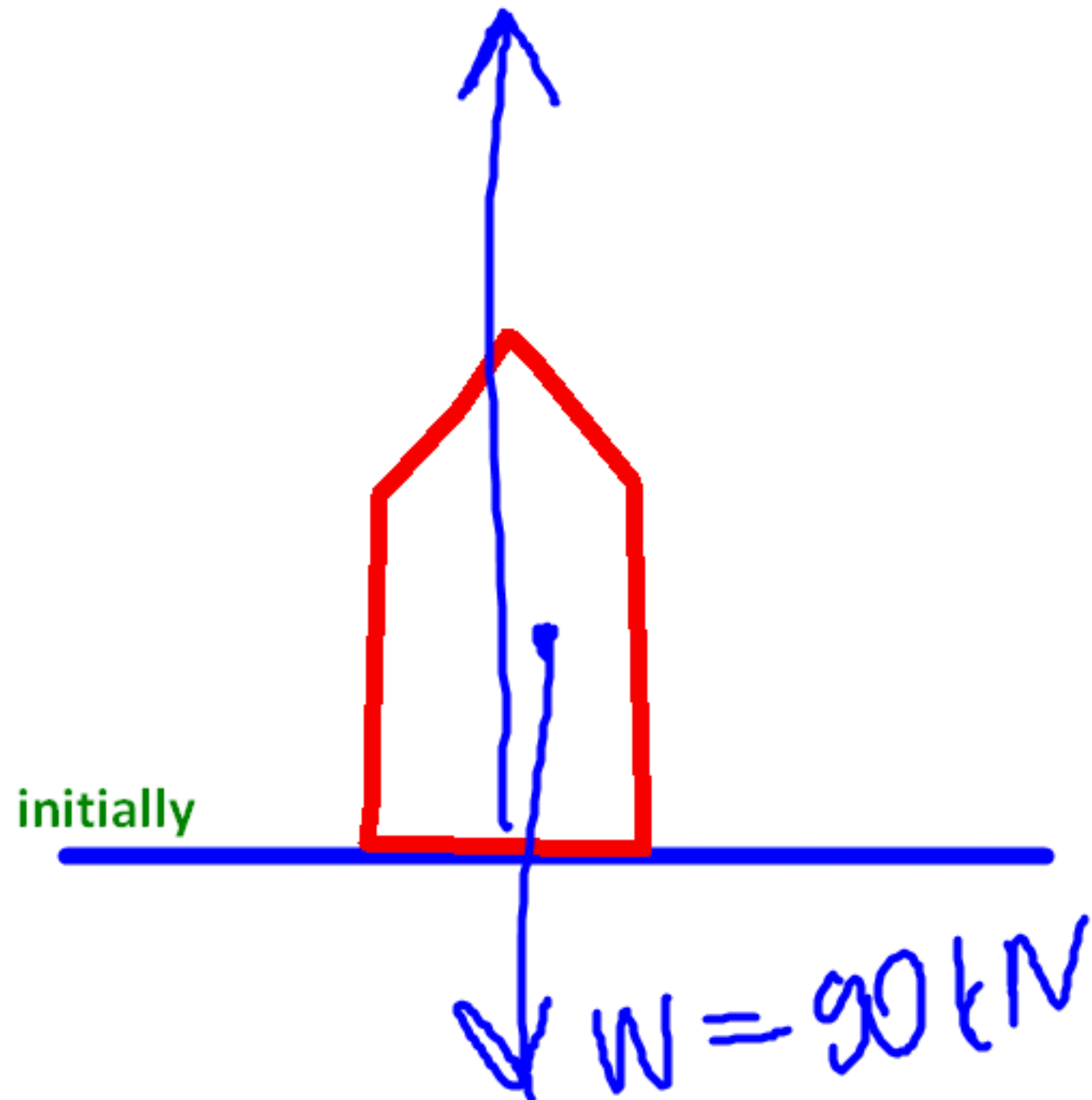
Calculating the g force on a rocket > The test rocket has a pre-launch mass of 9000 kg, of which 3000 kg is solid propellant. It is able to deliver a thrust of 120 000 N for a period of 5s. (take g as 10 m/s^2 and assume it stays constant) Assuming that the rocket is fired directly up, determine:
(a)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

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

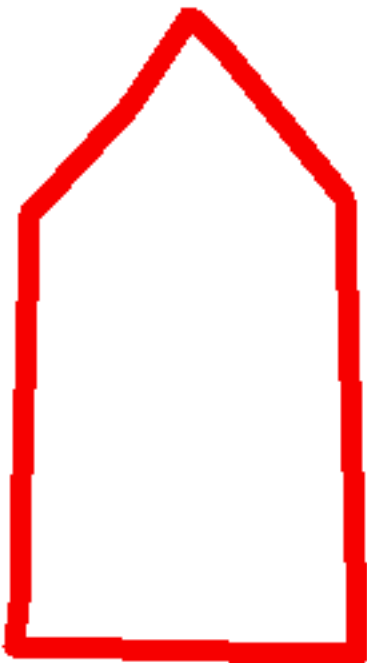
$$T = 120 \text{ kN}$$

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

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



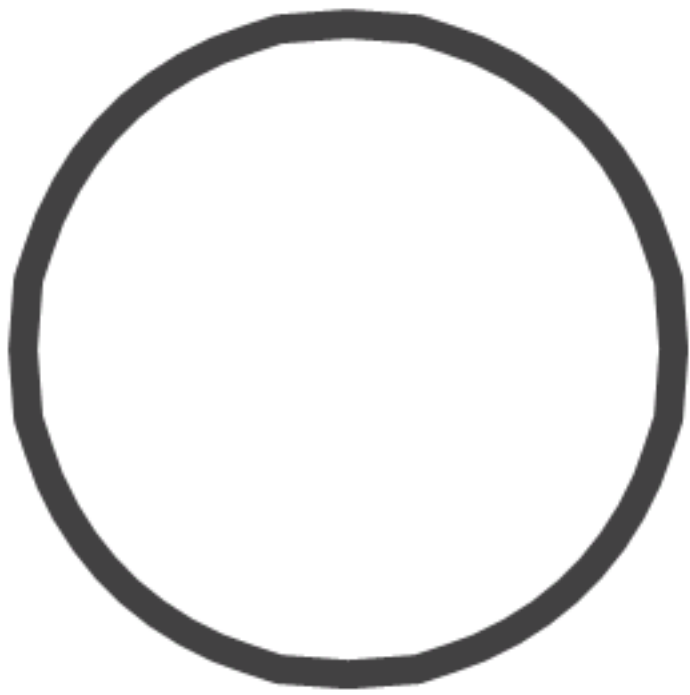
Calculating the g force on a rocket > The test rocket has a pre-launch mass of 9000 kg, of which 3000 kg is solid propellant. It is able to deliver a thrust of 120 000 N for a period of 5s. (take g as 10 m/s^2 and assume it stays constant) Assuming that the rocket is fired directly up, determine:
(a)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



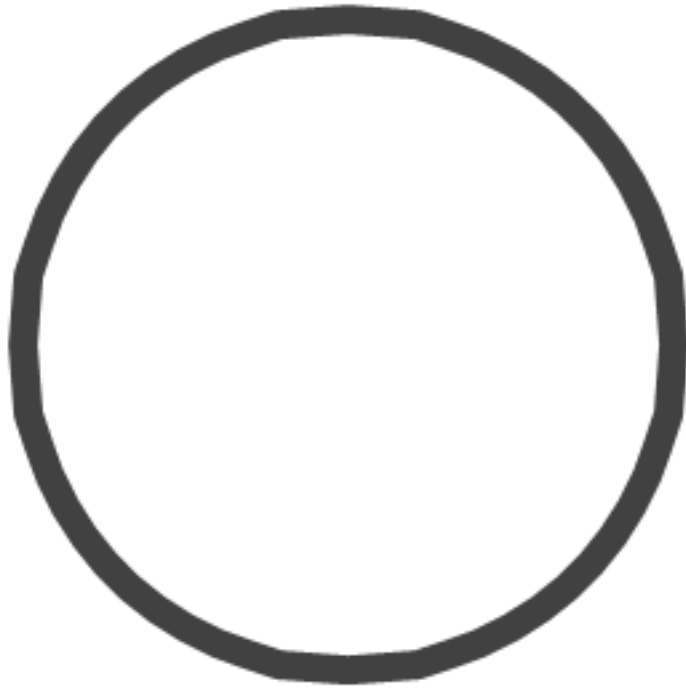
at the
exhaustion
of the fuel



VEHICLES CARRYING HUMANS GO TO SPACE. THEY SPEND DAYS AND WEEKS IN SPACE AROUND EARTH. **HOW DO THEY STAY THERE WITHOUT FALLING ON EARTH?**



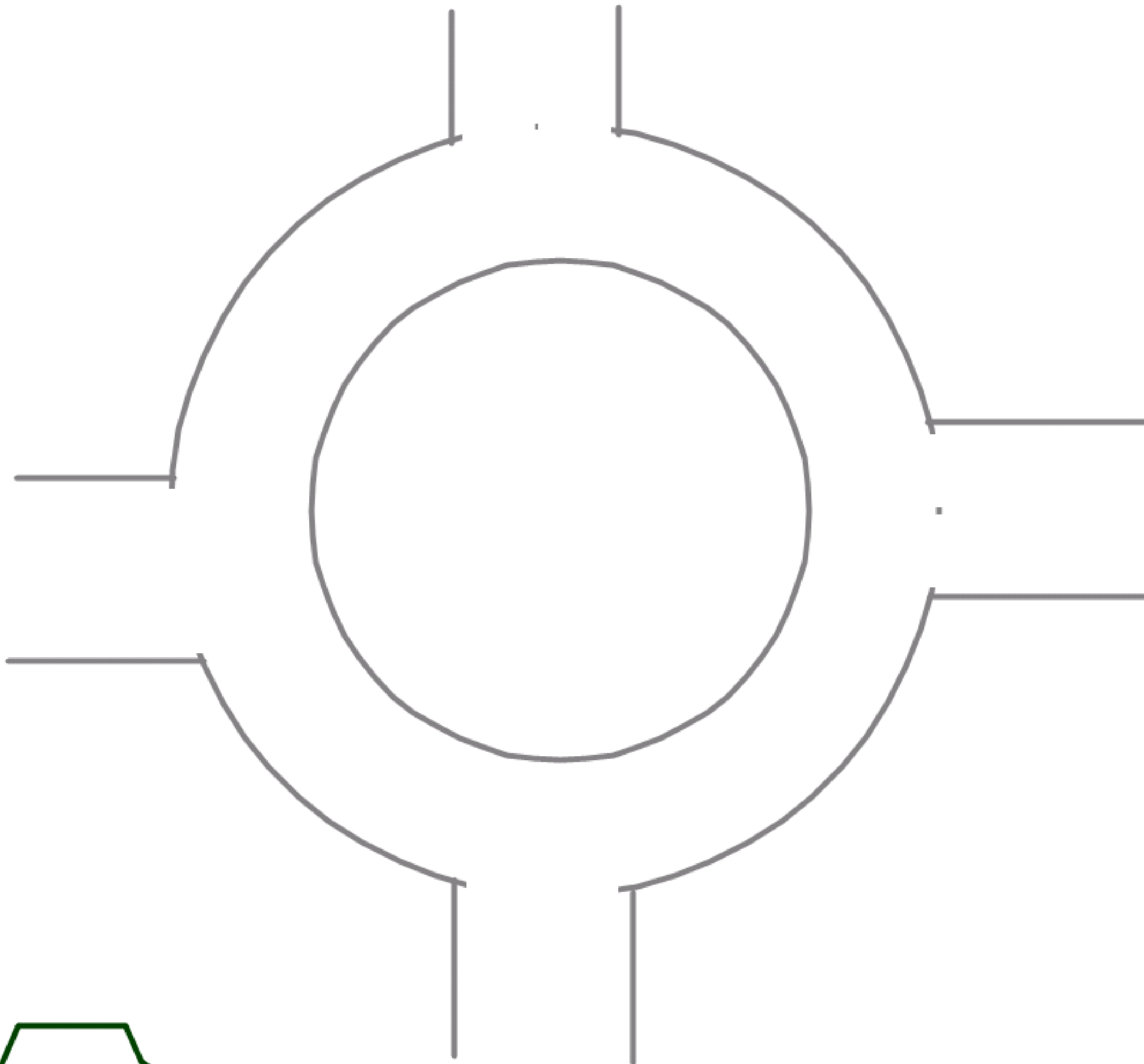
CIRCULAR MOTION



10.10 *Calculating acceleration and net force around a curve*

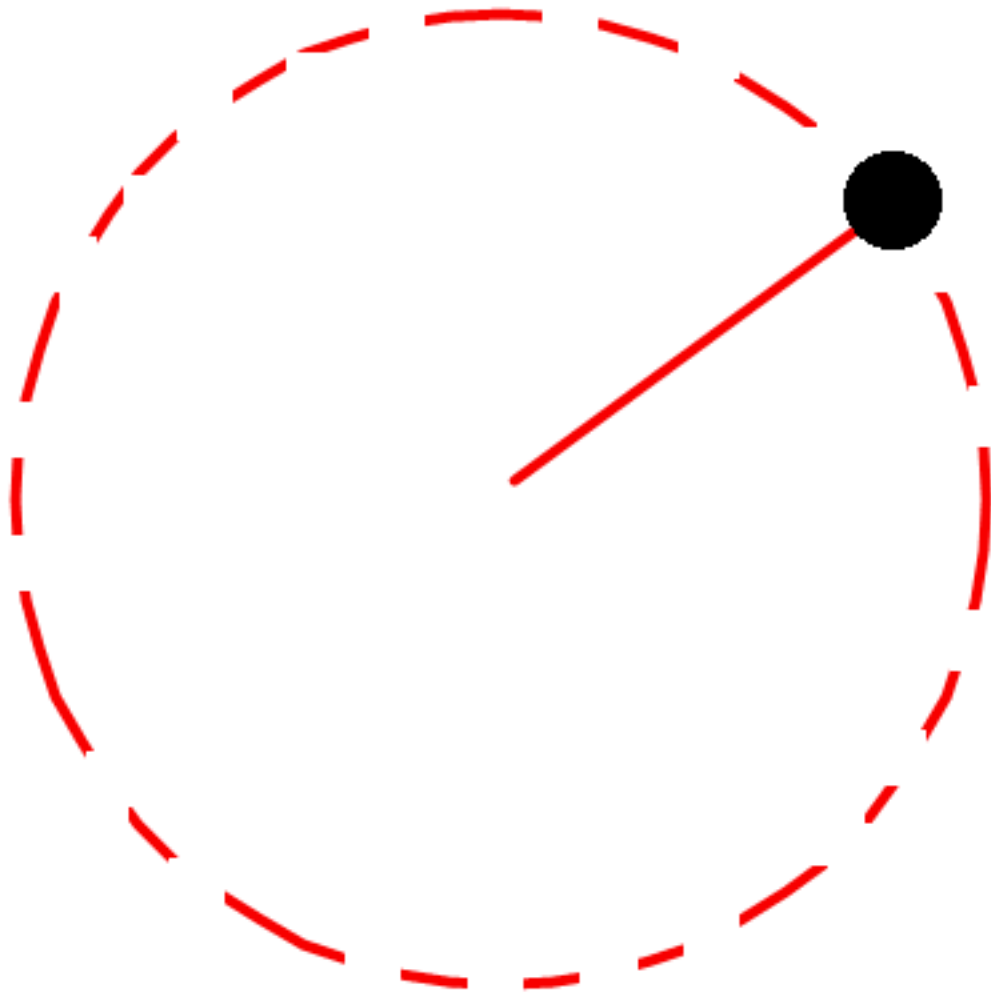
A car of mass 1200 kg is driven at a constant speed of 15 m s^{-1} around a curve with a radius of 12 m. Calculate:

- (a) the magnitude of acceleration of the car
- (b) the magnitude of net force acting on the car.

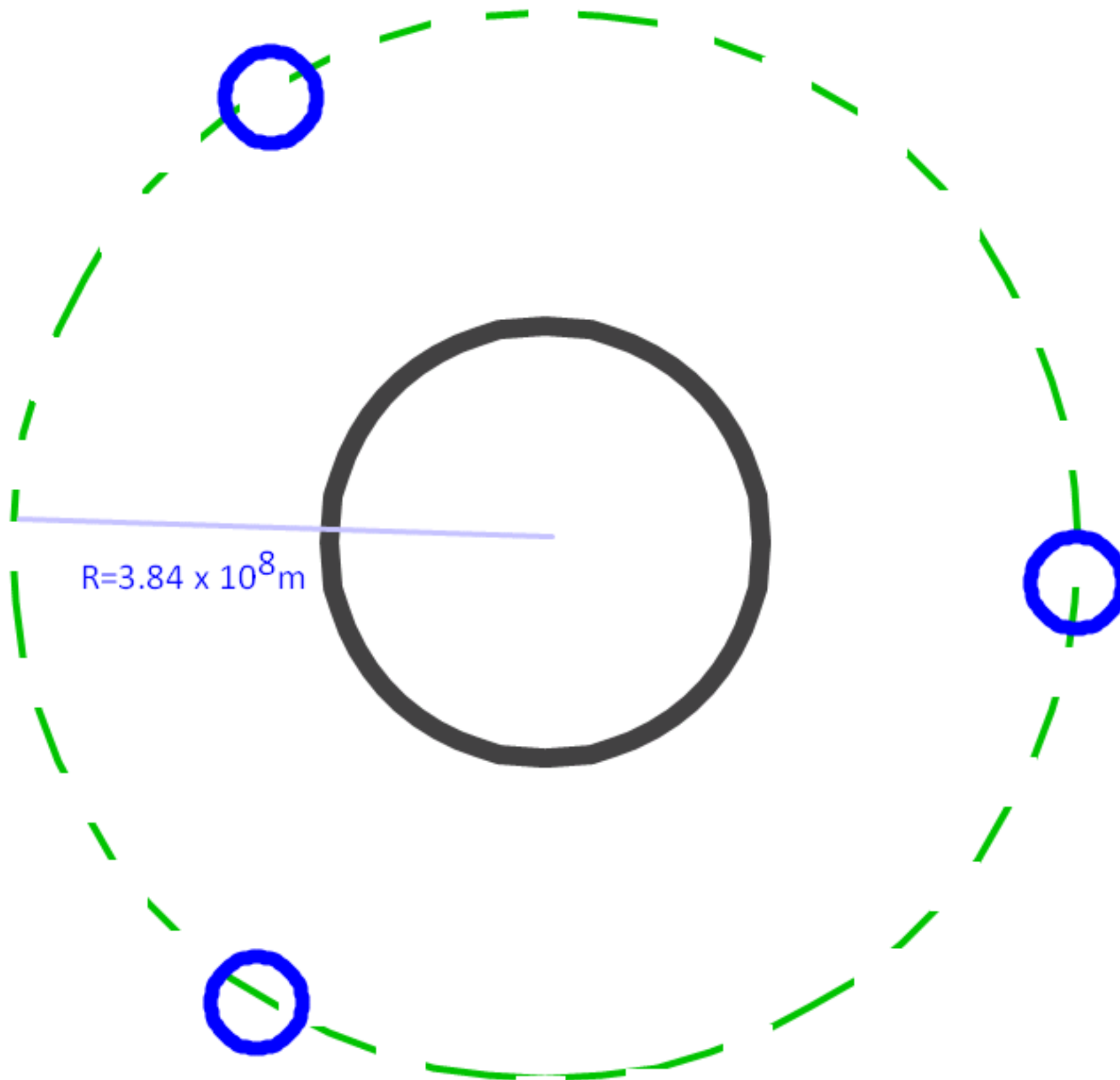


side view

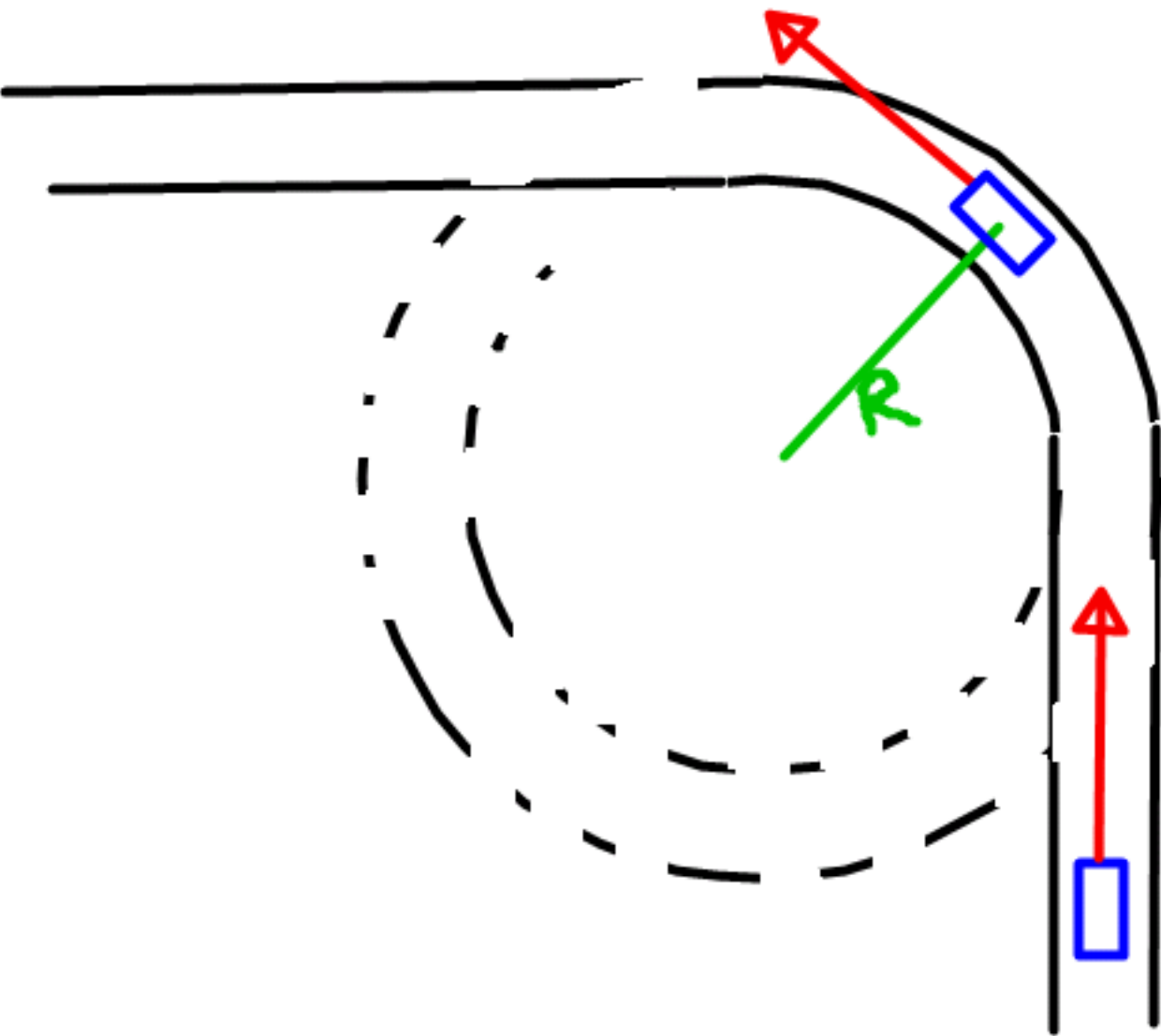
Exercise 2: A rock of mass 250 g is attached to the end of a 1.5 m long string and whirled in a horizontal circle at 15 m/s. Show the velocity, acceleration and net force on the rock and then calculate the centripetal force and acceleration of the rock.



Exercise 3: Find the orbital velocity of the moon and the force on the moon if it completes one orbit in 28 days and has an orbital radius of 384 000 km.



Exercise 4: A car of mass 1450 kg is driven around a bend of radius 70 m. Determine the frictional force required between the tyres and the road in order to allow the car to travel at 70 km/h?



SOURCES OF CENTRIPETAL FORCE

MOTION	F_c PROVIDED BY ...
Whirling rock on a string	The string
Electron orbiting atomic nucleus	Electron–nucleus electrical attraction
Car cornering	Friction between tyres and road
Moon revolving around Earth	Moon–Earth gravitational attraction
Satellite revolving around Earth	Satellite–Earth gravitational attraction

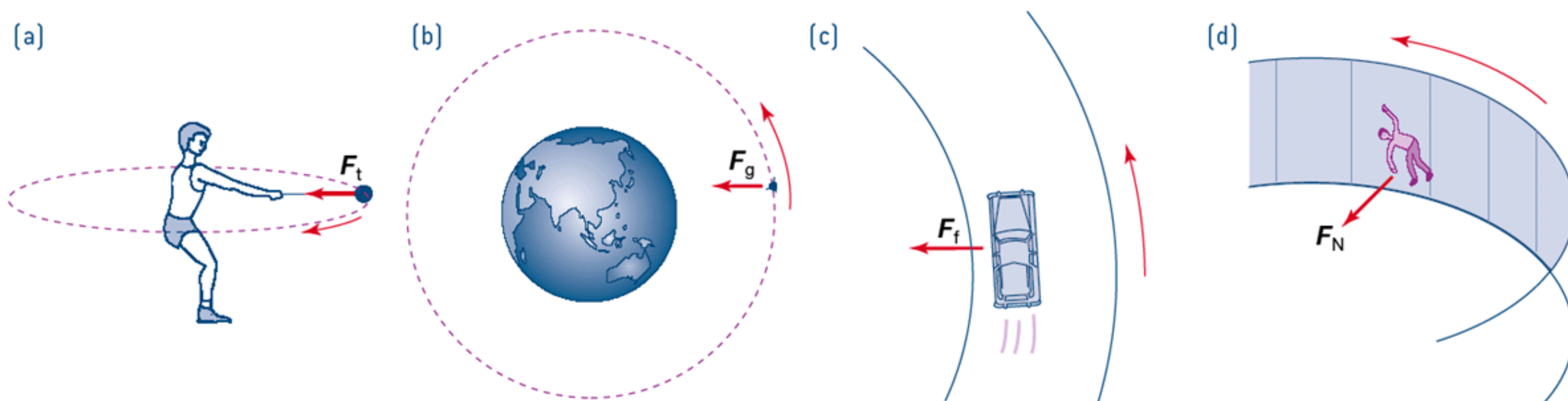


Figure 2.34 The centripetal force that produces a centripetal acceleration and hence a circular motion is provided by different real forces. (a) In a hammer throw or for any other object rotated while attached to an arm or wire, it is the tension in the arm or wire that provides the centripetal force. (b) For planets and satellites, the gravitational attraction to the central body provides the centripetal force. (c) For a car on a roundabout, it is the friction between the tyres and the road. (d) For a person in the Gravitron it is the normal force from the wall. Although the person feels that they are being pinned to the wall, the wall is in fact applying a force to their body.

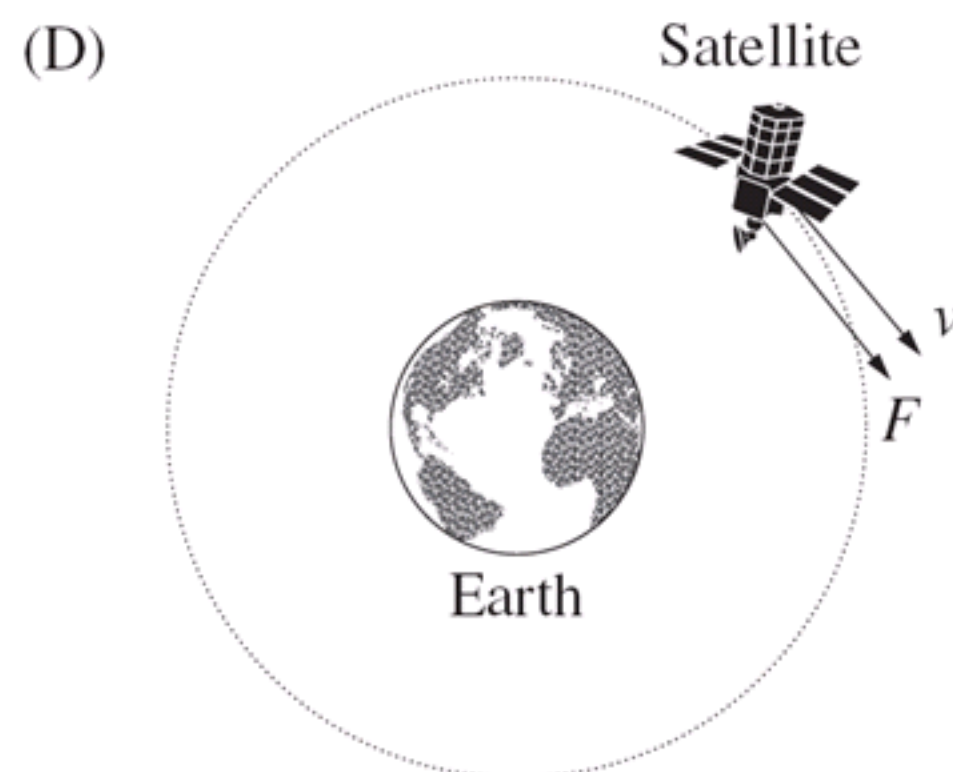
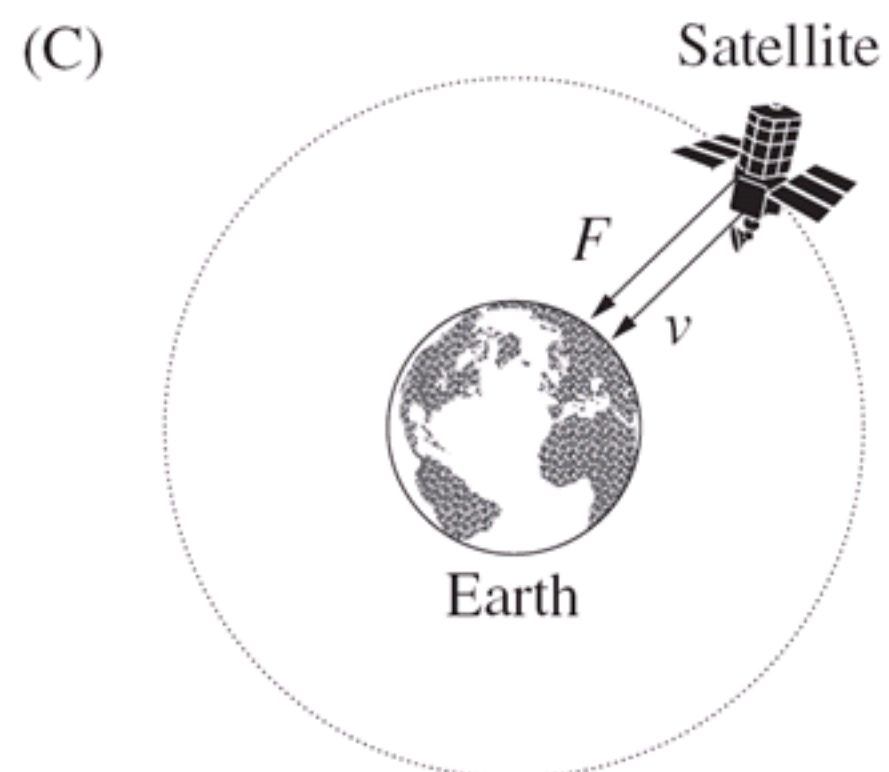
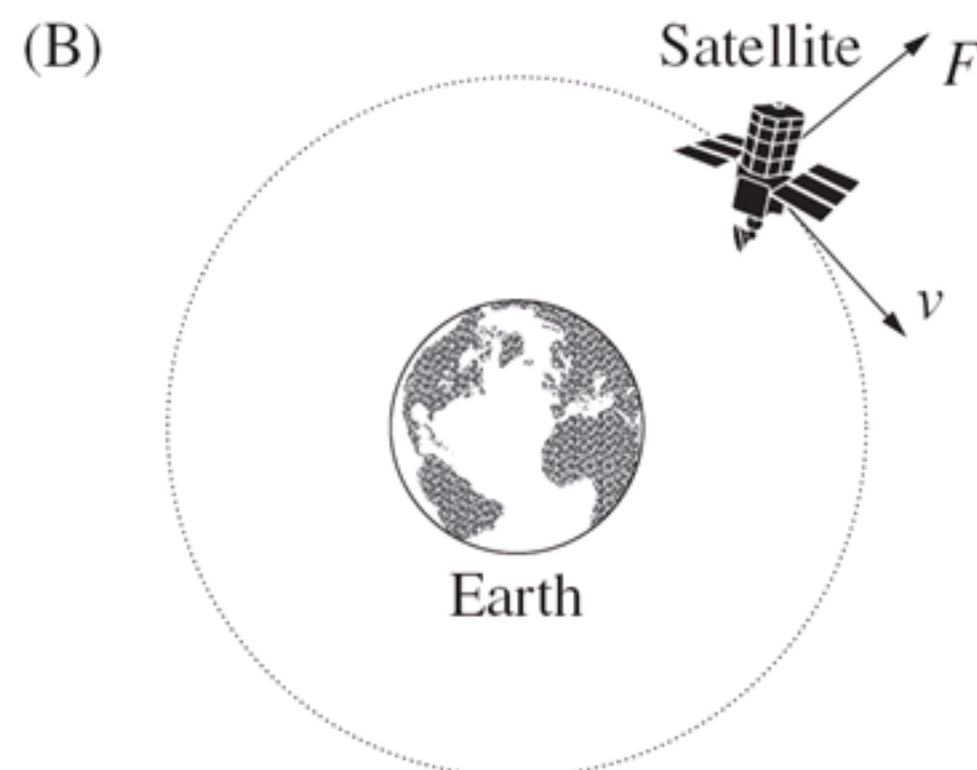
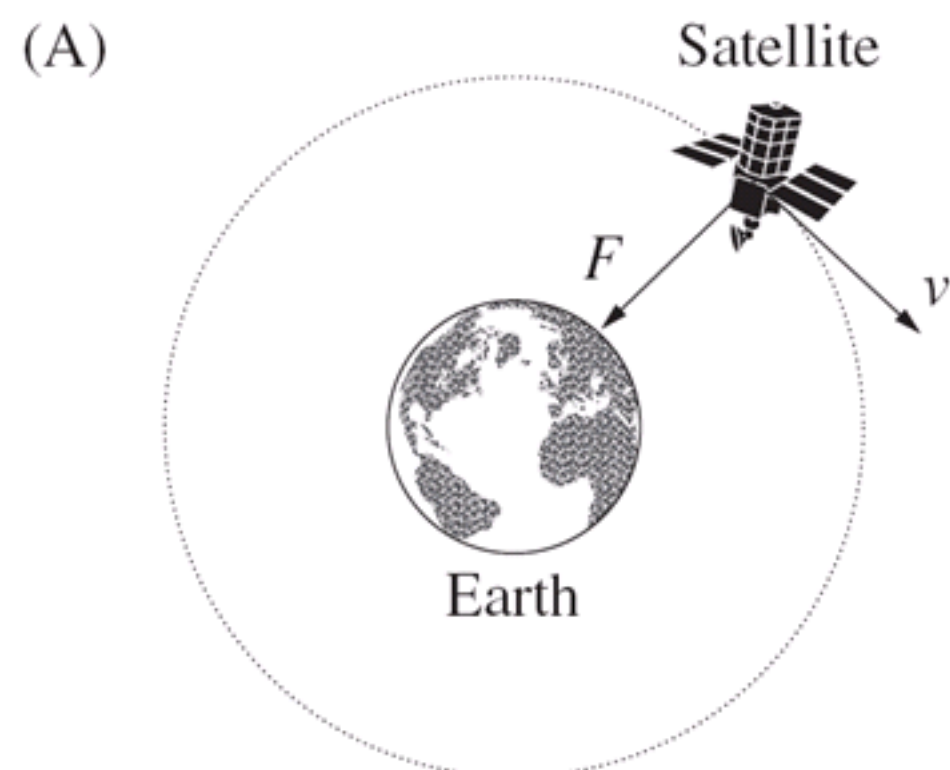
- 2 A satellite moves in uniform circular motion around Earth.

The following table shows the symbols used in the diagrams below.
These diagrams are NOT drawn to scale.

Key

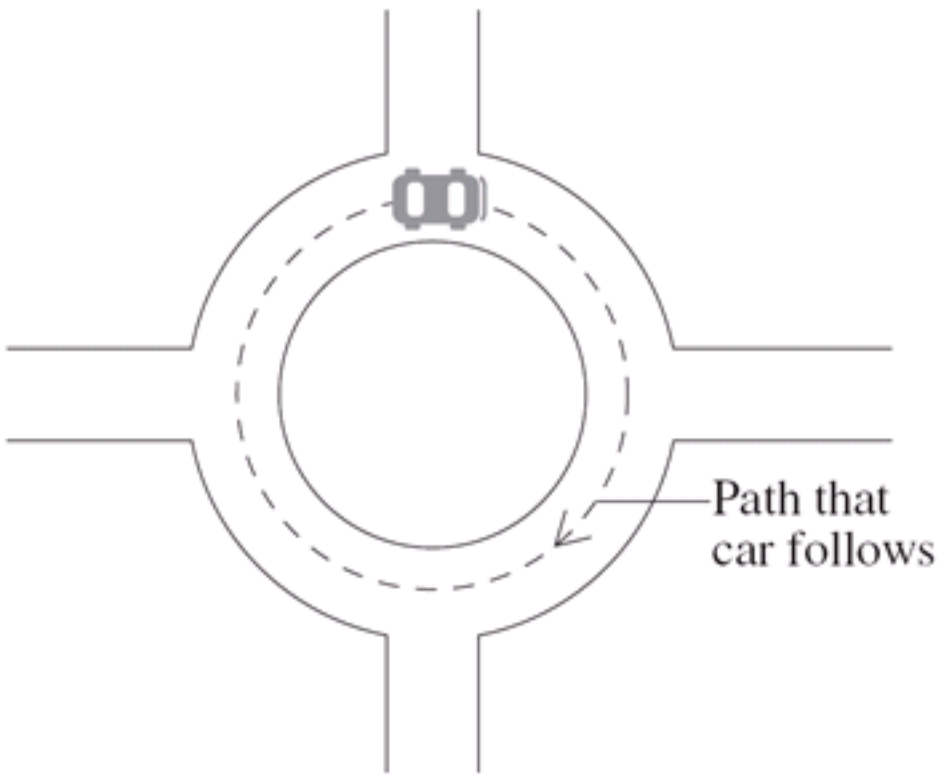
F	net force on satellite
v	velocity of satellite

Which diagram shows the direction of F and v at the position indicated?



Question 18 (4 marks)

A car with a mass of 800 kg travels at a constant speed of 7.5 m s^{-1} on a roundabout so that it follows a circular path with a radius of 16 m.



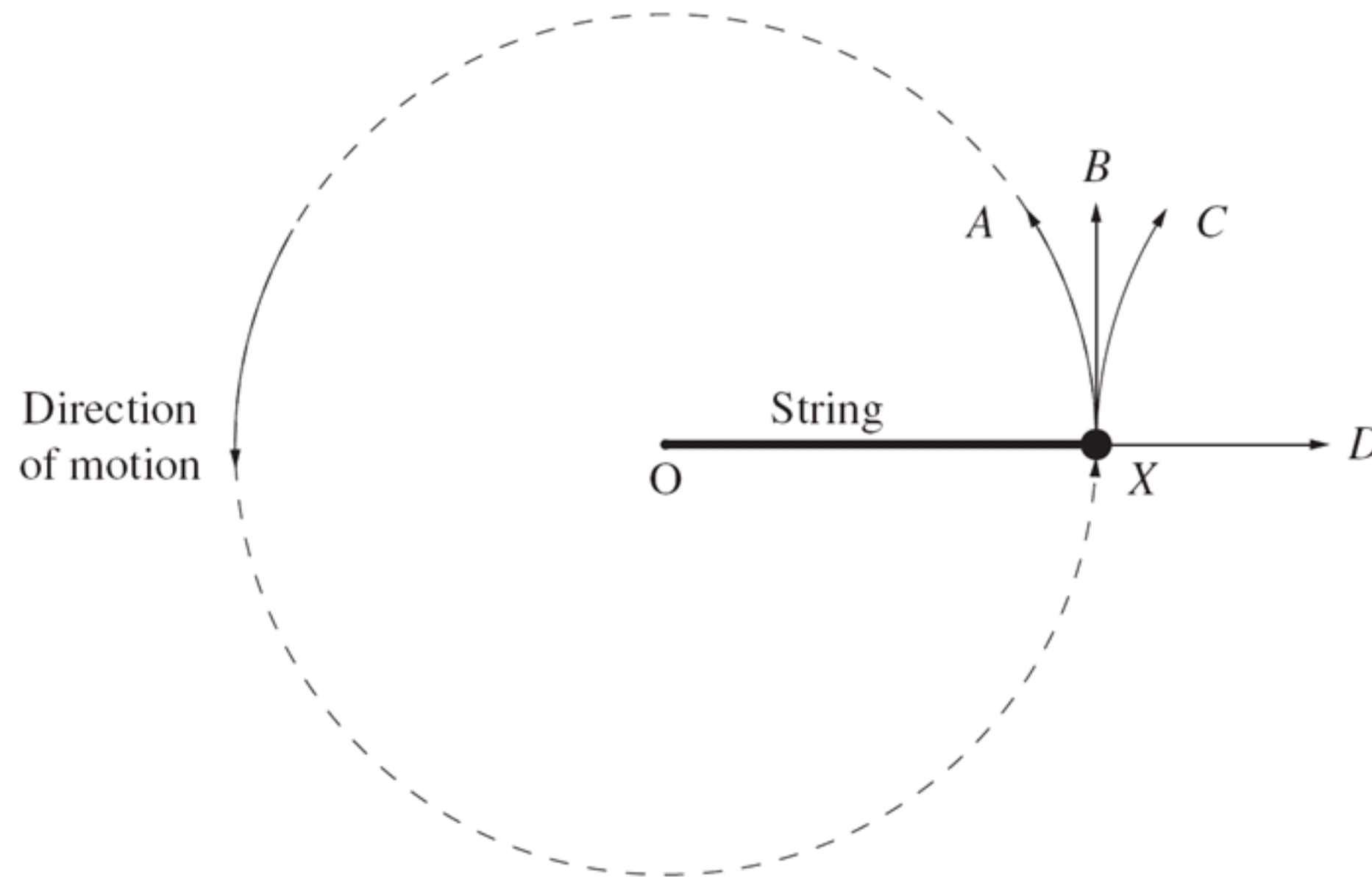
A person observing this situation makes the following statement.

‘There is no net force acting on the car because the speed is constant and the friction between the tyres and the road balances the centripetal force acting on the car.’

Assess this statement. Support your answer with an analysis of the horizontal forces acting on the car, using the numerical data provided above.

4

- 2 A mass attached to a length of string is moving in a circular path around a central point, O, on a flat, horizontal, frictionless table. This is depicted in the diagram below. The string breaks as the mass passes point X.



Which line best depicts the subsequent path of the mass?

- (A) Line A
- (B) Line B
- (C) Line C
- (D) Line D

Worked example 2.5A

An athlete is swinging a hammer of mass 7.0 kg in a circular path of radius 1.5 m. Calculate the speed of the hammer if it completes 3.0 revolutions per second.

Solution

The period of the hammer is: $T = \frac{1}{f} = \frac{1}{3.0} = 0.33 \text{ s}$

The speed is: $v = \frac{2\pi r}{T} = \frac{2 \times \pi \times 1.5}{0.33} = 29 \text{ m s}^{-1}$

Worked example 2.5B

A compact disk is rotating at a rate of 8.3 revolutions per second. Calculate the speed of a point on the inner track of the CD which is moving in a circular path of radius 2.25 cm.

Solution

If the disk is rotating at 8.3 revolutions per second, its period is:

$$T = \frac{1}{f} = \frac{1}{8.3} = 0.12 \text{ s}$$

The speed of a point on the inner track is:

$$v = \frac{2\pi r}{T} = \frac{2 \times \pi \times 2.25}{0.12} = 120 \text{ cm s}^{-1} \text{ or } 1.2 \text{ m s}^{-1}$$

At the outer rim of the disk, it has slowed to around 200 rpm or 3.3 revolutions per second. This is done to ensure that, as the disk is played, the laser beam can be drawn along the track at a constant rate.

Worked example 2.5C

An athlete in a hammer throw event is swinging the ball of mass 7.0 kg in a horizontal circular path. Calculate the tension in the wire if the ball is:

- a** moving at 20 m s⁻¹ in a circle of radius 1.6 m
- b** moving at 25 m s⁻¹ in a circle of radius 1.2 m.

Solution

- a** The centripetal acceleration is:

$$\begin{aligned} a &= \frac{v^2}{r} \\ &= \frac{20^2}{1.6} \\ &= 250 \text{ m s}^{-2} \text{ towards the centre} \end{aligned}$$

The tension is producing circular motion:

$$\begin{aligned} F_t &= \sum F \\ &= ma \\ &= 7.0 \times 250 \\ &= 1.8 \times 10^3 \text{ N towards the centre} \end{aligned}$$

- b** $a = \frac{v^2}{r}$
 $= \frac{25^2}{1.2} = 520 \text{ m s}^{-2} \text{ towards the centre}$

$$\begin{aligned} F_t &= \sum F \\ &= ma \\ &= 7.0 \times 520 \\ &= 3.6 \times 10^3 \text{ N towards the centre} \end{aligned}$$

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. Circular Motion Worksheet

Also

- 1. New Booklet (8 page)
- 2. Chapter 2 All Questions
- PM Practice Booklet
- All Questions in Period 7 & 8 Booklets
- Experiment 4 Report

NEXT PERIOD >

KEPLER'S THIRD LAW - LAW OF PERIODS

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:

$$v_x^2 = u_x^2$$

$$v = u + at$$

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

$$\Delta x = u_x t$$

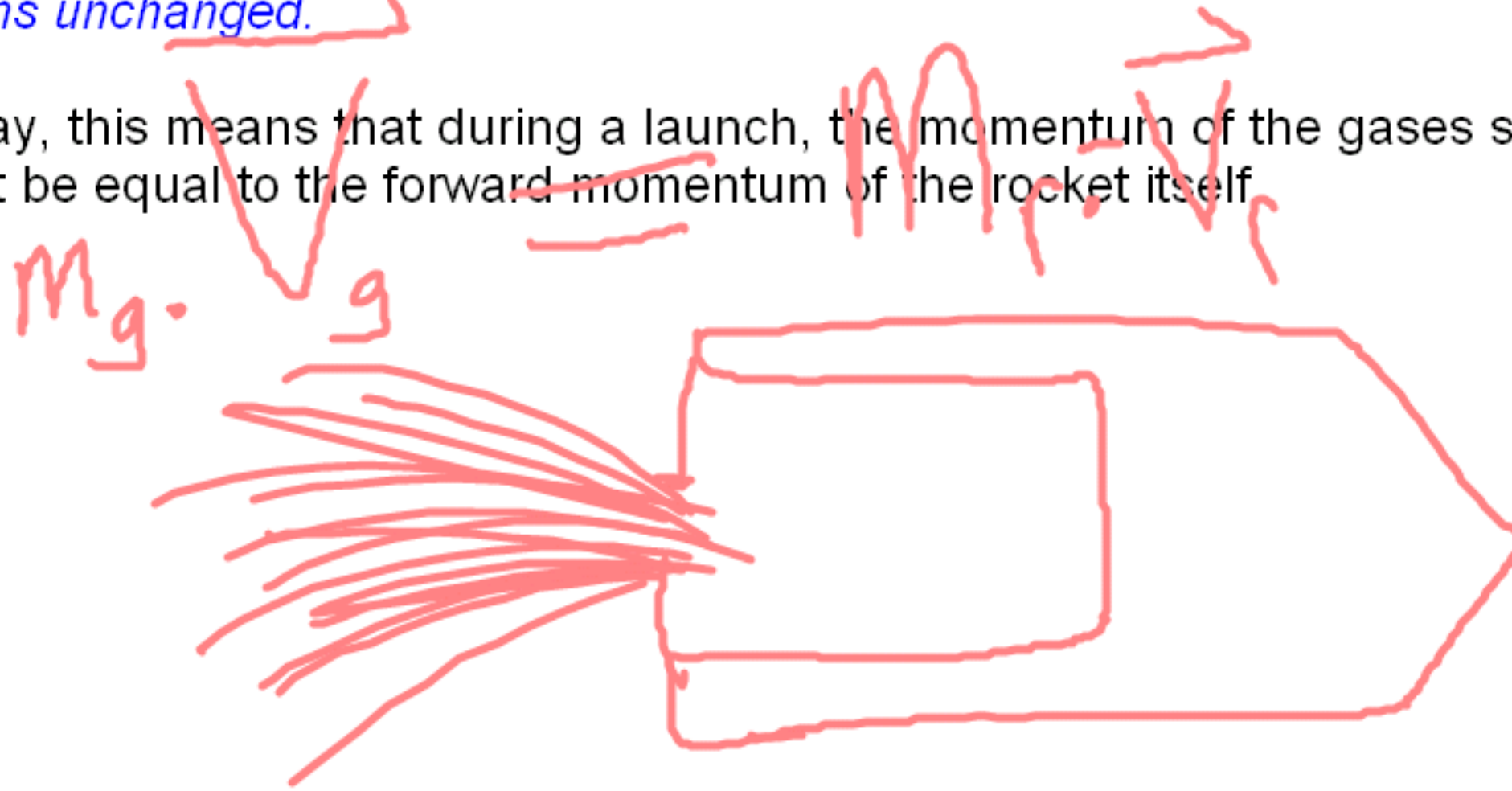
$$\Delta y = u_y t + \frac{1}{2} a_y t^2$$

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

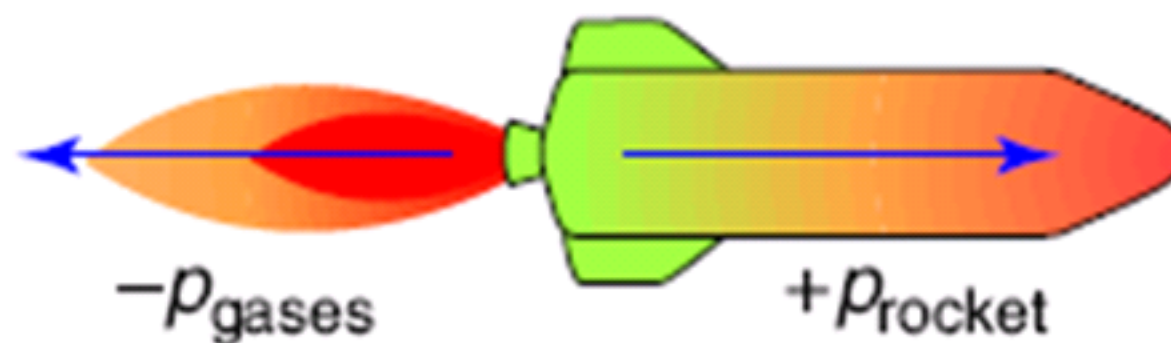
CONSERVATION OF MOMENTUM

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.

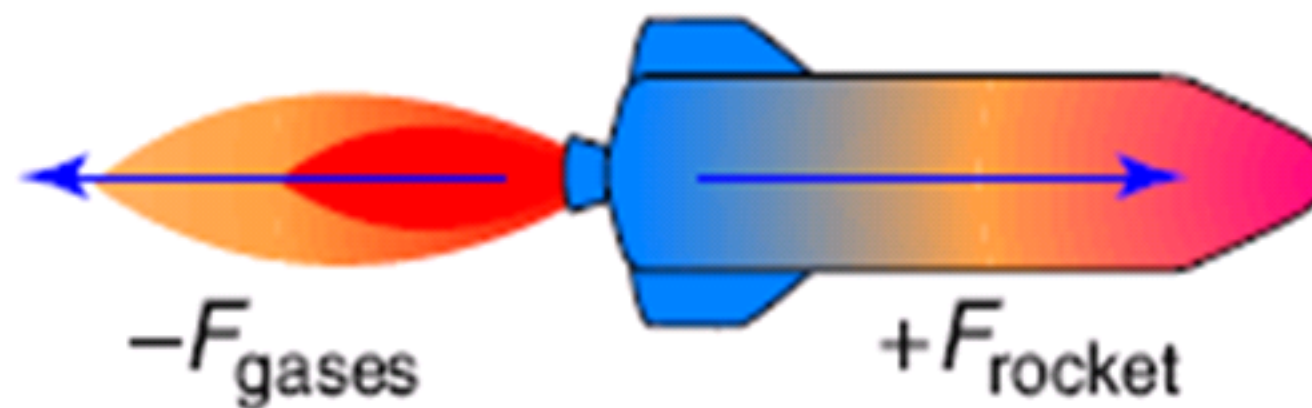
FORCES EXPERIENCED BY BOTH

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?

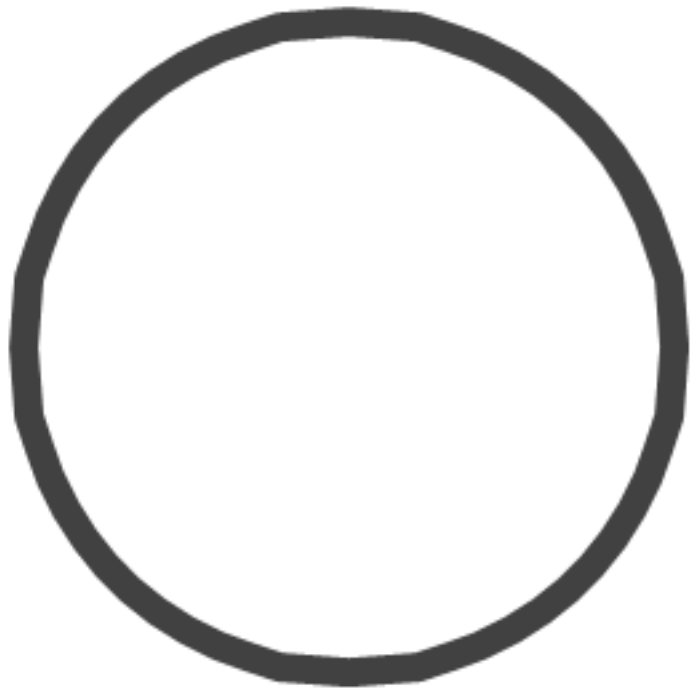
$$\overleftarrow{F_{\text{on gas by rocket}}} = - \overrightarrow{F_{\text{on rocket by gas}}}$$

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



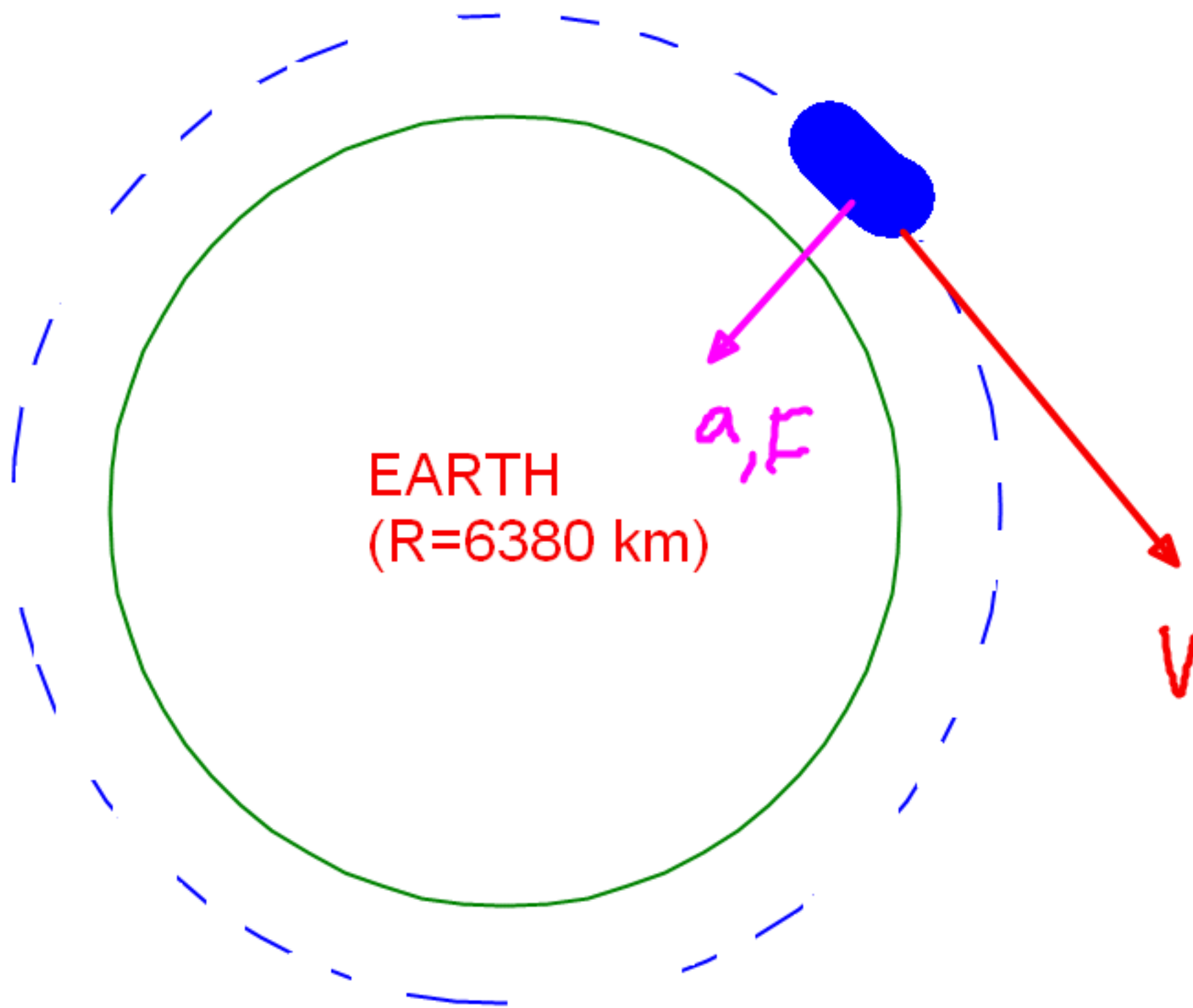
Although the two forces are equal and opposite, the rocket experiences just one of them — the forward push that we call thrust.

KEPLER'S THIRD LAW



Find the period (then velocity) of ISS which is orbiting around the Earth at an altitude of 360 km. Show the net force acting on it first.

$$R = 6380 + 360 = 6740 \text{ km} \\ = 6.74 \times 10^3 \text{ km} = 6.74 \times 10^6 \text{ m}$$



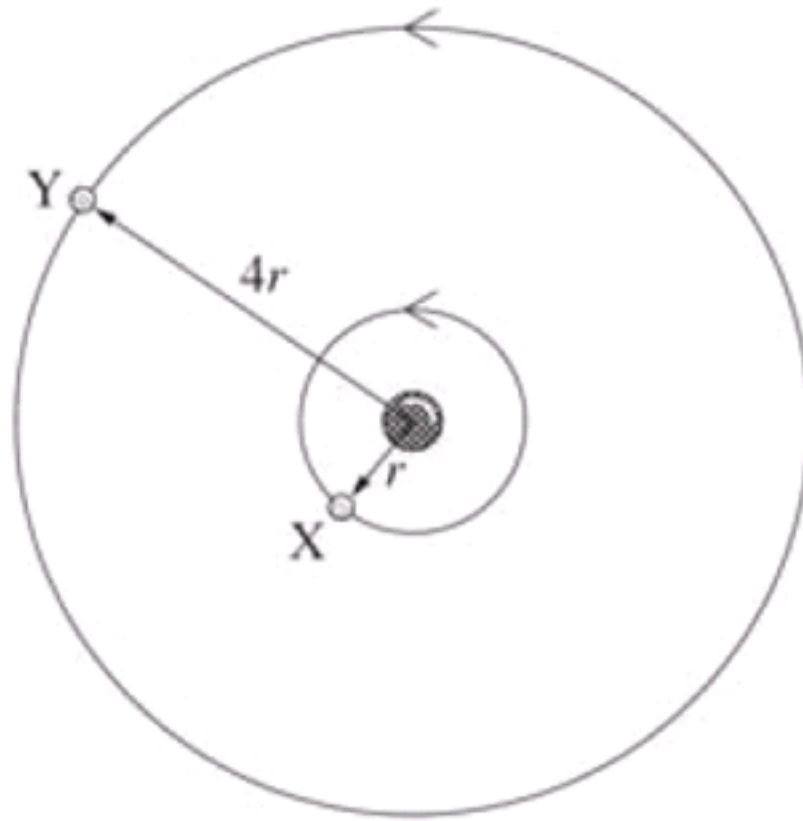
Find the orbital radius and velocity of the Earth around the sun if it completes one turn in 365.25 days



2003 HSC QUESTION

- 4 Two planets, X and Y, travel around a star in the same direction, in circular orbits.

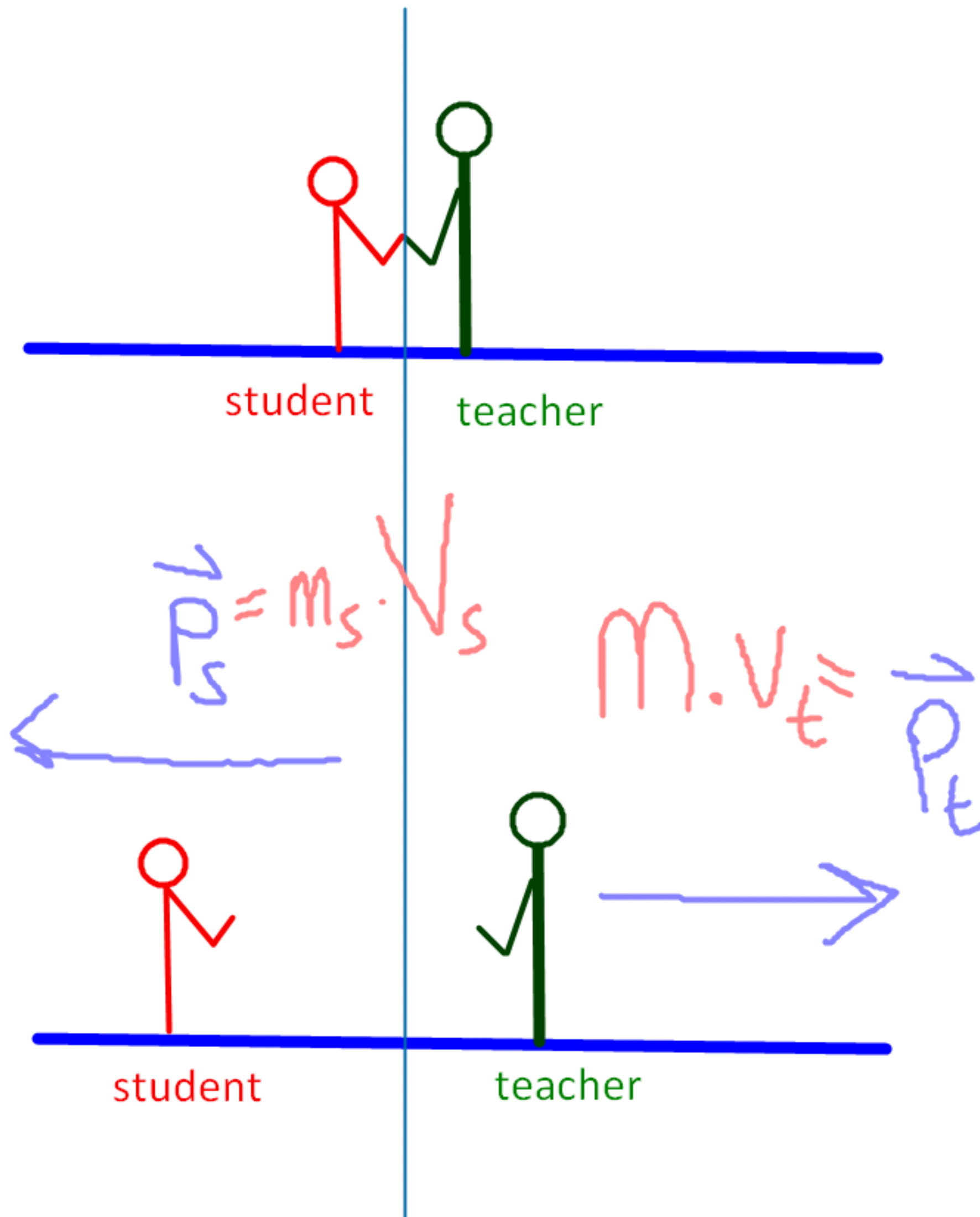
Planet X completes one revolution about the star in time T . The radii of the orbits are in the ratio 1 : 4.



How many revolutions does planet Y make about the star in the same time T ?

- (A) $\frac{1}{8}$ revolution
- (B) $\frac{1}{2}$ revolution
- (C) 2 revolutions
- (D) 8 revolutions

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?

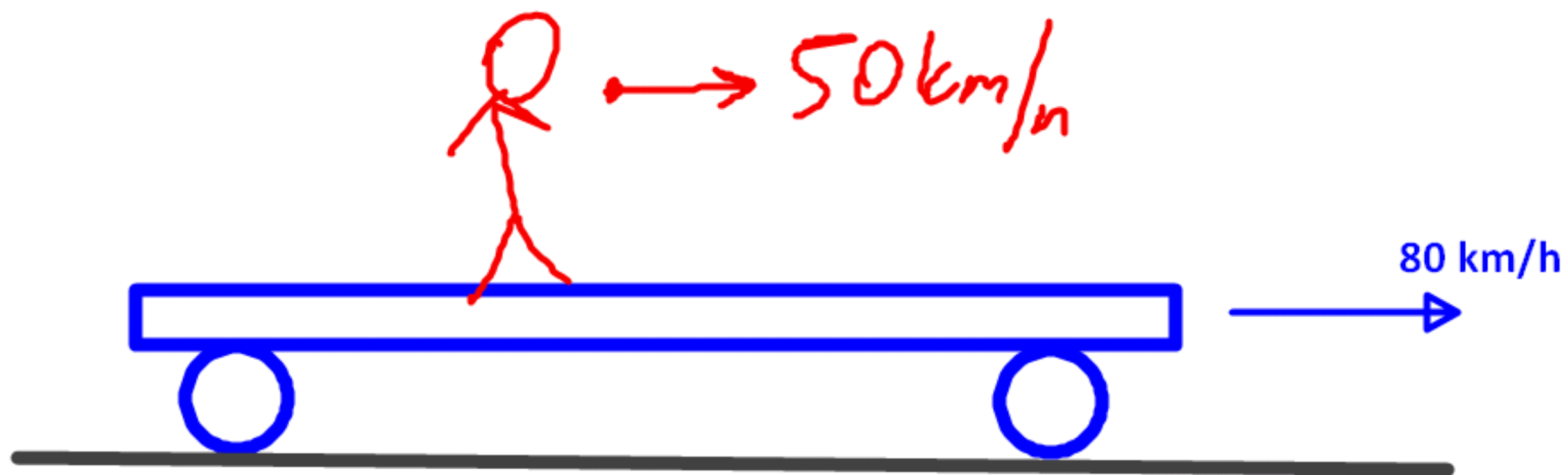


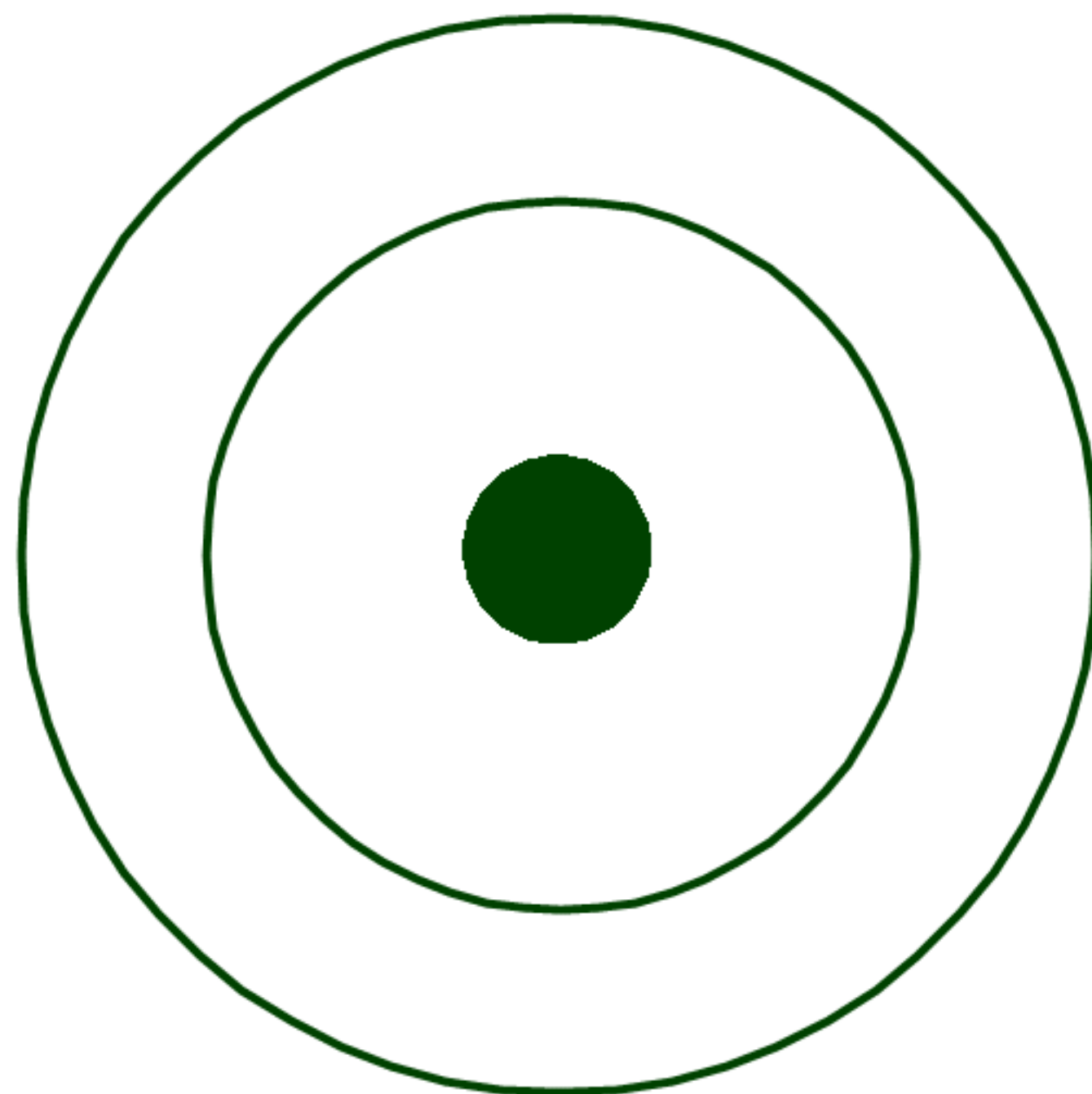
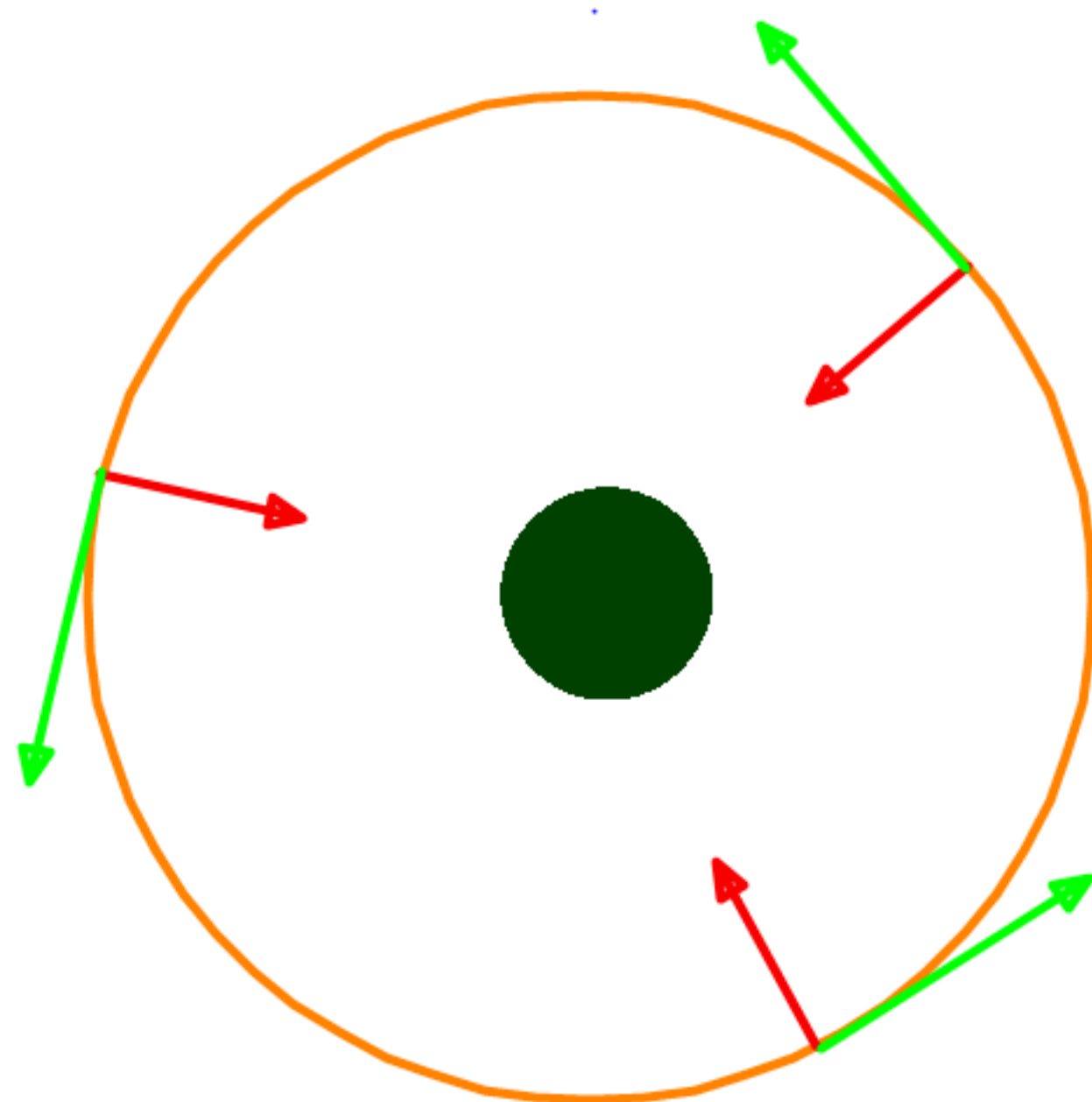
$$\vec{p}_i = 0 = \vec{p}_f$$

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

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

FIRING PROJECTILES FROM A MOVING PLATFORM





Steps in solving PM questions.

Step 1 > Read the question.

Step 2 > Understand the question.

Step 3 > Make sure you understand "What is given/provided" and "What is asked".

Step 4 > Draw a diagram.

Step 5 > Select your interval (A to B). Mark A and B on your diagram.

Step 6 > Draw the data table and fill in the details as much as you can. Mark unknowns.

Step 7 > Select the appropriate formula and solve it for unknowns.

