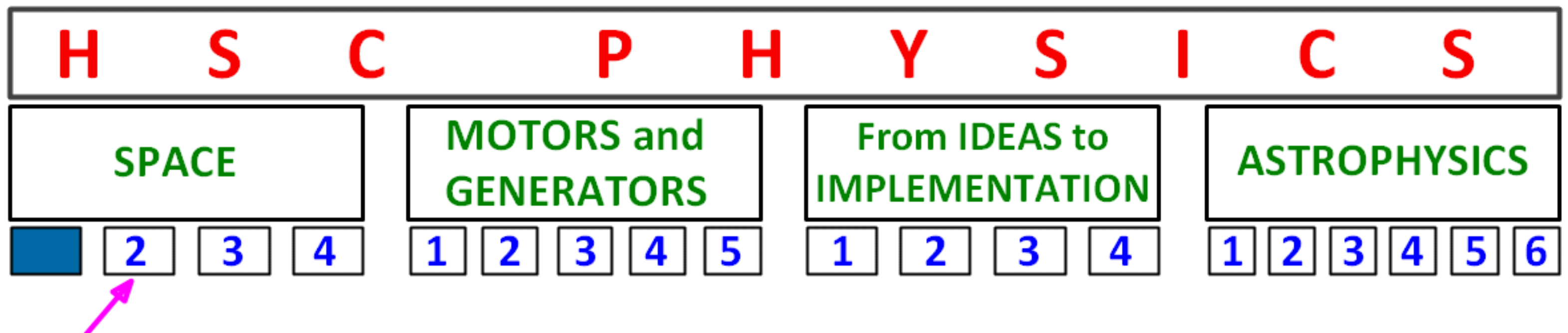


# SPACE

1<sup>st</sup> Quarter; Module 1

## PERIOD 8

Escape Velocity



## 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

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

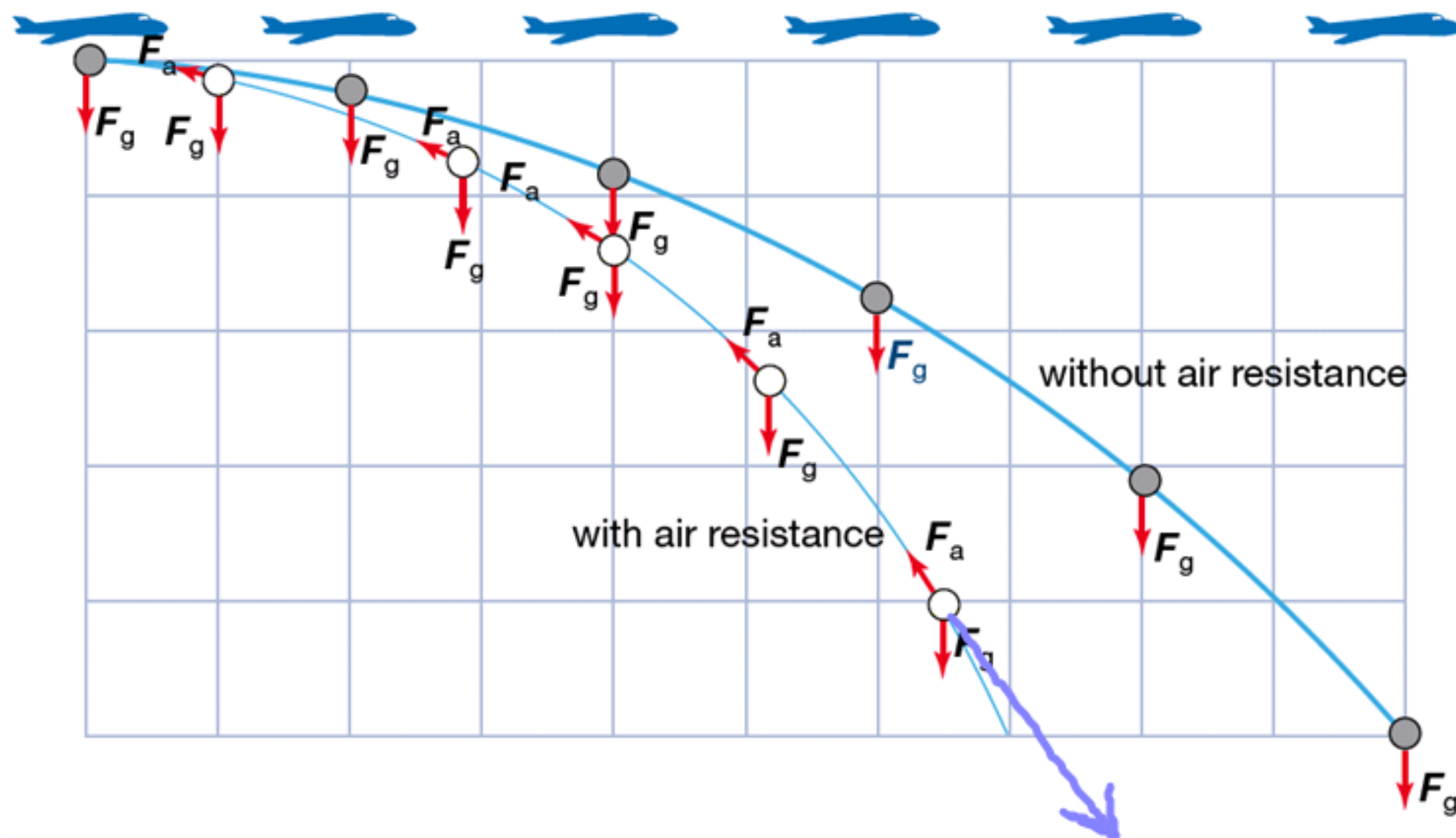
- solve problems and analyse information using:

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

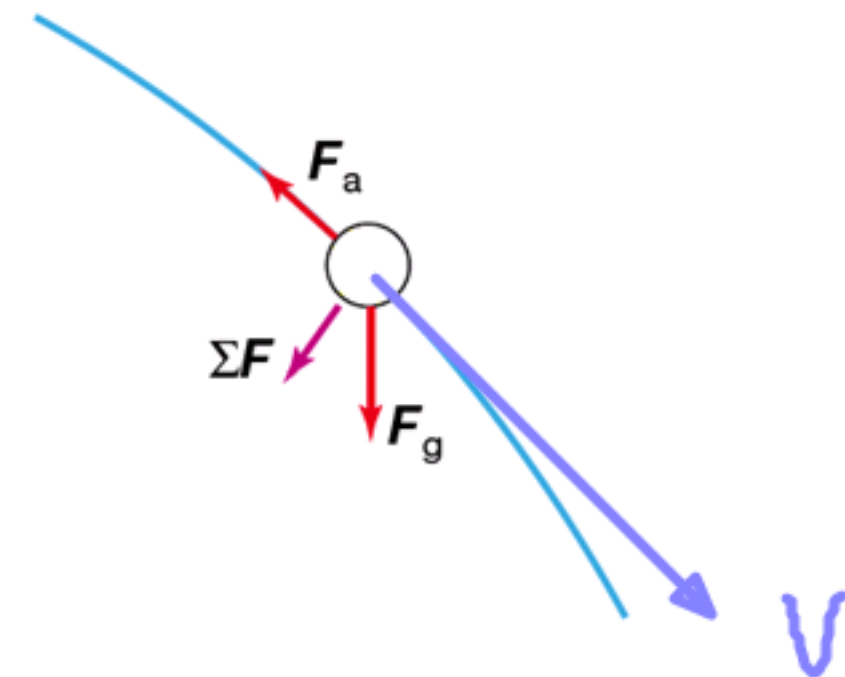
# THE EFFECT OF AIR RESISTANCE!

Figure 1.23 shows a food parcel being dropped from a plane moving at a constant velocity. If air resistance is ignored, the parcel falls in a parabolic arc. It would continue moving horizontally at the same rate as the plane; that is, as the parcel falls it would stay directly beneath the plane until it hits the ground. The effect of air resistance is also shown. Air resistance (or drag) is a retarding force and it acts in a direction that is opposite to the motion of the projectile. If air resistance is taken into account, there are now two forces acting—weight,  $\mathbf{F}_g$ , and air resistance,  $\mathbf{F}_a$ . Therefore, the resultant force,  $\Sigma\mathbf{F}$ , that acts on the projectile is *not* vertically down. The magnitude of the air resistance force is greater when the speed of the body is greater.

(a)



(b)



**Figure 1.23** (a) The path of a food parcel dropped from a plane. If the plane maintains a constant speed and in the absence of air resistance, the parcel will fall in a parabolic path and remain directly below the plane. Air resistance makes the parcel fall more slowly, over a shorter path. (b) When air resistance is acting, the net force on the parcel is not vertically down.



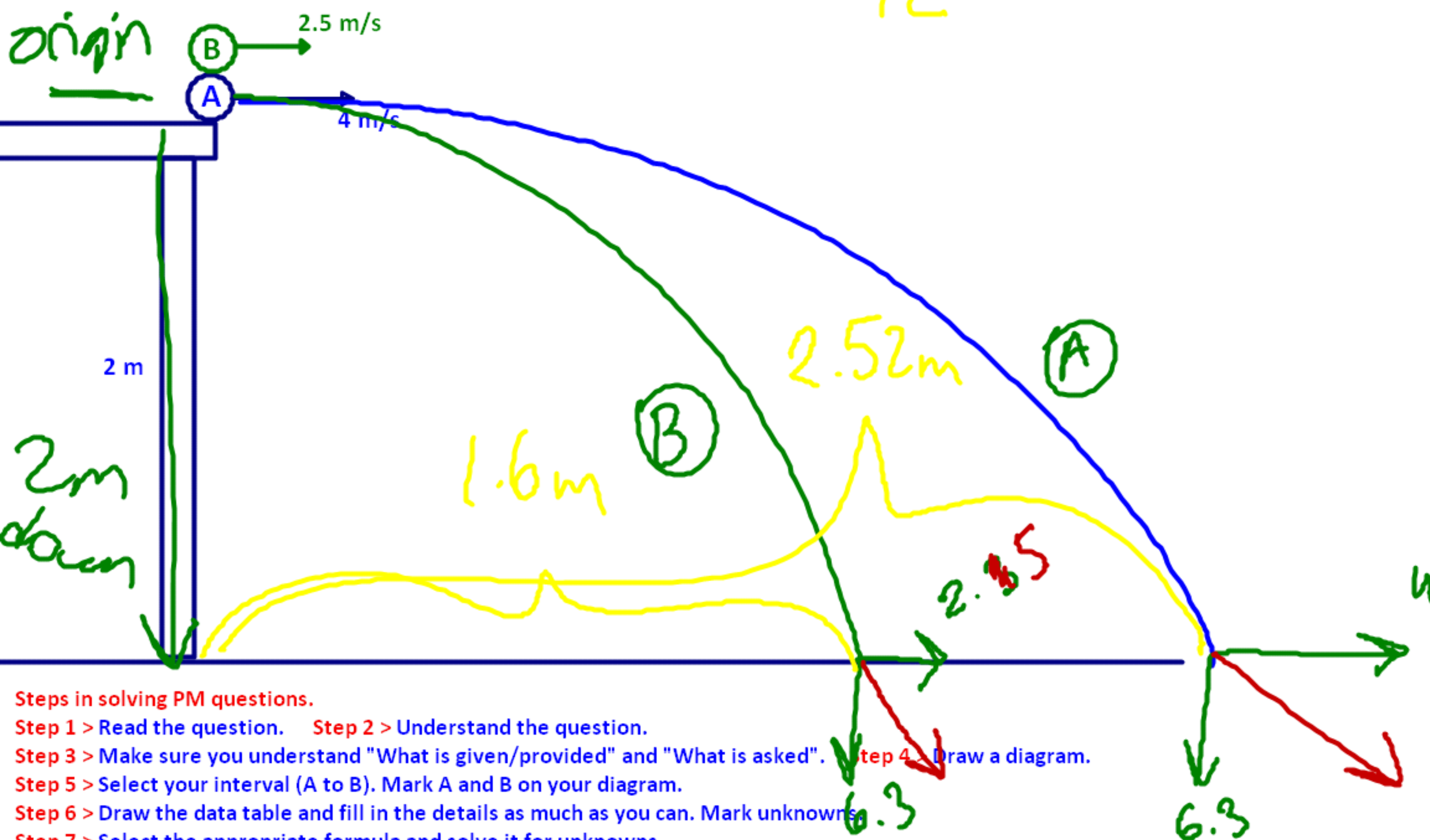
### Question 8

Two balls, A and B, each of mass 1.6 kg are rolling along a horizontal table 2.0 m above the floor. Both balls roll off the end of the table and reach the floor below. A has a horizontal velocity of  $4.0 \text{ m s}^{-1}$  as it leaves the table, while B has a horizontal velocity of  $2.5 \text{ m s}^{-1}$ .

- What is the time taken for:
  - A to reach the floor?
  - B to reach the floor?
- What is the kinetic energy of A just before it strikes the floor?
- What is the kinetic energy of B just before it strikes the floor?
- What is the difference in the horizontal distances travelled by A and B before they strike the floor?

$$E_k = \frac{1}{2}mv^2$$

$$2.52 - 1.6 = 0.92 \text{ m}$$



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.

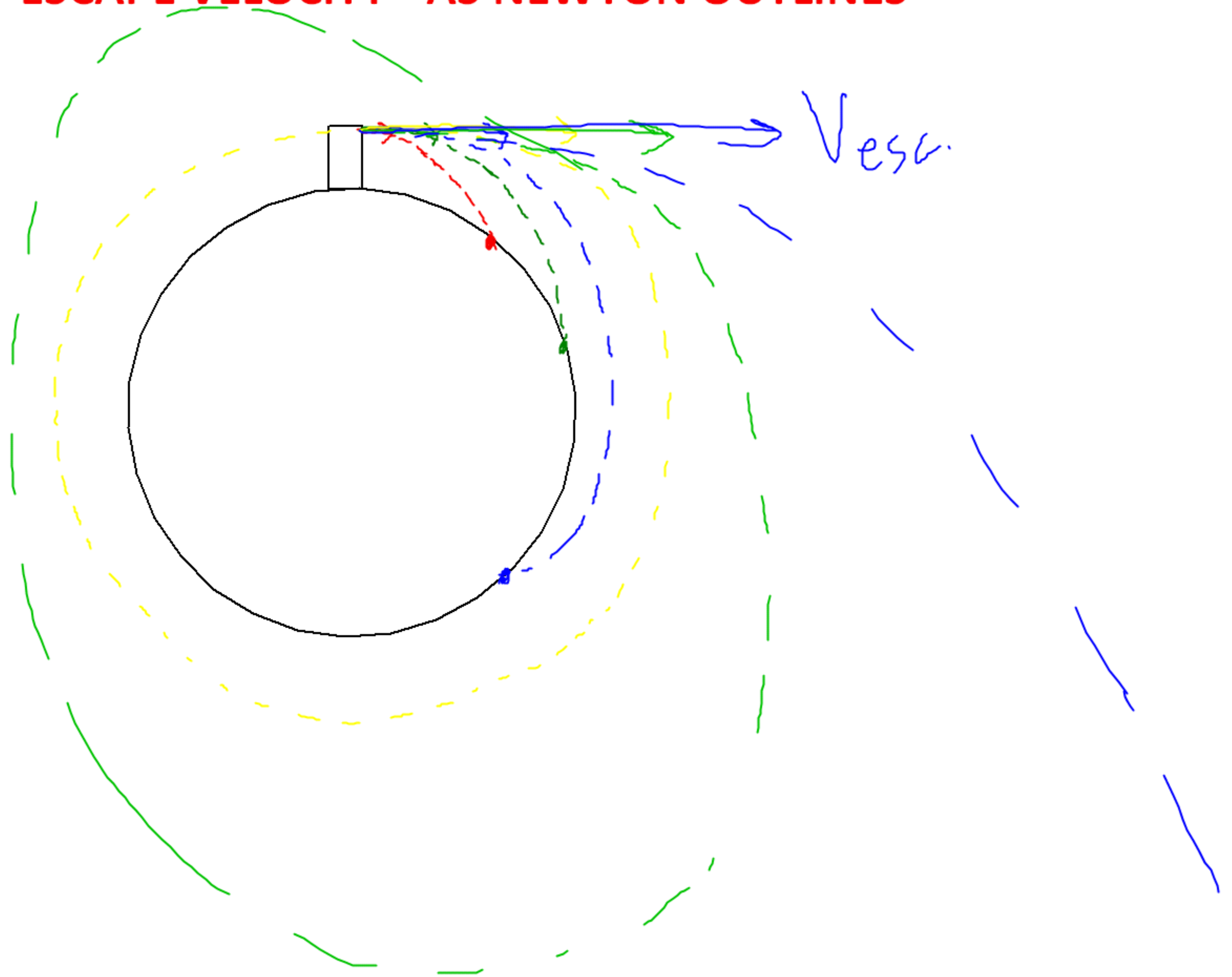
Step 5 > Select your interval (A to B). Mark A and B on your diagram.

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.



# ESCAPE VELOCITY - AS NEWTON OUTLINES





# ESCAPE VELOCITY - AS NEWTON OUTLINES

- ✓ A stone thrown from a tall tower will cover a considerable range before striking the ground.

- ✓ If it is thrown faster, it will travel further before stopping.

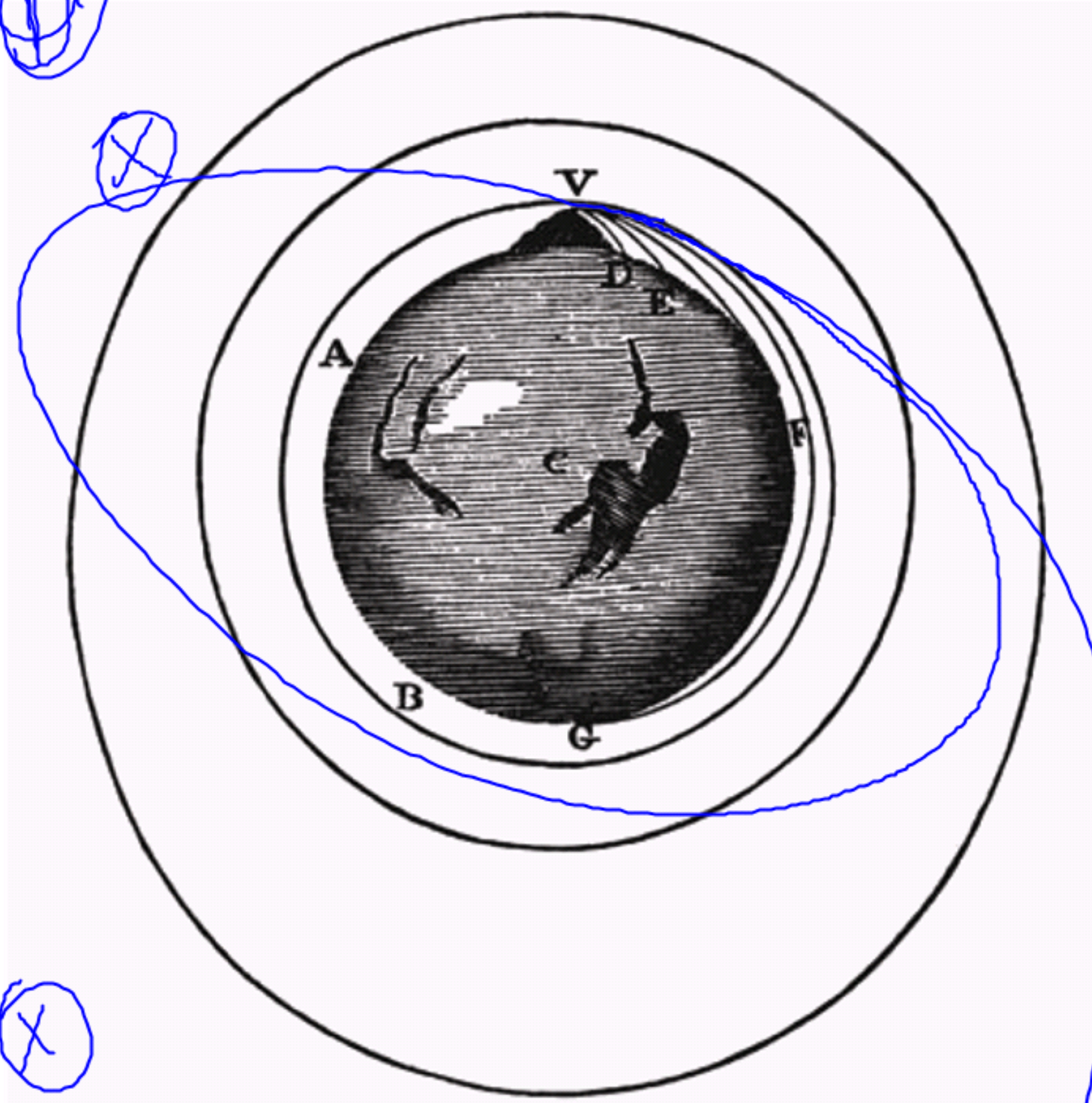
- ✓ If thrown faster still, it will have an even greater range.

- ✓ If thrown fast enough then, as the stone falls, the Earth's surface curves away, so that the falling stone never actually lands on the ground and orbits the Earth.

It was only a **thought experiment**, of course. He had no way of testing this idea but it does hit upon one important fact — that for any given altitude, there is a specific velocity required for any object to achieve a stable circular orbit.

- ✓ If this specific velocity is exceeded slightly, then the object will follow an elliptical orbit around the Earth.

- ✓ If the specific velocity is exceeded further still, then the object will follow a parabolic or hyperbolic path away from the Earth.



**Figure 3.13** Newton's original sketch shows how a projectile that was fired fast enough would fall all the way around the Earth and become an Earth satellite.

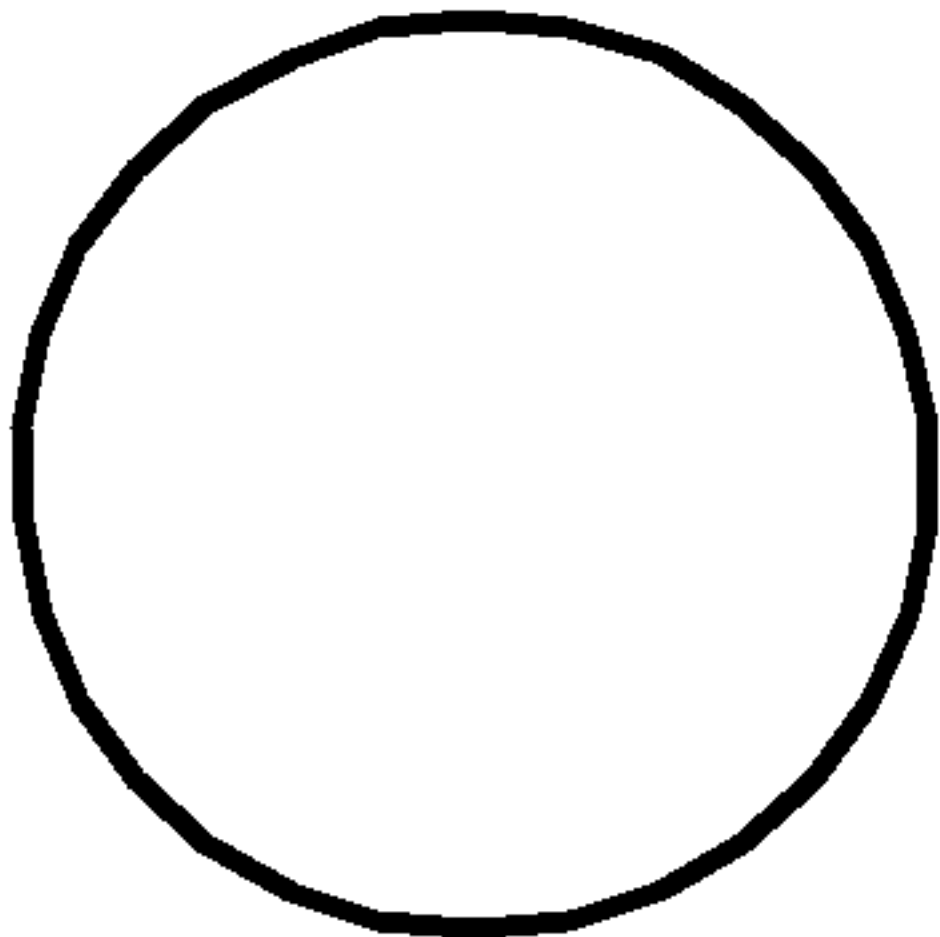


# ESCAPE VELOCITY - AS WE OUTLINE IT

For earth  $V_{esc} = 11200 \text{ m/s}$

if  $V < V_{esc}$  then

$E_{tot} < 0 \Rightarrow$  You are still trapped in Earth's gr. field.



if  $V > V_{esc}$  then

$E_{tot} > 0 \Rightarrow$  You are in space with some  $E_k$  (vel.)

# ESCAPE VELOCITY - AS WE OUTLINE IT



# ESCAPE VELOCITY - AS WE OUTLINE IT

***EXERCISE 1: Calculating escape velocity***

Determine the escape velocity of the planet Venus, given that its mass is  $4.87 \times 10^{24}$  kg and its radius is 6052 km



## Find the escape velocity (from the surface of the following celestial bodies.

Table 3.4 Data for the Sun, its eight planets and Earth's Moon

Body	Mass (kg)	Radius (m)	Period of rotation	Mean orbital radius (m)	Period of orbit	Av. orbital speed (km s <sup>-1</sup> )
Sun	$1.98 \times 10^{30}$	$6.95 \times 10^8$	24.8 days	NA	NA	NA
Mercury	$3.28 \times 10^{23}$	$2.57 \times 10^6$	58.4 days	$5.79 \times 10^{10}$	88 days	47.8
Venus	$4.83 \times 10^{24}$	$6.31 \times 10^6$	243 days	$1.08 \times 10^{11}$	224.5 days	35.0
Earth	$5.98 \times 10^{24}$	$6.38 \times 10^6$	23 h 56 min	$1.49 \times 10^{11}$	365.25 days	29.8
Mars	$6.37 \times 10^{23}$	$3.43 \times 10^6$	24.6 h	$2.28 \times 10^{11}$	688 days	24.2
Jupiter	$1.90 \times 10^{27}$	$7.18 \times 10^7$	9.8 h	$7.78 \times 10^{11}$	11.9 years	13.1
Saturn	$5.67 \times 10^{26}$	$6.03 \times 10^7$	10 h	$1.43 \times 10^{12}$	29.5 years	9.7
Uranus	$8.80 \times 10^{25}$	$2.67 \times 10^7$	10.8 h	$2.87 \times 10^{12}$	84.3 years	6.8
Neptune	$1.03 \times 10^{26}$	$2.48 \times 10^7$	15.8 h	$4.50 \times 10^{12}$	164.8 years	6.5
Moon	$7.34 \times 10^{22}$	$1.74 \times 10^6$	27.3 days	$3.8 \times 10^8$	27.3 days	1.0

## 2003 HSC PAPER

### Question 17 (6 marks)

A satellite of mass 150 kg is launched from Earth's surface into a uniform circular orbit of radius  $7.5 \times 10^6$  m.

- (b) From this uniform circular orbit, the satellite can escape Earth's gravitational field when its kinetic energy is equal to the magnitude of the gravitational potential energy.

**3**

Use this relationship to calculate the escape velocity of the satellite.



# 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. Find the Escape velocities of the celestial bodies listed in Practical Activity 2, (page 12 of the book)
2. Questions 15 - 17 of Chapter 2

Also

1. PM Practice Booklet
2. All Questions in Period 7 Booklet
3. Chapter 2 Questions 1-13

## NEXT PERIOD >

"g" FORCES "WHY DO WE USE THE TERM?"