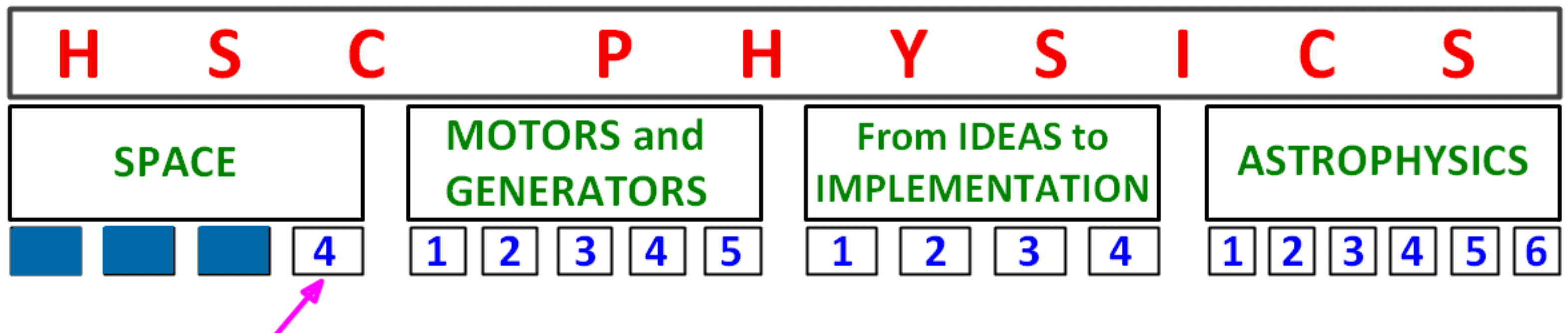


SPACE

1st Quarter; Module 1

PERIOD 20

Eather and Michelson&Morley's Experiment



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

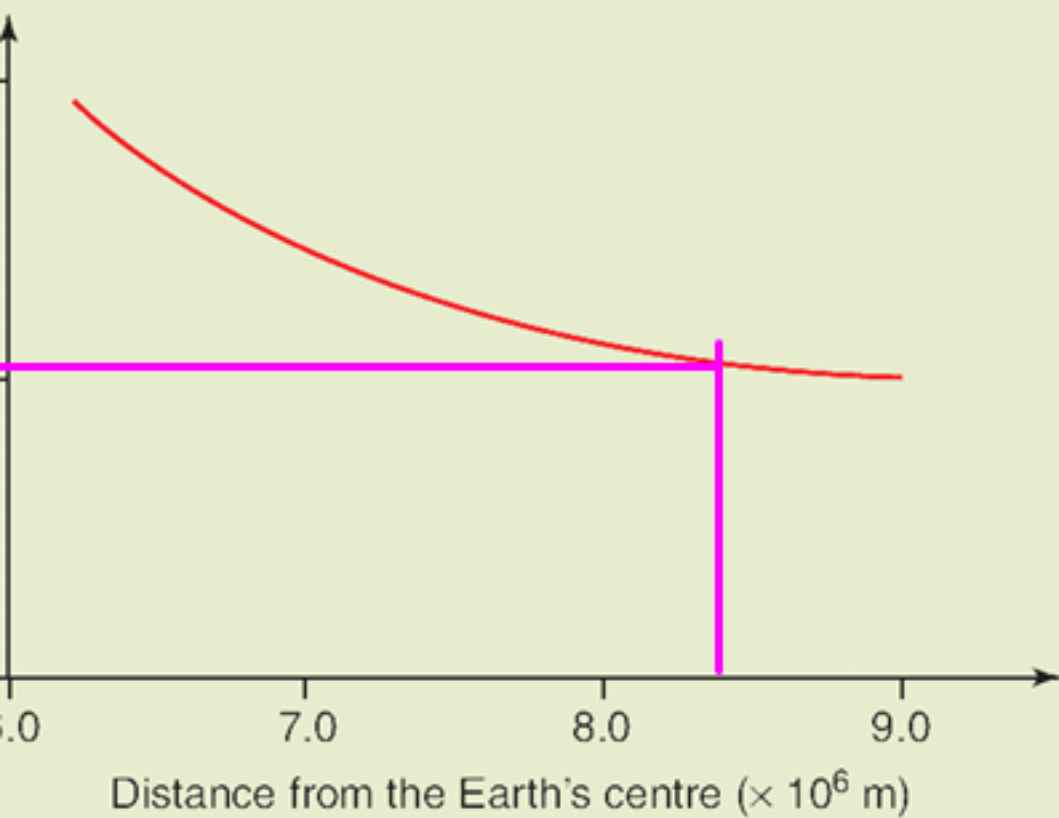
*Apart from **reading the relevant pages from the textbook and solving the rest of the questions in this booklet***

your homework is:

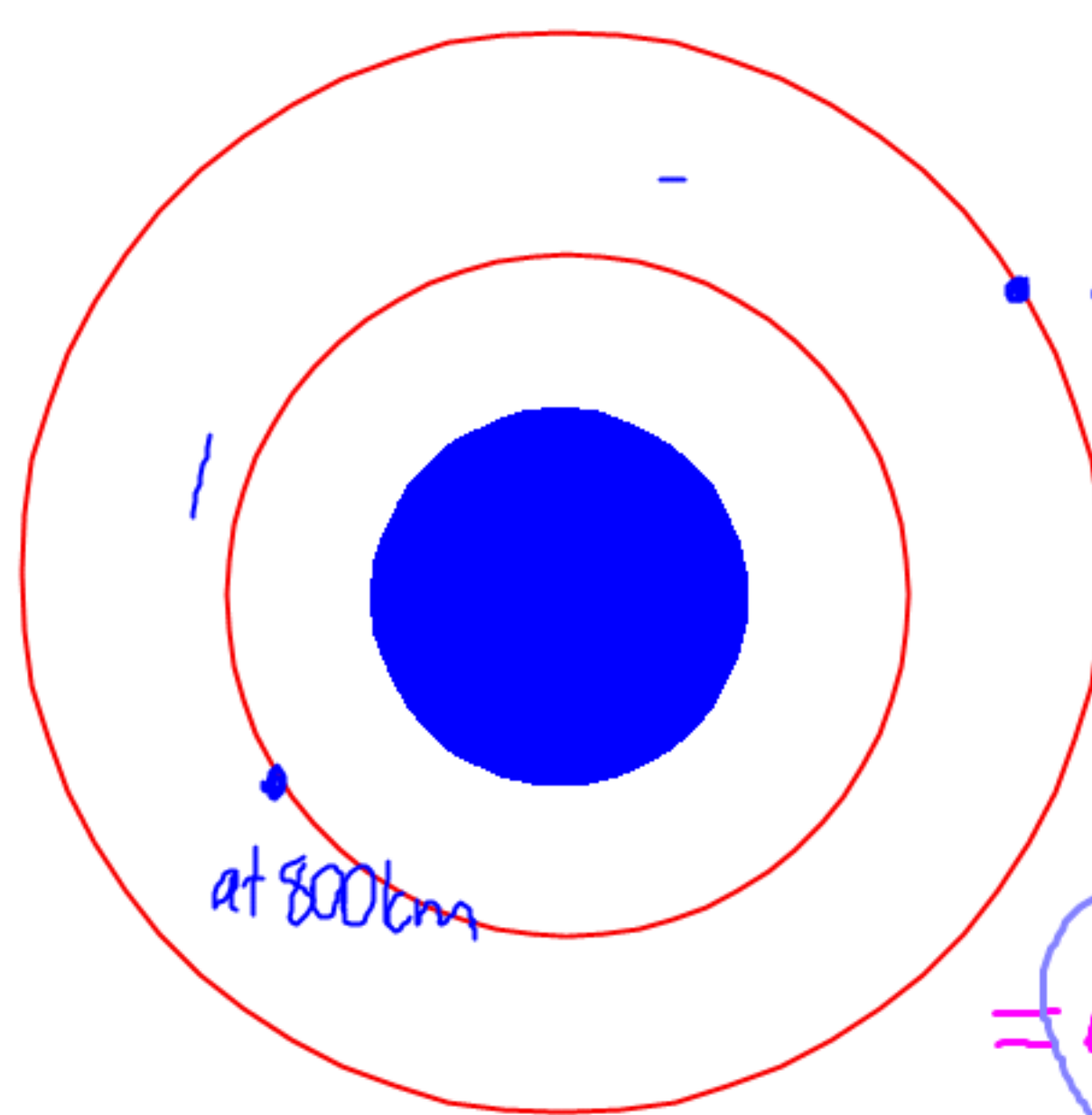
- ✓ Study CSU Space 3 notes
- ✓ New Dot Points booklet (pages 24-27)
- ✓ 12 questions in this booklet
- ✓ Chapter 4 all questions
- ✓ 12 questions of P18
- ✓ 8 questions of P17
- ✓ Experiment 5 Report
- ✓ Relevant pages in Multiple Choice Dot Points Book (DPB)
- ✓ New 8 page booklet (pages 16-23)
- ✓ Chapter 3 all questions

NEXT PERIOD > EITHER THEORY - MICHELSON&MORLEY EXPERIMENT

A satellite of mass 2400 kg is in orbit around Earth at a height of 2000 km above sea level. It falls to a height of 800 km before its built-in rocket system can be activated to stop the fall.



Calculate the gravitational force on the satellite while it is in its initial orbit.
 Calculate the loss of gravitational potential energy of the satellite during its fall.
 If the speed of the satellite during its initial orbit is 6900 m s^{-1} , what is its speed when the rocket system is activated?



at 2000km

$$F_g = G \cdot \frac{M_{\text{em}}}{d^2}$$

$$= 6.67 \times 10^{-11} \times \frac{6 \times 10^{24} \times 2400}{(8.4 \times 10^6)^2}$$

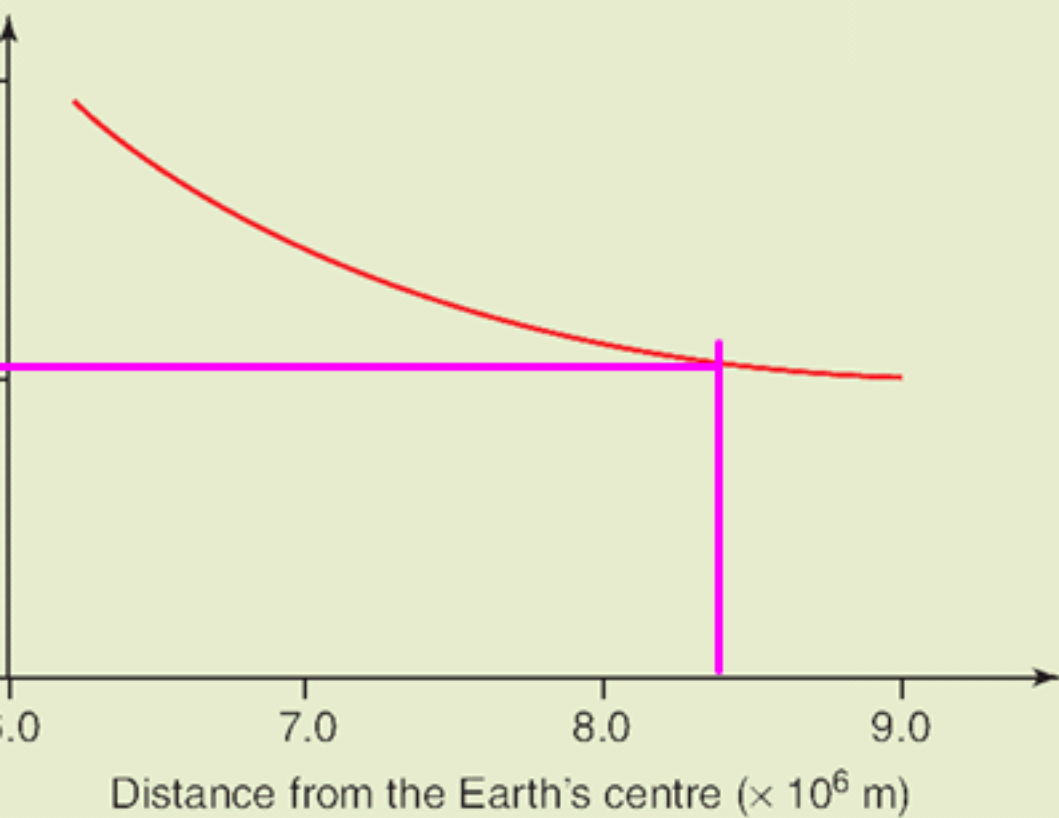
$$= 13600 \text{ N}$$

$$F_g = m \cdot g$$

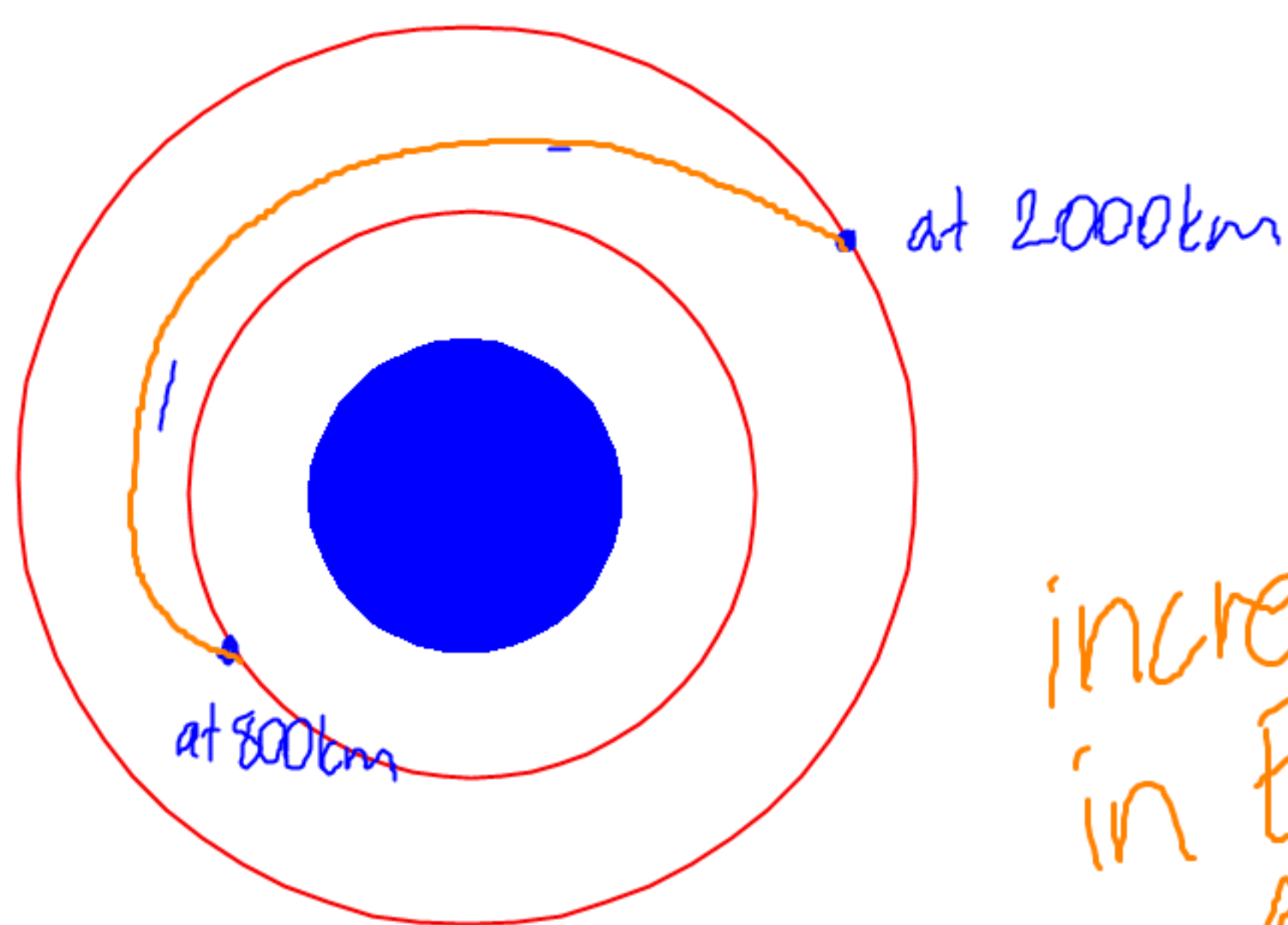
$$= 2400 \times 5$$

$$= 12000 \text{ N}$$

A satellite of mass 2400 kg is in orbit around Earth at a height of 2000 km above sea level. It falls to a height of 800 km before its built-in rocket system can be activated to stop the fall.



Calculate the gravitational force on the satellite while it is in its initial orbit.
 Calculate the loss of gravitational potential energy of the satellite during its fall.
 If the speed of the satellite during its initial orbit is 6900 m s^{-1} , what is its speed when the rocket system is activated?



increase
in E_k

$$\Delta E_p = E_p \text{ at } 800\text{km} - E_p \text{ at } 2000\text{km} =$$

$$= -\frac{6 \text{ Mm}}{7.2 \times 10^6} - -\frac{6 \text{ Mm}}{8.4 \times 10^6}$$

$$= -4.9 \times 10^3 \text{ J} \approx 5000 \text{ J} = -1.1 \times 10^4 \text{ J}$$

THE AETHER MODEL



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THE AETHER MODEL

Having concluded that light moves as a waveform, nineteenth-century physicists turned to other wave motions in order to better understand light. There were many others known, including sound waves, water waves, and earthquake waves. All of these waveforms need a medium through which to travel, and so it was believed that light waves would also require a medium. Nobody could find such a medium but belief in its existence was so strong that it was given a name, the ‘luminiferous **aether**’, and its properties were identified. The aether:

- filled all of space, had low density and was perfectly transparent
- permeated all matter and yet was completely permeable to material objects
- had great elasticity to support and propagate the light waves.

This list of properties may seem odd to us now and the whole concept of the aether may seem strange in hindsight, but bear in mind that nineteenth-century physicists were trying to understand a phenomenon completely unknown to them. It is not unlike the situation facing modern cosmologists in trying to understand why the universe seems to have much more matter than can be observed, and why the expansion of the universe seems to be accelerating. Some explanations of these modern-day puzzles attribute some similarly unusual properties to otherwise ‘ordinary’ space.

The search for the aether was to occupy physicists for several decades before it was finally accepted that (a) the aether does not actually exist, and (b) electromagnetic waves (including light) are unique in that they do not require a **medium** of any sort in order to move.

The **aether** was the proposed medium for light and other electromagnetic waves, before it was realised that these waveforms do not need a medium in order to travel.

Why did we need "aether" in the first place

anyway!

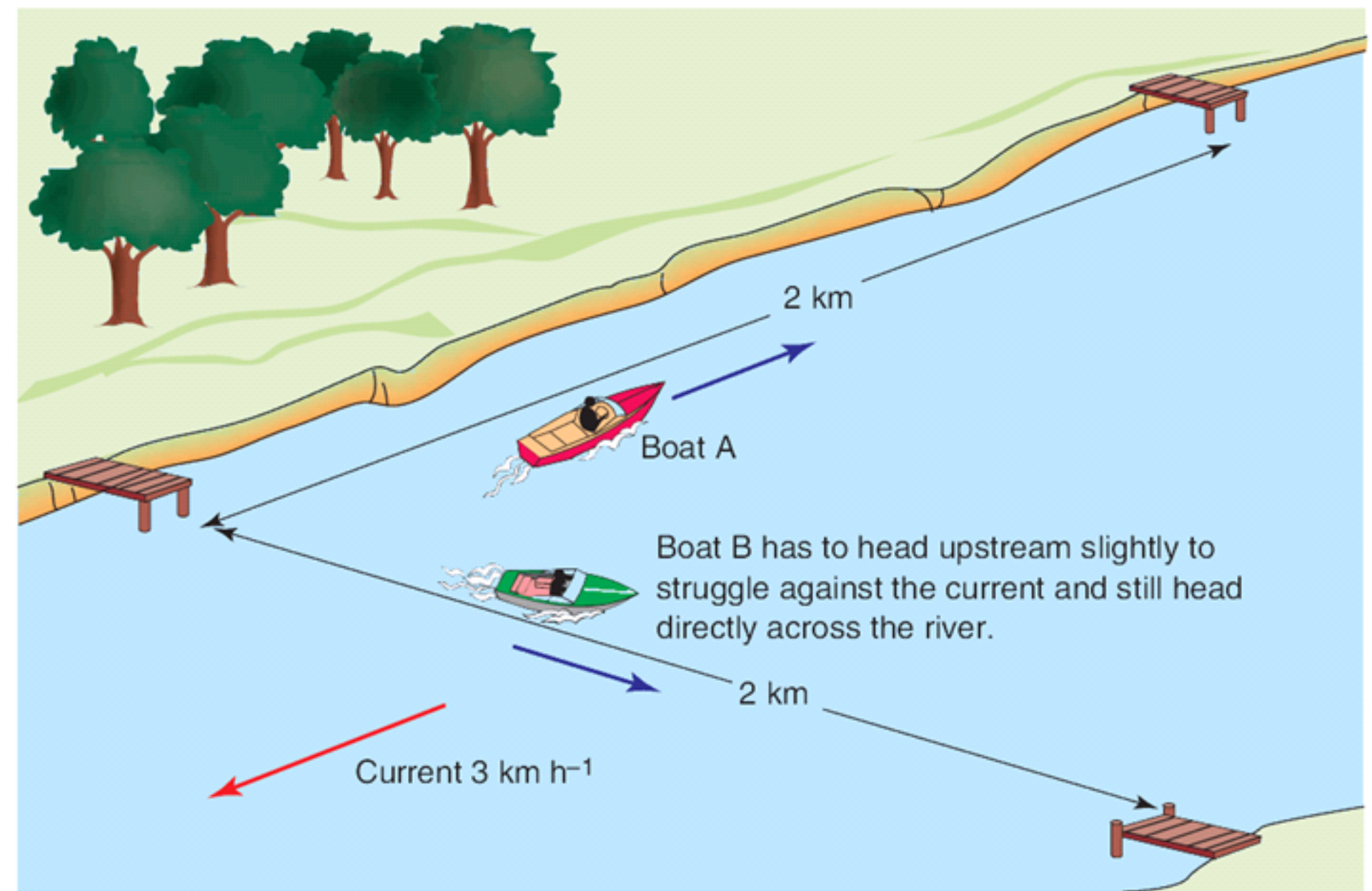
* they believed light travels as a wave.

* all waves they knew needed a medium to travel (water waves in water, waves in string, sound in air)

* So, light travels in space, there is no air/water in space, but ~~it~~ it needs a medium!

* Aether is the medium for light to travel.

ANALOGY TO BETTER UNDERSTAND THE "MM EXPERIMENT"



(a) The situation for boat A heading along the river

→ Journey out (against current)

Boat speed = 5 km h⁻¹ through the water
= 2 km h⁻¹ as seen from the river bank

$$\therefore \text{time taken} = \frac{\text{distance}}{\text{speed}} = \frac{2 \text{ km}}{2 \text{ km h}^{-1}} = 1 \text{ h}$$

← Current 3 km h⁻¹

← Return journey (with current)

Boat speed = 5 km h⁻¹ through the water
= 8 km h⁻¹ as seen from the river bank

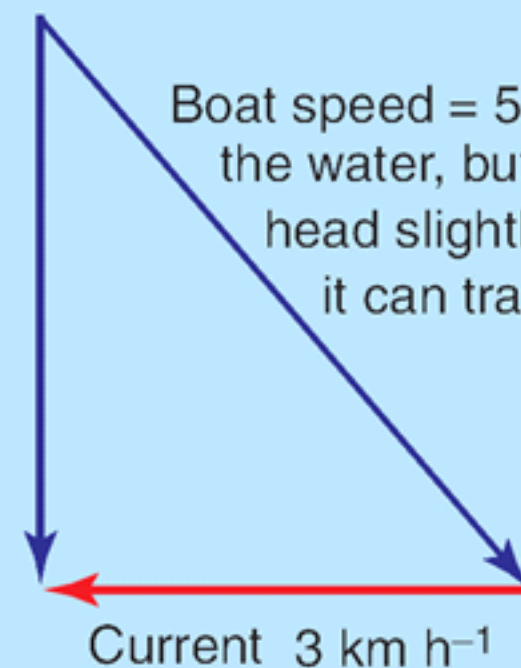
$$\therefore \text{time taken} = \frac{\text{distance}}{\text{speed}} = \frac{2 \text{ km}}{8 \text{ km h}^{-1}} = 0.25 \text{ h} = 15 \text{ min}$$

Hence, total time taken = 1 h 15 min

(b) The situation for boat B heading across the river

From Pythagoras' theorem,
boat speed = $\sqrt{5^2 - 3^2}$
= 4 km h⁻¹
as seen from the river bank

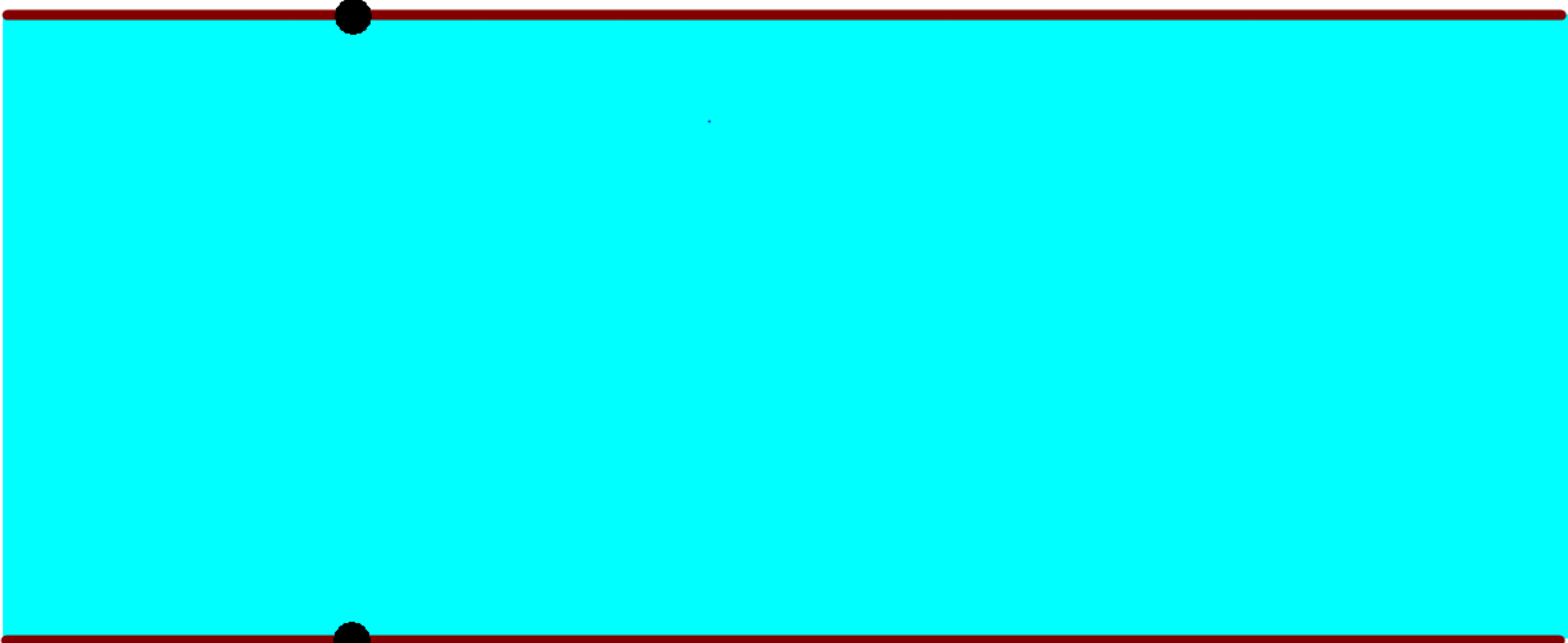
Boat speed = 5 km h⁻¹ through the water, but this boat must head slightly upstream so that it can travel directly across.



$$\therefore \text{time taken} = \frac{\text{distance}}{\text{speed}} = \frac{2 \text{ km}}{4 \text{ km h}^{-1}} = 0.5 \text{ h each way}$$

Hence, total time taken = 1 h and this boat wins!

River - still



B

A

River - water flow

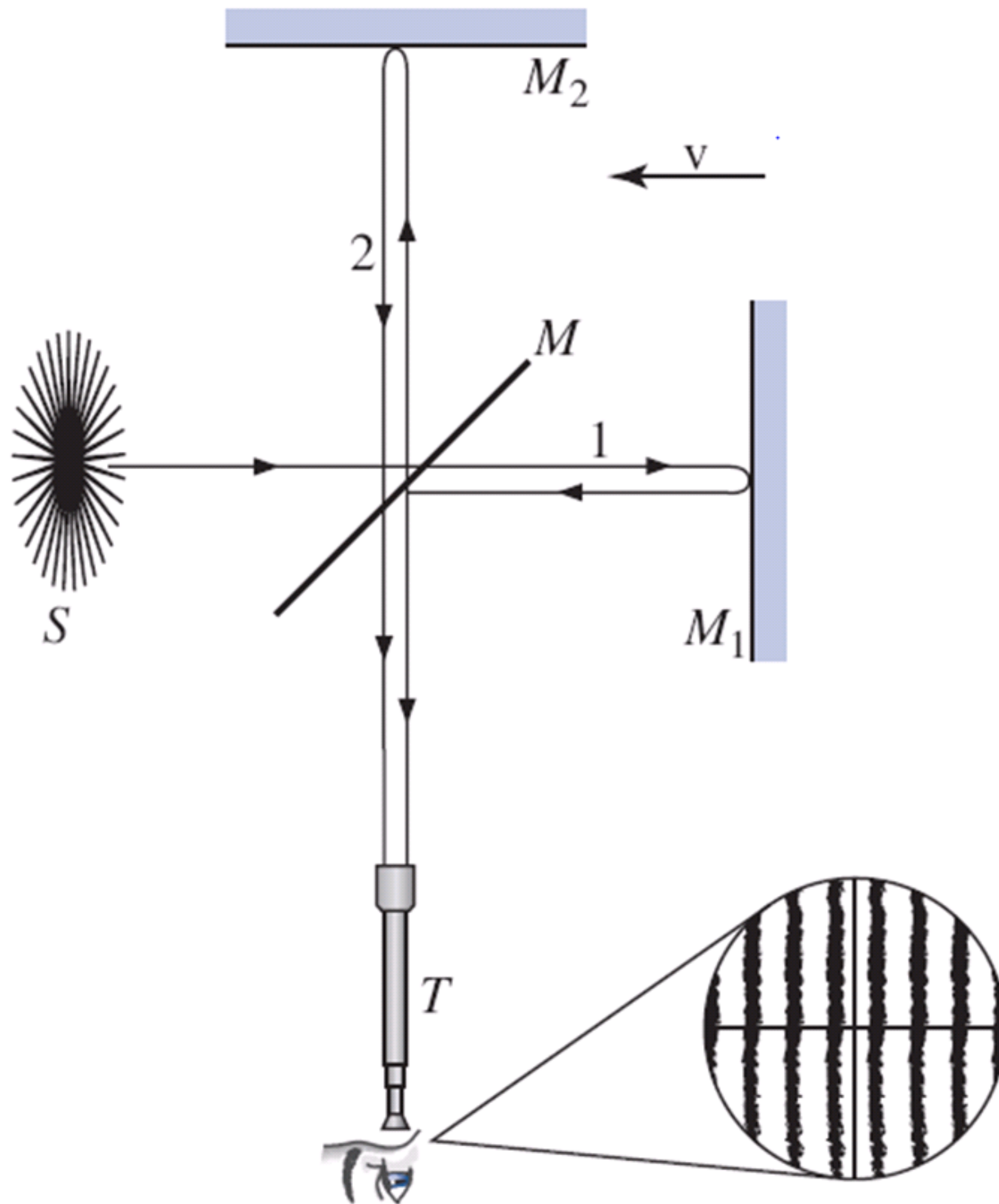
B



A

Michelson-Morley experiment

Aim: to measure the speed of Earth through aether



Micholson-Morley experiment

Aim: to measure the speed of Earth through aether

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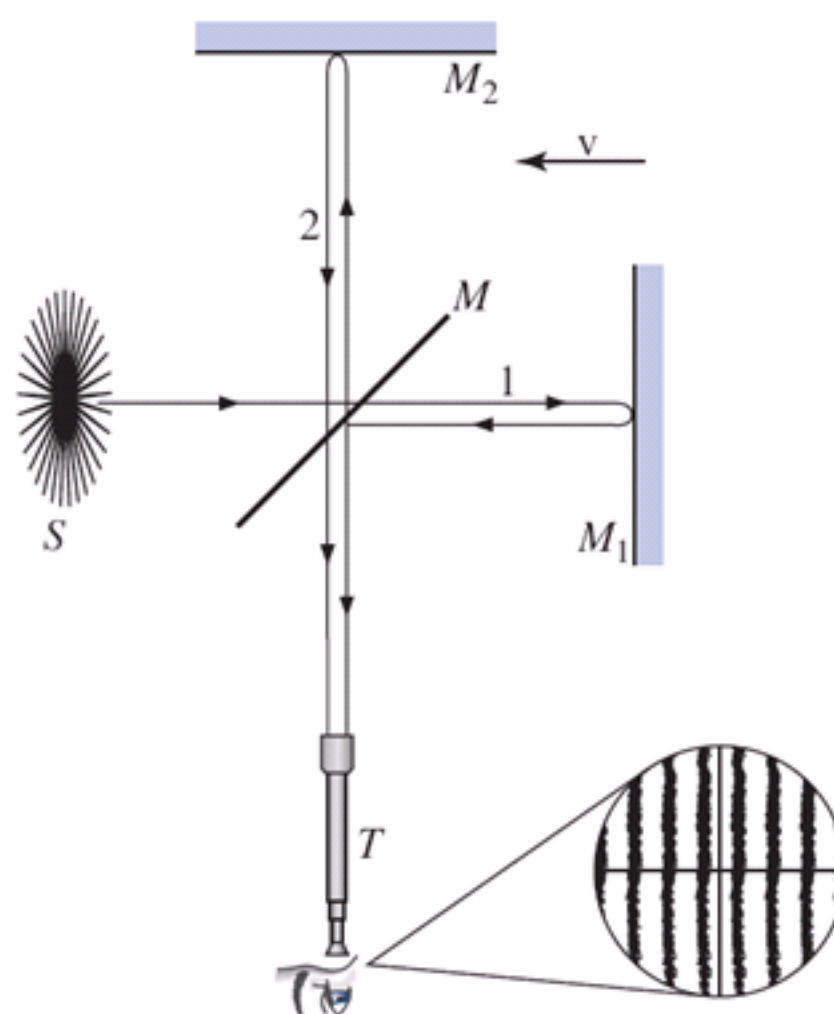
Micholson-Morley experiment

Aim: to measure the speed of Earth through aether

.

This is essentially what Michelson and Morley did — they raced two light rays over two courses, one into the supposed aether wind and one across it, then swung the apparatus through 90 degrees to interpose the rays. They were looking for a difference between the rays as they finished their race, from which they could calculate the value of the aether wind. Figure 5.4 shows their apparatus, while figure 5.5 uses a simplified diagram to show how it worked.

Figure 5.5 A simplified diagram showing the light rays' paths in the Michelson–Morley experiment. A light ray from the source is split into two by the half-silvered mirror. Ray A heads into the aether wind then reflects against mirror M_1 and returns. Ray B heads across the aether wind before reflecting back. Both rays finish their journey at the telescope, where they are compared.



The method of comparing the light rays involves a very sensitive effect called ‘interference’, and hence this apparatus is referred to as an ‘interferometer’. Essentially, when looking into the telescope a pattern of light and dark bands will be seen, as shown in figure 5.5. If the aether wind exists, so that one light ray is indeed faster than the other, then when the apparatus is rotated, so that the rays are interposed, the interference pattern should be seen to shift. However, no such shift was observed.

The experiment was repeated many times by Michelson and Morley, at different times of the day and year, but no evidence of an aether wind was ever found. The scientific community was not quick to abandon the aether model, however, and adapted the theory to keep it alive. One suggestion was that a large object such as a planet could drag the aether along with it. Another was that objects contract in the direction of the aether wind. However, none of these modifications survived close scrutiny. Further, the Michelson–Morley experiment has been repeated many times since 1887 by different groups with more and more sensitive equipment, and no evidence of an aether has ever been found. Yet belief in the necessity of the aether was so strong that physicists found it difficult to let go of the idea until, in 1905, Albert Einstein showed that the aether was not necessary at all.

HOMEWORK DUE 12 NOV THURSDAY

1 Which of the following statements is correct? A satellite in a stable circular orbit 100 km above the Earth will move:

- A with an acceleration of 9.8 m s^{-2}
- B with a constant velocity
- C with zero acceleration
- D with an acceleration of less than 9.8 m s^{-2} .

2 Explain why the gravitational field of the Earth does no work on a satellite in a stable circular orbit.

The following information applies to questions 3 and 4. The gravitational field strength at the location where the Optus D1 satellite is in stable orbit around the Earth is equal to 0.22 N kg^{-1} . The mass of this satellite is $2.3 \times 10^3 \text{ kg}$.

- 3 Using only the information given, calculate the net force acting on this satellite as it orbits.
- 4 Identify the source of this net force.
- 5 The planet Neptune has a mass of $1.02 \times 10^{26} \text{ kg}$. One of its moons, Triton, has a mass of $2.14 \times 10^{22} \text{ kg}$ and an orbital radius equal to $3.55 \times 10^8 \text{ m}$. For Triton, calculate its:
- a orbital acceleration
 - b orbital speed
 - c orbital period (in days).

9 The data for two of Saturn's moons, Atlas and Helene, is as follows. The orbit of Helene is about twice as far from the centre of Saturn as that of Atlas.

	Orbital radius (m)	Orbital period (days)
Atlas	1.37×10^8	0.602
Helene	3.77×10^8	2.75

- a Calculate the value of these ratios:
- i orbital speed of Atlas/orbital speed of Helene
 - ii acceleration of Atlas/acceleration of Helene.
- b The largest of Saturn's moons is Titan. It has an orbital radius of $1.20 \times 10^9 \text{ m}$. Use Kepler's third law to show that the orbital period of Titan is 15.6 days.

10 The space shuttle is launched into orbit from a point A on the Equator, as shown. The shuttle then enters a stable circular orbit of radius R_o at point B. The radius of the Earth is $6.4 \times 10^6 \text{ m}$. The ratio of the gravitational field strength at A to that at B is equal to 1.2. Calculate the distance R_o .



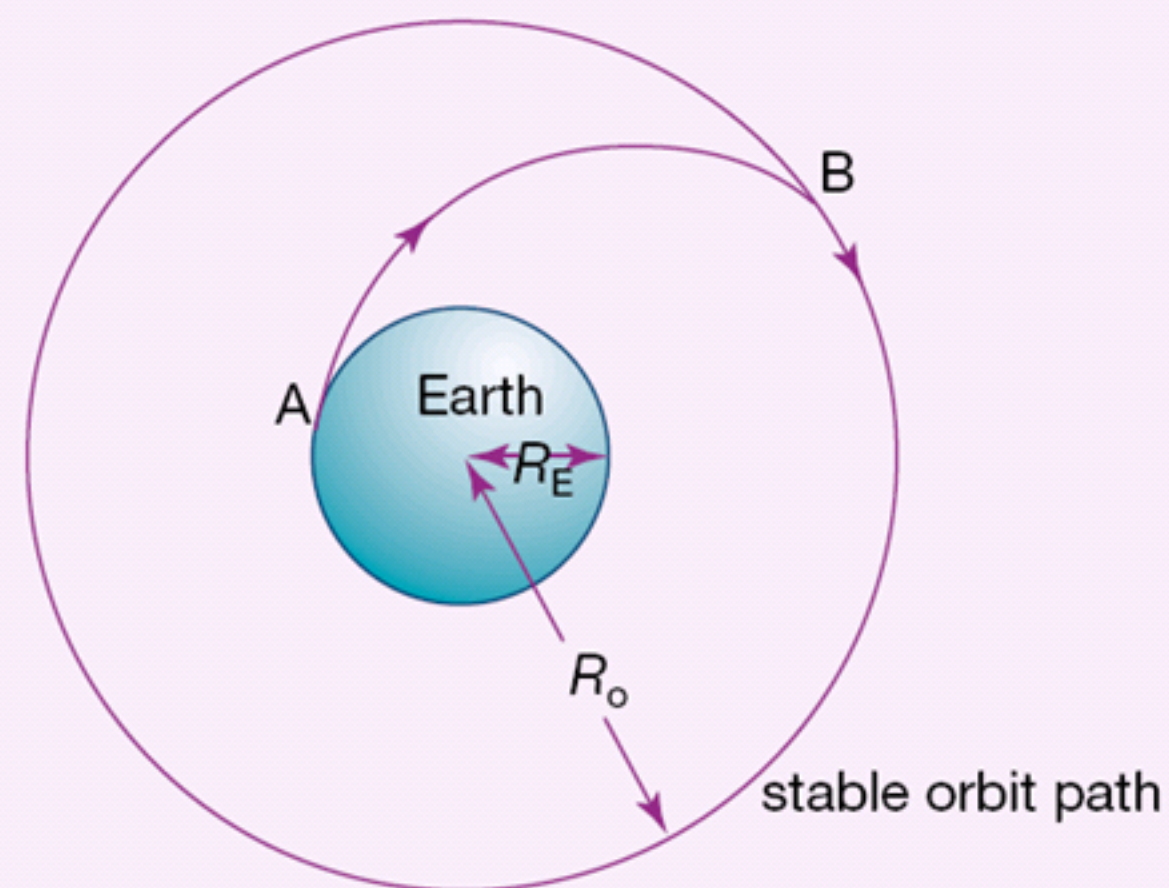
force acting on this satellite as it orbits.

- 4 Identify the source of this net force.
- 5 The planet Neptune has a mass of 1.02×10^{26} kg. One of its moons, Triton, has a mass of 2.14×10^{22} kg and an orbital radius equal to 3.55×10^8 m. For Triton, calculate its:
 - a orbital acceleration
 - b orbital speed
 - c orbital period (in days).

The following information applies to questions 6 and 7. One of Saturn's moons, Titan, has a mass of 1.35×10^{23} kg and an orbital radius of 1.22×10^9 m. The orbital period of Titan is 1.38×10^6 s.

- 6 Calculate the:
 - a orbital speed of Titan (in km s^{-1})
 - b orbital acceleration of Titan.
- 7 Using this data, calculate the mass of Saturn.
- 8 A satellite is in a geosynchronous orbit around the Earth if its period of rotation is the same as that of the Earth, i.e. 24 h. Such a satellite is called a geostationary satellite. Venus has a mass of 4.87×10^{24} kg and a radius of 6.05×10^6 m. The length of a day on Venus is 2.10×10^7 s. For a satellite to be in a synchronous orbit around Venus, calculate:
 - a the orbital radius of the satellite
 - b its orbital speed
 - c its orbital acceleration.

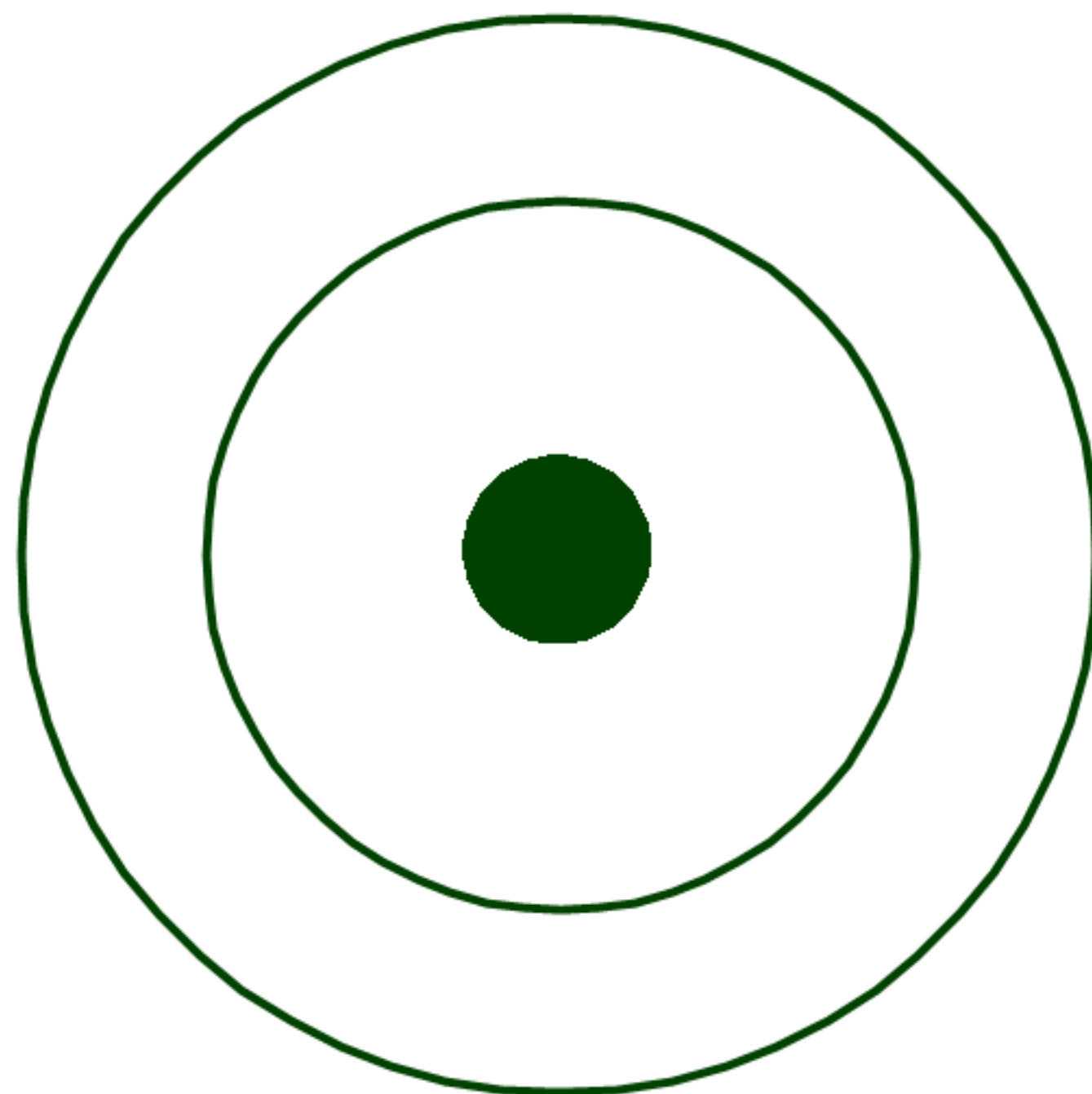
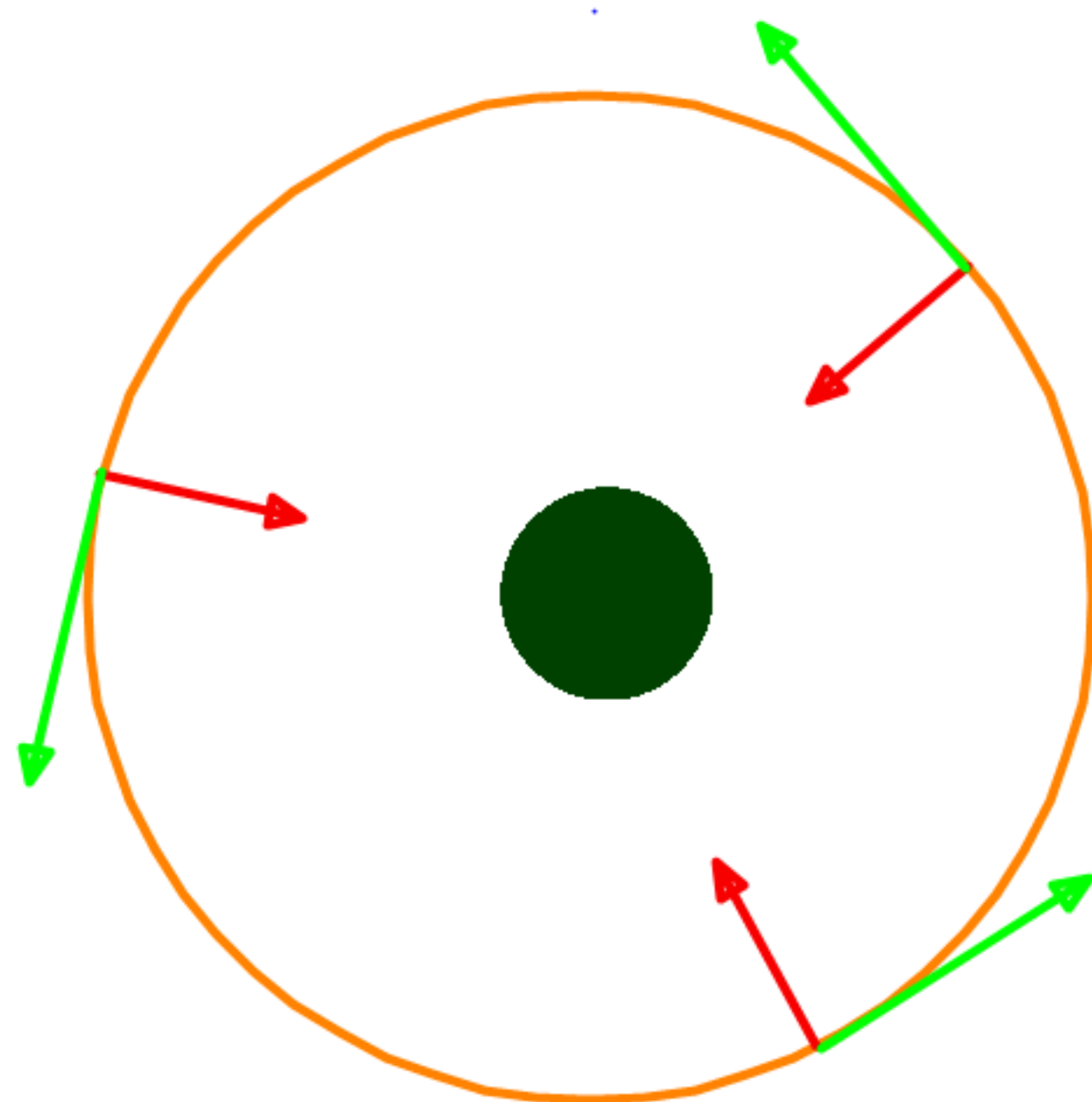
- 10 The space shuttle is launched into orbit from a point A on the Equator, as shown. The shuttle then enters a stable circular orbit of radius R_o at point B. The radius of the Earth is 6.4×10^6 m. The ratio of the gravitational field strength at A to that at B is equal to 1.2. Calculate the distance R_o .



- 11 Melbourne TV stations can use pictures from the Japanese MTSAT-1R weather satellite, which is in a geostationary orbit over the Equator to the north of Australia. Why is it not possible to place a satellite in orbit so that it is always directly over Melbourne?
- 12 Ceres, the first asteroid to be discovered, was found by Giuseppe Piazzi in 1801. Ceres has mass 7.0×10^{20} kg and radius 385 km.
 - a What is the gravitational field strength at the surface of Ceres?
 - b Determine the speed required by a satellite in order to remain in orbit 10 km above the surface of Ceres.

1. (6 marks) Discuss issues associated with safe re-entry into the Earth's atmosphere and landing on the Earth's surface.

2. (4 marks) Find the Orbital speed and the period of HST (hubble Space Telescope) positioned at around 1000 km from earth's surface. (Mass of the Earth is 6×10^{24} kg, average radius of earth is 6380 km, mass of the telescope is 680 kg)



Space 2

The Solar System is held together by gravity.

Students learn to:

- describe a gravitational field in the region surrounding a massive object in terms of its effects on other masses in it
- define Newton's Law of Universal Gravitation

$$F = G \frac{m_1 m_2}{d^2}$$

- discuss the importance of Newton's Law of Universal Gravitation in understanding and calculating the motion of satellites
- identify that a slingshot effect can be provided by planets for space probes

Students:

- present information and use available evidence to discuss the factors affecting the strength of the gravitational force
- solve problems and analyse information using

$$F = G \frac{m_1 m_2}{d}$$