



3420U20-1

FRIDAY, 24 MAY 2024 – MORNING

PHYSICS – Unit 2:
Forces, Space and Radioactivity

FOUNDATION TIER

**1 hour 45 minutes plus your additional
time allowance**

Surname _____

First name(s) _____

Centre Number _____

Candidate Number 0 _____

ADDITIONAL MATERIALS

In addition to this paper you will require a calculator and a ruler.

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

A separate Data Booklet.

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball-point pen or your usual method.

Write your name, centre number and candidate number in the spaces provided on the front cover.

Answer ALL questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional pages at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question 6(c).

(Turn over)

For Examiner’s use only		
Question	Maximum Mark	Mark Awarded
1.	6	
2.	6	
3.	6	
4.	6	
5.	10	
6.	9	
7.	12	
8.	5	
9.	10	
10.	10	
Total	80	

Answer ALL questions.

1 (a) Draw straight lines below to match the energy store on the left with an example on the right. [2 marks]

**ENERGY
STORE**

**kinetic
energy**

**elastic
energy**

**gravitational
potential
energy**

EXAMPLE

**ball held above
the ground**

**stretched
rubber band**

**ball rolling
along level
ground**

(Turn over)

1 (b) A box is pulled 2m up a slope by a force of 100 N. See DIAGRAM 1.1 in the separate Diagram Booklet

(i) Use the equation:

work done = force $\times$ distance

to determine the work done by the 100 N force. [2 marks]

work done = _____ J

**(ii) State how much energy is transferred by the force.
Include a unit with your answer.
[2 marks]**

energy transferred = _____

unit = _____

2 **DIAGRAM 2.1** in the separate Diagram Booklet shows the forces acting on a high-mass star that is on the main sequence.

(a) Complete the sentences below by **CIRCLING** the correct answer.

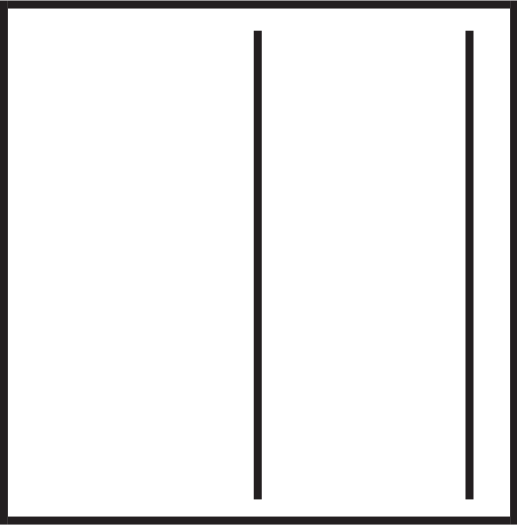
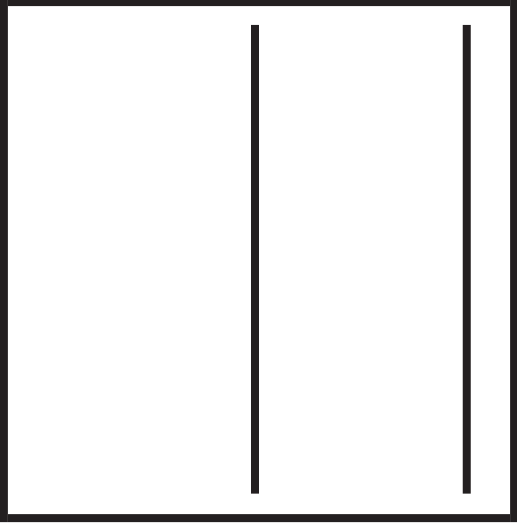
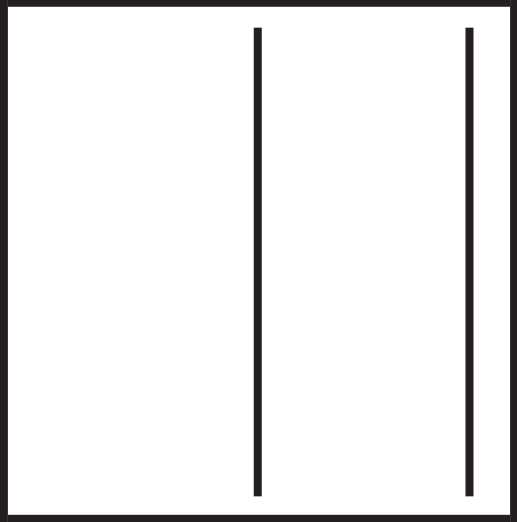
(i) The star is
 (burning / fusing / melting)
 hydrogen. [1 mark]

(ii) The star is currently stable because
 the forces acting on it are
 (balanced / unbalanced / zero).
 [1 mark]

(Turn over)

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2 (b)(i)

**Use the words from the box below to complete the diagram on the opposite page to show the stages in the life cycle of a HIGH-MASS star.
[3 marks]**

supergiant	protostar
yellow dwarf	red giant
neutron star	white dwarf

(Turn over)

2 (b)(ii)

Tick (✓) the box next to the correct statement to complete the following sentence. [1 mark]

During the supernova stage of the star's life cycle:

☐

the star is red shifted

☐

heavy elements are returned to space

☐

nuclear fission takes place

6

(Turn over)

3 (a)(i)

Air bags help to keep passengers safe in the event of an accident.

**UNDERLINE the words that correctly complete the sentences below.
[3 marks]**

Air bags

(increase / decrease / remove)

the time it takes to reduce the passengers'

(momentum / inertia / mass)

to zero. This

(increases / decreases / doubles)

the force acting on them.

(Turn over)

3 (a)(ii)

Air bags are one safety feature of cars designed to reduce harm to passengers.

**Name ONE other safety feature.
[1 mark]**

(Turn over)

**3 (b) Explain why cars are designed to have a more aerodynamic shape.
[2 marks]**

6

(Turn over)

- 4** **DIAGRAM 4.1** in the separate Diagram Booklet shows the absorption spectra of 4 different galaxies compared to part of the Sun's absorption spectrum.
- (a)(i)** One absorption line in the spectrum from the Sun is labelled.
The wavelength of the same absorption line from each galaxy is given in **TABLE 4.2** in the separate Diagram Booklet.
COMPLETE TABLE 4.2 with the estimated wavelength of that absorption line in galaxy C. [1 mark]

(Turn over)

4 (a)(ii)

The absorption lines in the galaxies are red shifted.

State which galaxy is furthest from the Sun.

Explain how you know. [2 marks]

(iii) State what the red shift of these lines tells us about the Universe. [1 mark]

(Turn over)

4 (b) Absorption lines can tell us which elements are present in a star.

TABLE 4.3 in the separate Diagram Booklet shows the wavelengths of one absorption line from some common elements.

The observed spectrum from a star is shown in DIAGRAM 4.4 in the separate Diagram Booklet.

Rhodri states that the star contains helium and iron.

Use the information from TABLE 4.3 and the observed spectrum (DIAGRAM 4.4) to explain whether you agree. [2 marks]

continue answer on next page

(Turn over)

6

- 5** **DIAGRAM 5.1** in the separate Diagram Booklet shows two ice skaters, Abi and Rachel, skating in the same direction.

(a)(i) Use DIAGRAM 5.1 and the equation:

$$\text{momentum} = \text{mass} \times \text{velocity}$$

**to calculate RACHEL'S momentum.
[2 marks]**

**Rachel's
momentum = _____ kg m/s**

- (ii) Use your answer to (a)(i) and information from DIAGRAM 5.1 to determine the total momentum of the ice skaters. [1 mark]**

**total
momentum = _____ kg m/s**

(Turn over)

5 (a)(iii)

**Abi catches up with Rachel and lifts her as shown in DIAGRAM 5.2 in the separate Diagram Booklet.
This can be thought of as a collision.**

State the total momentum of the ice skaters after this collision has taken place. [1 mark]

**total
momentum = _____ kg m/s**

(iv) Use the equation:

$$\text{velocity} = \frac{\text{total momentum}}{\text{mass}}$$

to calculate the velocity of the ice skaters after the collision. [2 marks]

velocity = _____ m/s

(Turn over)

5 (a)(v)

The ice skaters glide freely from this velocity, u .

After a time, t , of 25 s their velocity, v , is 0 m/s.

Use the equation:

$$x = \frac{1}{2}(u + v)t$$

to calculate the distance, x , that they travel. [2 marks]

$x =$ _____ m

(Turn over)

5 (b) Abi suggests that if she doubles her velocity the total momentum of Abi and Rachel will also double. Explain whether Abi is correct. [2 marks]

10

(Turn over)

6 The highway code has the information shown in DIAGRAM 6.1 in the separate Diagram Booklet about stopping distances.

(a) Calculate the overall stopping distance for a car travelling at 30 mph. [1 mark]

**overall
stopping
distance = _____ m**

(Turn over)

**6 (b) Use the data from DIAGRAM 6.1 to describe the relationship between speed and thinking distance.
[2 marks]**

(Turn over)

6 (c) One factor that affects thinking distance is the age of the driver.

State what is meant by the terms thinking distance and braking distance AND describe some other factors that affect each of these distances. [6 marks QER]

continue answer on next page (Turn over)

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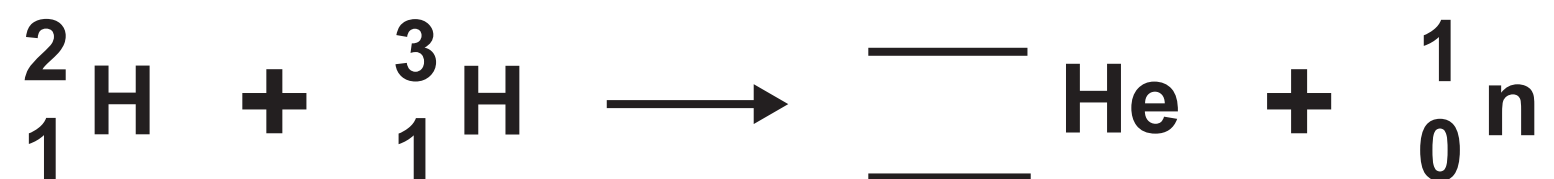
continue answer on next page (Turn over)

9

7 There are two types of nuclear reaction: fission and fusion.

(a) Two isotopes of hydrogen ${}^2_1\text{H}$ and ${}^3_1\text{H}$ can fuse together to form helium (He).

(i) **COMPLETE** the equation for this fusion reaction.



(ii) **COMPLETE** TABLE 7.1 in the separate Diagram Booklet to give the number of protons and neutrons in the nuclei of each hydrogen isotope.
[4 marks]

(Turn over)

7 (a)(iii)

**State TWO reasons why nuclear fusion is difficult to achieve on Earth.
[2 marks]**

1. _____

2. _____

(Turn over)

7 (b) Nuclear fission is used to produce electricity in power stations.

DIAGRAM 7.2 in the separate Diagram Booklet shows a cross-section of a fission reactor.

In a nuclear power station, a neutron is absorbed by a uranium nucleus, producing two lighter nuclei and more neutrons.

Part of the chain reaction is shown in DIAGRAM 7.3 in the separate Diagram Booklet.

(i) State the number of neutrons produced in the fission reaction shown in DIAGRAM 7.3. [1 mark]

number of neutrons = _____

(Turn over)

7 (b)(ii)

State which part of a nuclear reactor slows down neutrons. [1 mark]

(iii) State why neutrons need to be slowed down. [1 mark]

(Turn over)

7 (b)(iv)

**State the purpose of the control rods.
[1 mark]**

12

(Turn over)

- 8 Brachytherapy is a form of radiotherapy used in treating prostate cancer. Small pellets containing radioactive material are planted inside the prostate.**
- (a) One patient has 75 pellets containing iodine-125 planted in his prostate. EACH PELLET HAS AN INITIAL ACTIVITY OF 16 MBq.**
- (i) Calculate the initial activity of ALL 75 pellets. [1 mark]**

initial activity = _____ MBq

(Turn over)

8 (a)(ii)

The iodine-125 has a half-life of 60 days.

This means that the activity halves every 60 days.

Calculate the activity of the 75 pellets after 120 days. [2 marks]

**activity after
120 days = _____ MBq**

(Turn over)

8 (b) Iodine-123 is another isotope of iodine.

It has a half-life of 13 hours.

Explain why iodine-123 is not suitable for this treatment. [2 marks]

5

(Turn over)

- 9 A group of students is investigating background radiation.**
- (a) They find PIE CHARTS 9.1, 9.2 and 9.3 in the separate Diagram Booklet, which show the background radiation in 3 different locations, A, B and C, in the UK.**

The map in DIAGRAM 9.4 in the separate Diagram Booklet shows radon levels across the UK.

The 3 locations, A, B and C are shown on the map.

The darker the area on the map the higher the levels of radon.

(Turn over)

9 (a)(i)

Adam studies the diagrams and concludes that LOCATION A must be Aberystwyth. Explain whether you agree. [2 marks]

(Turn over)

9 (a)(ii)

Their teacher measures the background count in LOCATION A. The teacher records 30 counts in 60 seconds.

I. Determine the count rate in counts per second. [1 mark]

count rate = _____ cps

II. Use information from PIE CHART 9.1 to determine how many of the 30 counts are due to radon gas. [1 mark]

counts due to radon = _____

(Turn over)

9 (a)(iii)

Chloe states that people are more at risk from man-made sources of background radiation than natural sources.

Use data from PIE CHART 9.1 for LOCATION A to explain whether you agree. [2 marks]

(Turn over)

9 (b) TABLE 9.5 in the separate Diagram Booklet shows how much radiation people receive from some different sources.

Workers in nuclear power stations have their exposure to radiation carefully monitored.

If they receive a total of 20 UNITS of radiation from all sources including background radiation in one year, they can no longer work with radiation.

(Turn over)

9 (b)(i)

Sophia works in a nuclear power station.

In one year, she flies from London to New York and back.

She also has a dental X-ray and a CT scan to her chest.

Sophia is worried about the level of radiation she has been exposed to.

Use data to explain whether it is still safe for her to work with radiation.

[2 marks]

(Turn over)

9 (b)(ii)

Jack states that workers in a nuclear power station are exposed to more radiation in one year than airline pilots flying on the London to New York route.

Use data to explain whether he is correct. [2 marks]

- 10 Students investigate the terminal speed of a ball bearing in oil. Their apparatus is shown in DIAGRAM 10.1 in the separate Diagram Booklet. They measure the time it takes for the ball bearing to drop different distances through the oil.**

The results from the experiment are shown in TABLE 10.2 in the separate Diagram Booklet.

- (a)(i) Freya states that the mean time for 20 cm is incorrect and should be 6.6 s. Explain whether Freya is correct. [2 marks]**

continue answer on next page (Turn over)

10 (a)(ii)

**Evaluate the repeatability of the data.
[1 mark]**

(Turn over)

10 (b)

State ONE source of inaccuracy in this method AND how it could be reduced. [2 marks]

(Turn over)

10 (c)

A graph of the students' data is given in GRAPH 10.3 in the separate Diagram Booklet.

The section of the graph where the line is straight represents the ball bearing travelling at terminal speed.

- (i) Estimate the time at which the ball bearing reaches terminal speed.
[1 mark]**

time = _____ s

(Turn over)

10 (c)(ii)

The gradient of a distance-time graph represents the speed of an object.

Use the equation:

speed = gradient of distance-time graph

and the triangle shown on the graph to calculate the terminal speed of the ball bearing. [2 marks]

terminal speed = _____ cm/s

(Turn over)

10 (c)(iii)

State how the ACCELERATION of the ball bearing changes as it falls through the oil. [2 marks]

10

END OF PAPER

Question number	Additional page, if required. Write the question numbers in the left-hand margin.

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[illegible]

[illegible]



GCSE

3420U20-1

FRIDAY, 24 MAY 2024 – MORNING

PHYSICS – Unit 2:

Forces, Space and Radioactivity

FOUNDATION TIER

**1 hour 45 minutes plus your additional
time allowance**

DIAGRAM BOOKLET

**This Diagram Booklet MUST be handed in
to the invigilators and sent for marking.**

Surname _____

First name(s) _____

Centre Number _____

Candidate Number 0 _____

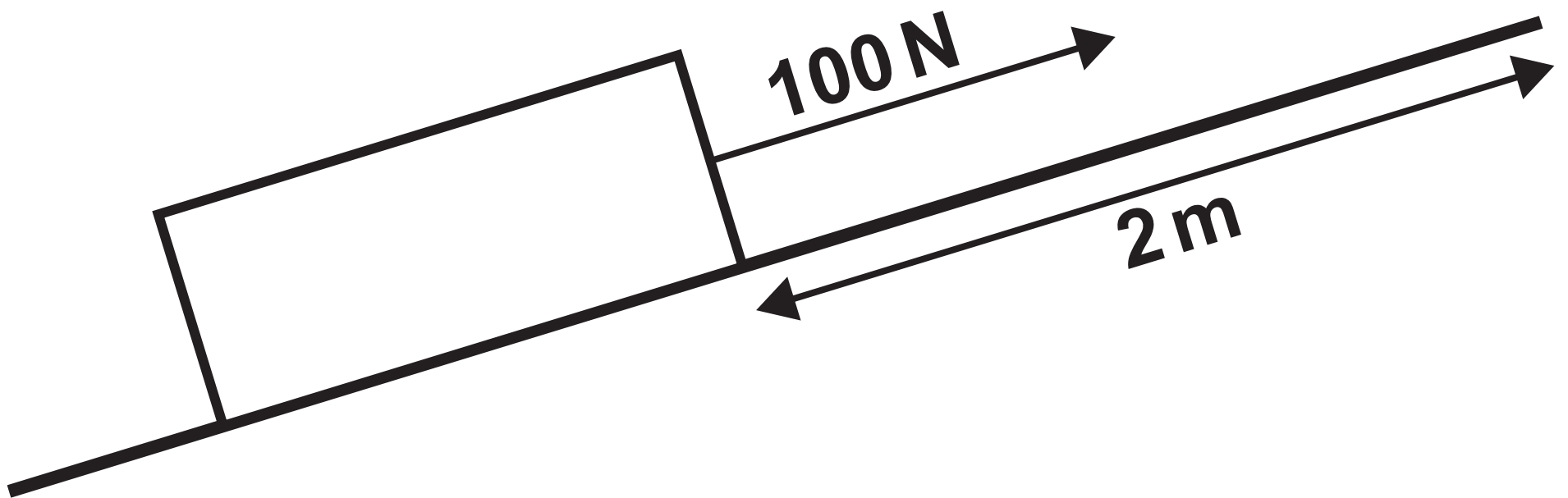
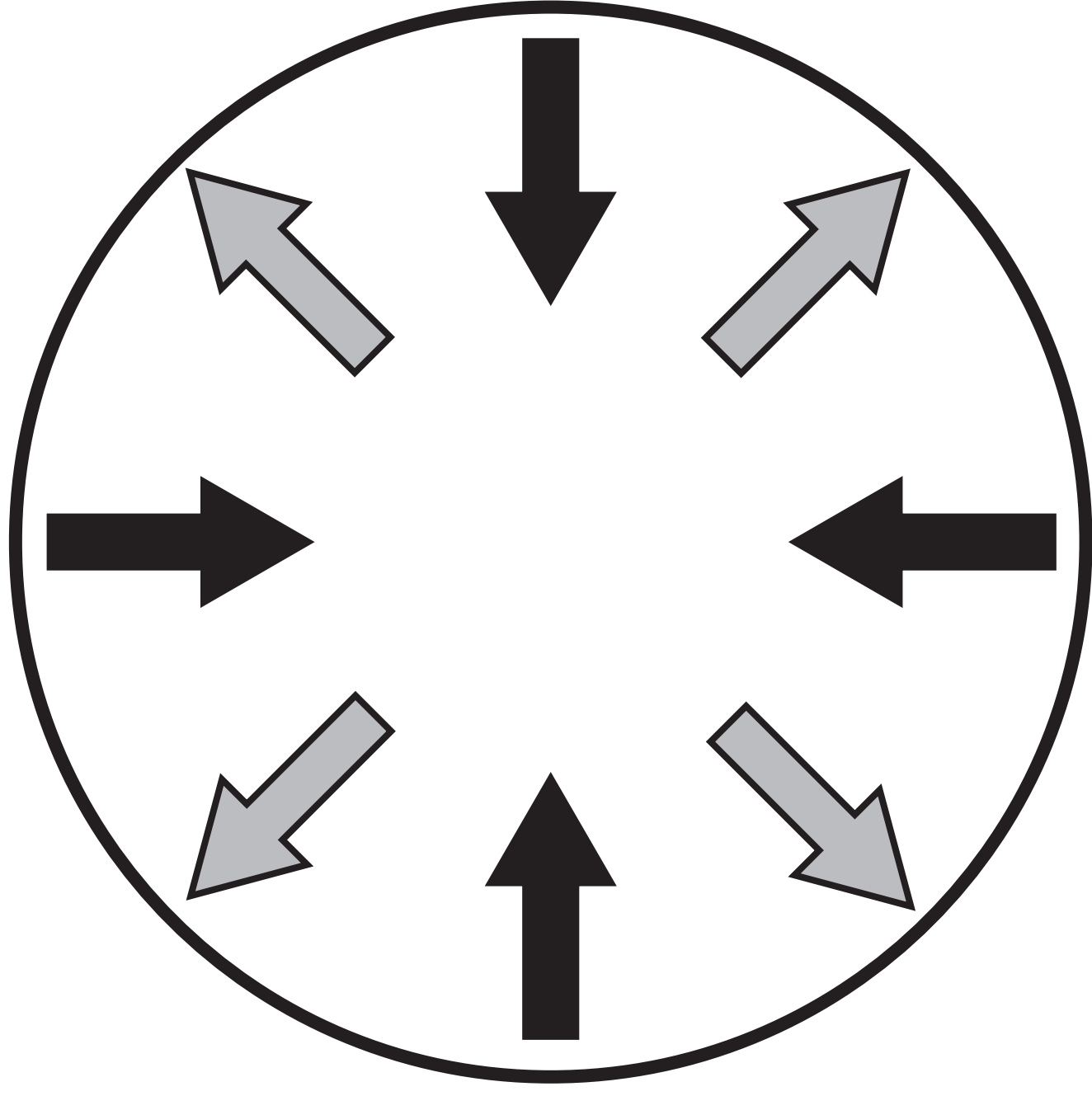
DIAGRAM 1.1

DIAGRAM 2.1



gravitational force

**gas and radiation
pressure**

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DIAGRAM 4.1

absorption line

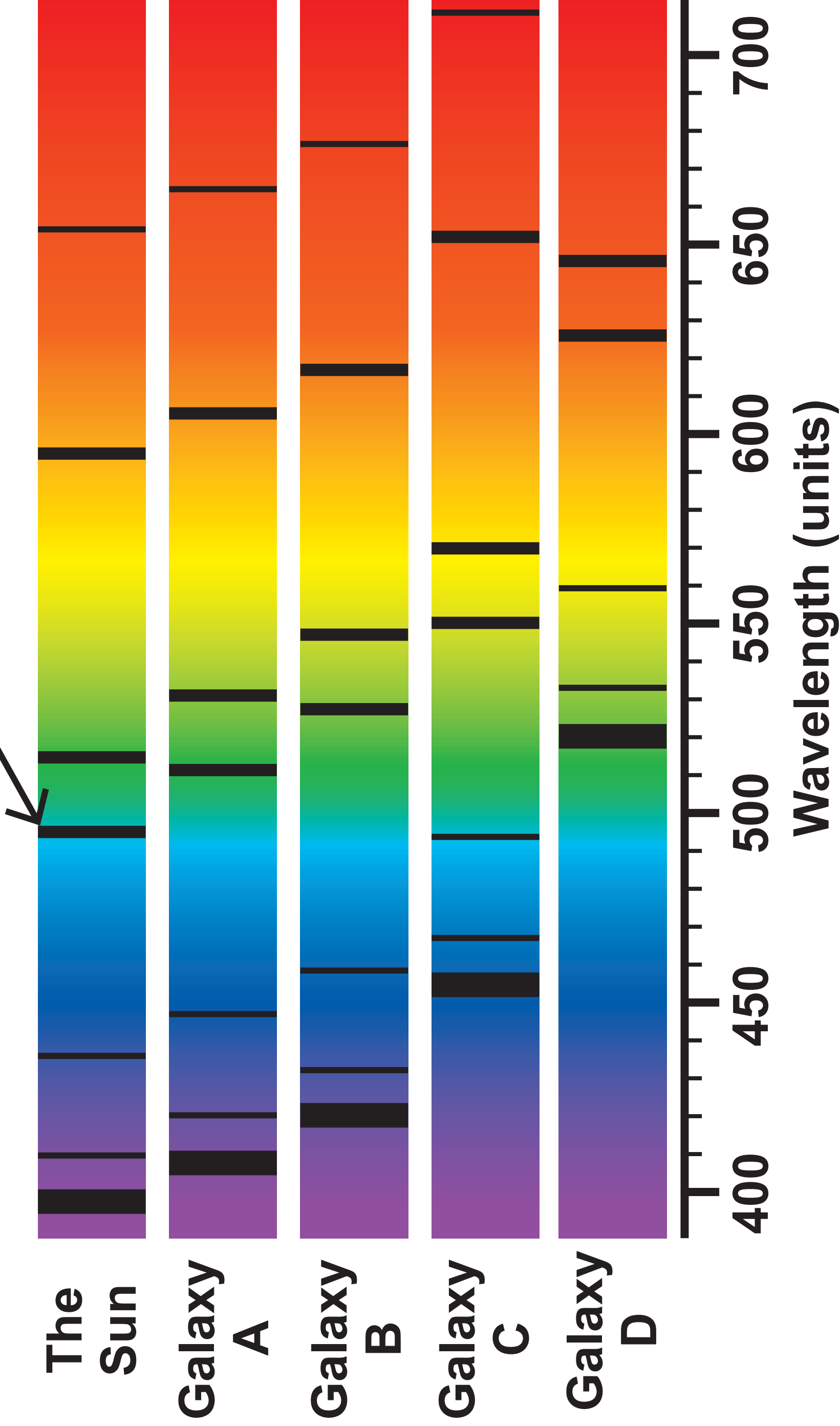


TABLE 4.2

Star or galaxy	Wavelength (units)
The Sun	495
Galaxy A	512
Galaxy B	528
Galaxy C	
Galaxy D	626

TABLE 4.3

Element	Wavelength of absorption line (units)
helium	587
calcium	430
magnesium	516
iron	527

DIAGRAM 4.4

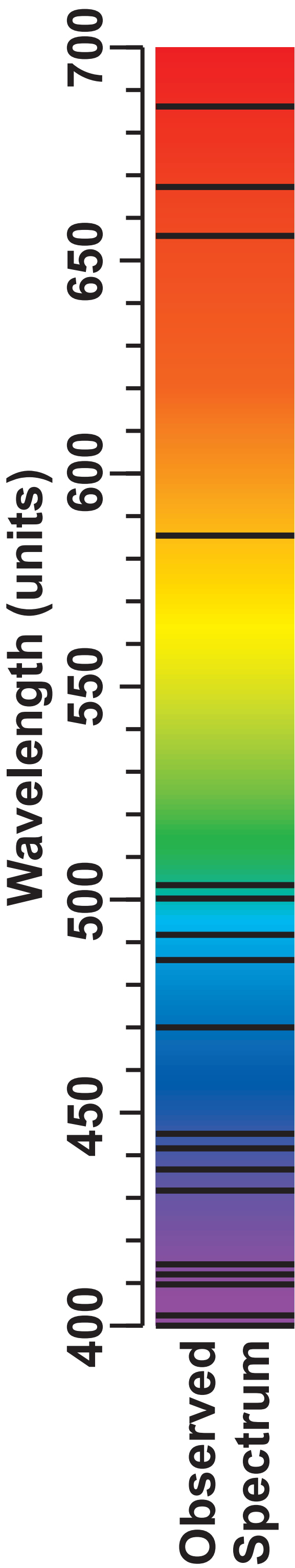


DIAGRAM 5.1

Abi



mass = 50 kg
velocity = 3 m/s
momentum = 150 kg m/s

Rachel



mass = 40 kg
velocity = 2 m/s

DIAGRAM 5.2

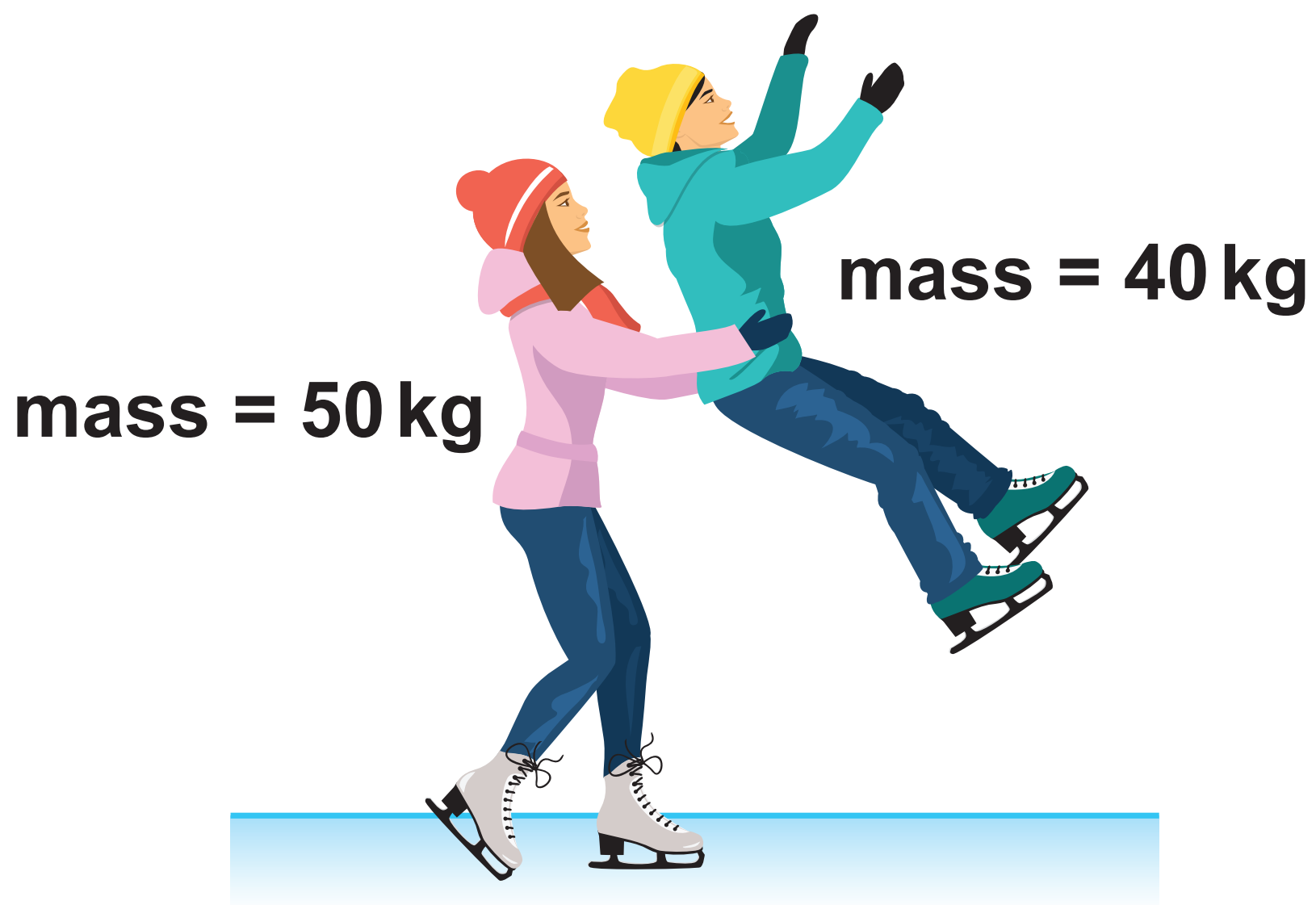


DIAGRAM 6.1

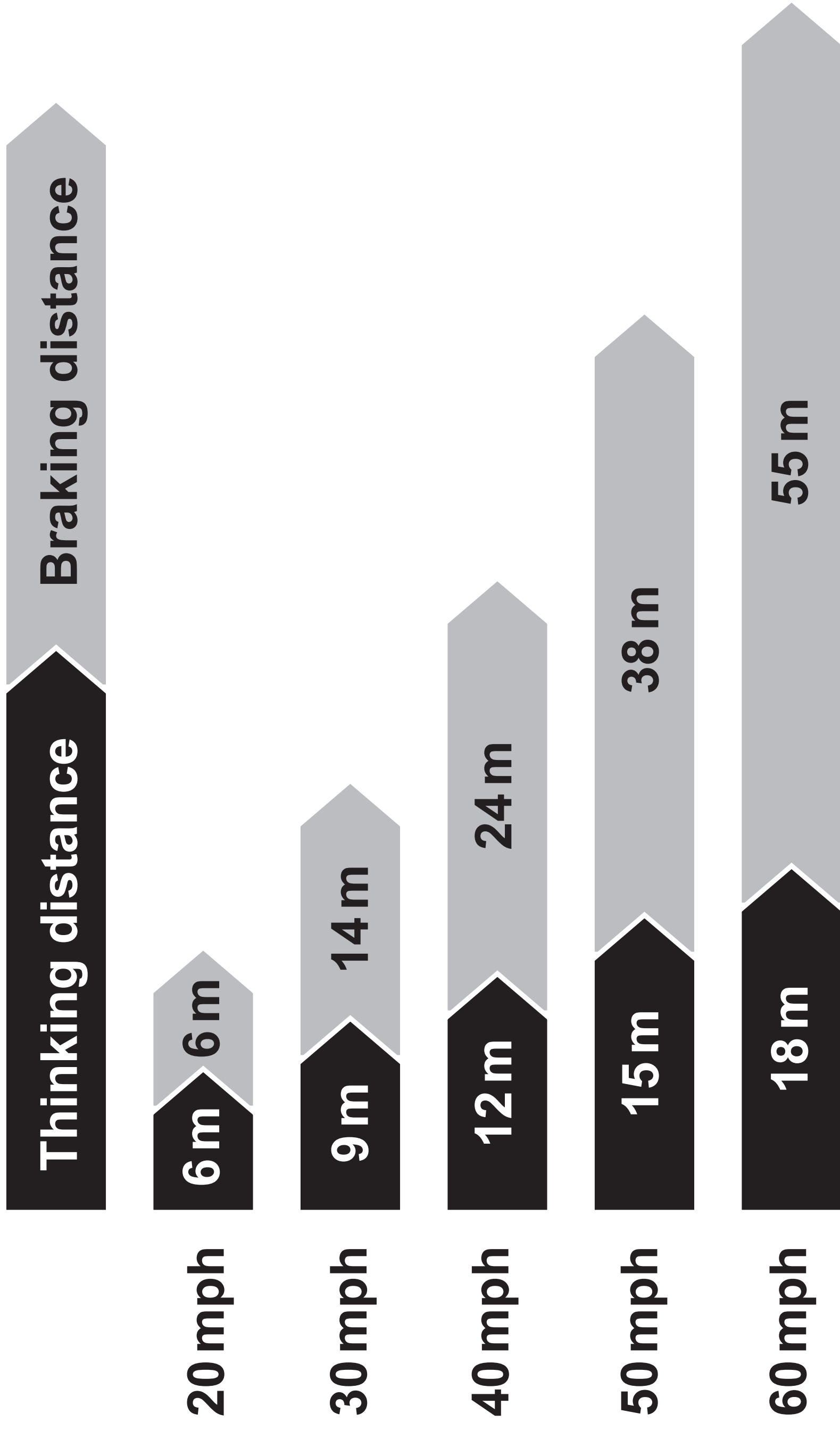


TABLE 7.1

Isotope	${}^2_1\text{H}$	${}^3_1\text{H}$
number of protons		
number of neutrons		

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DIAGRAM 7.2

boron control rods

**uranium
fuel rods**

**graphite
moderator**

hot gas

gas flow

cold gas

core

thick concrete shield

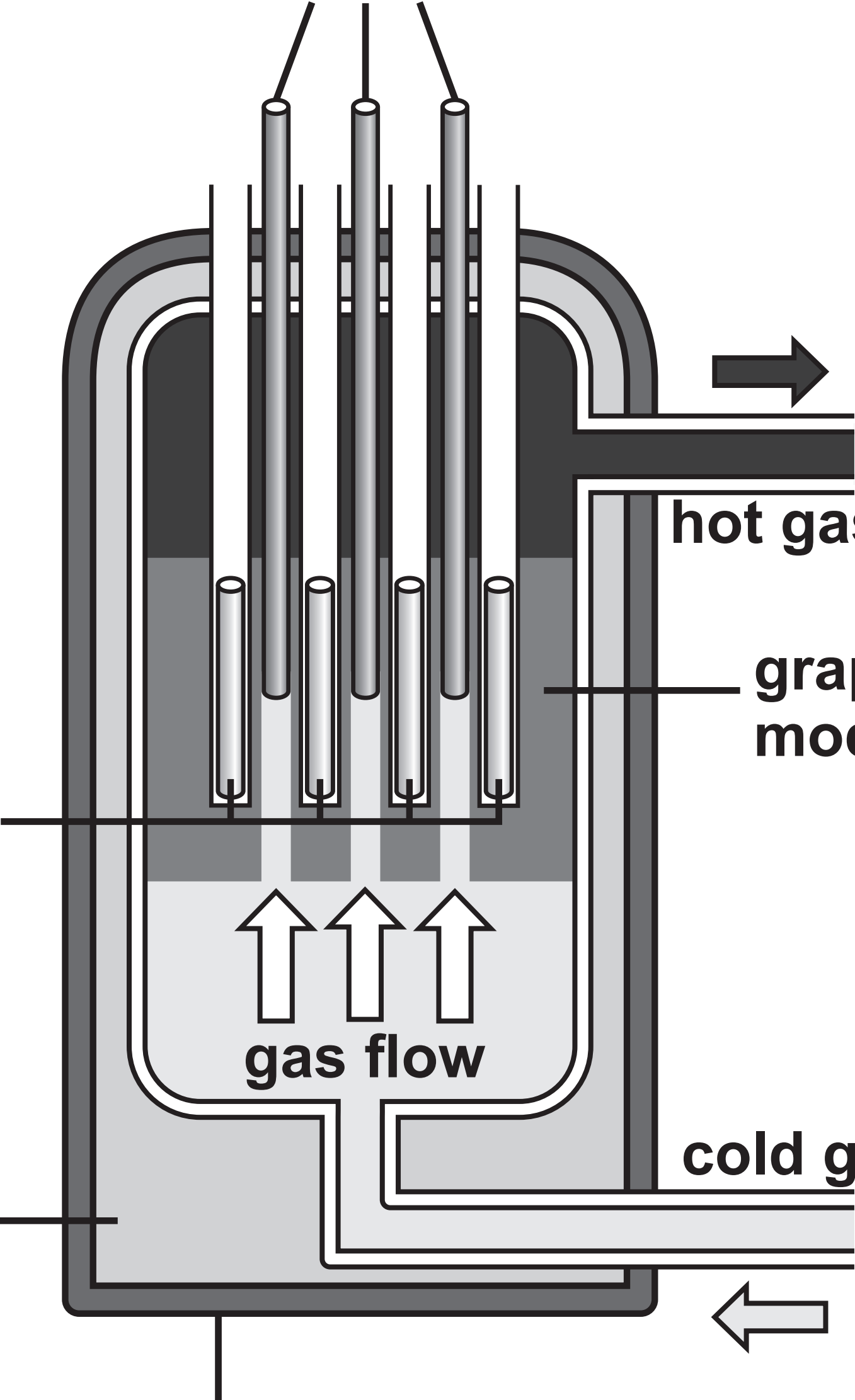
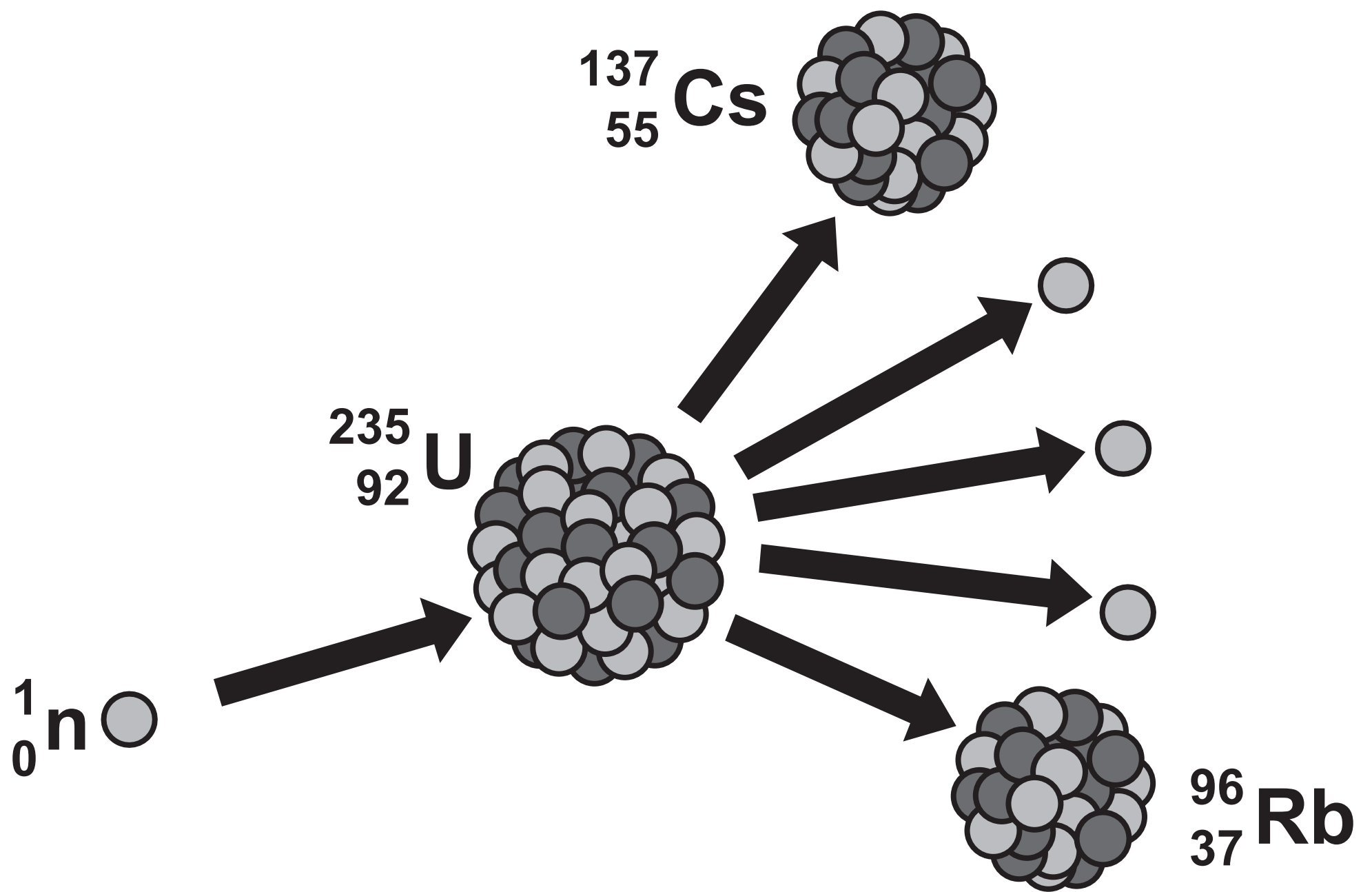
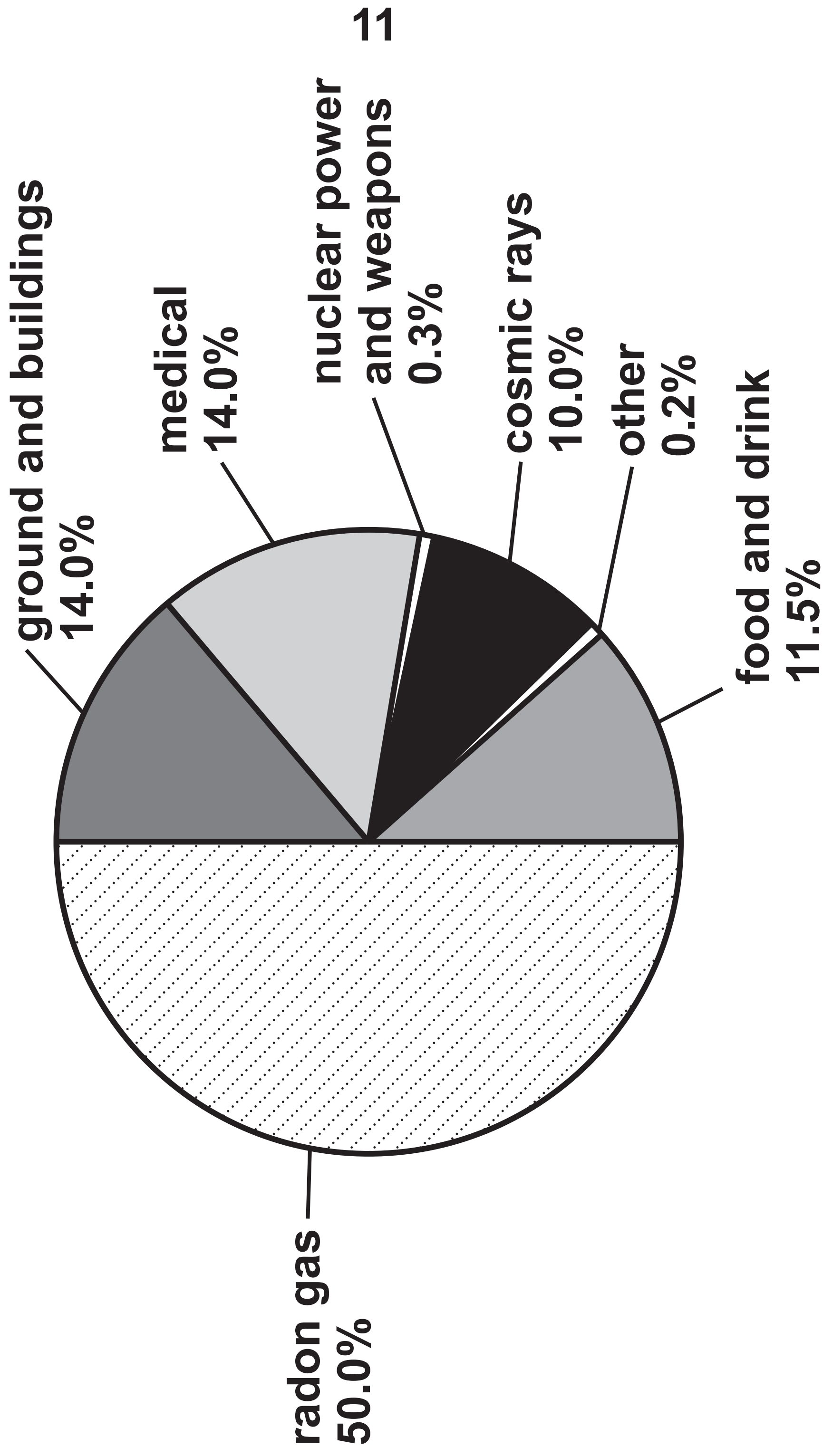


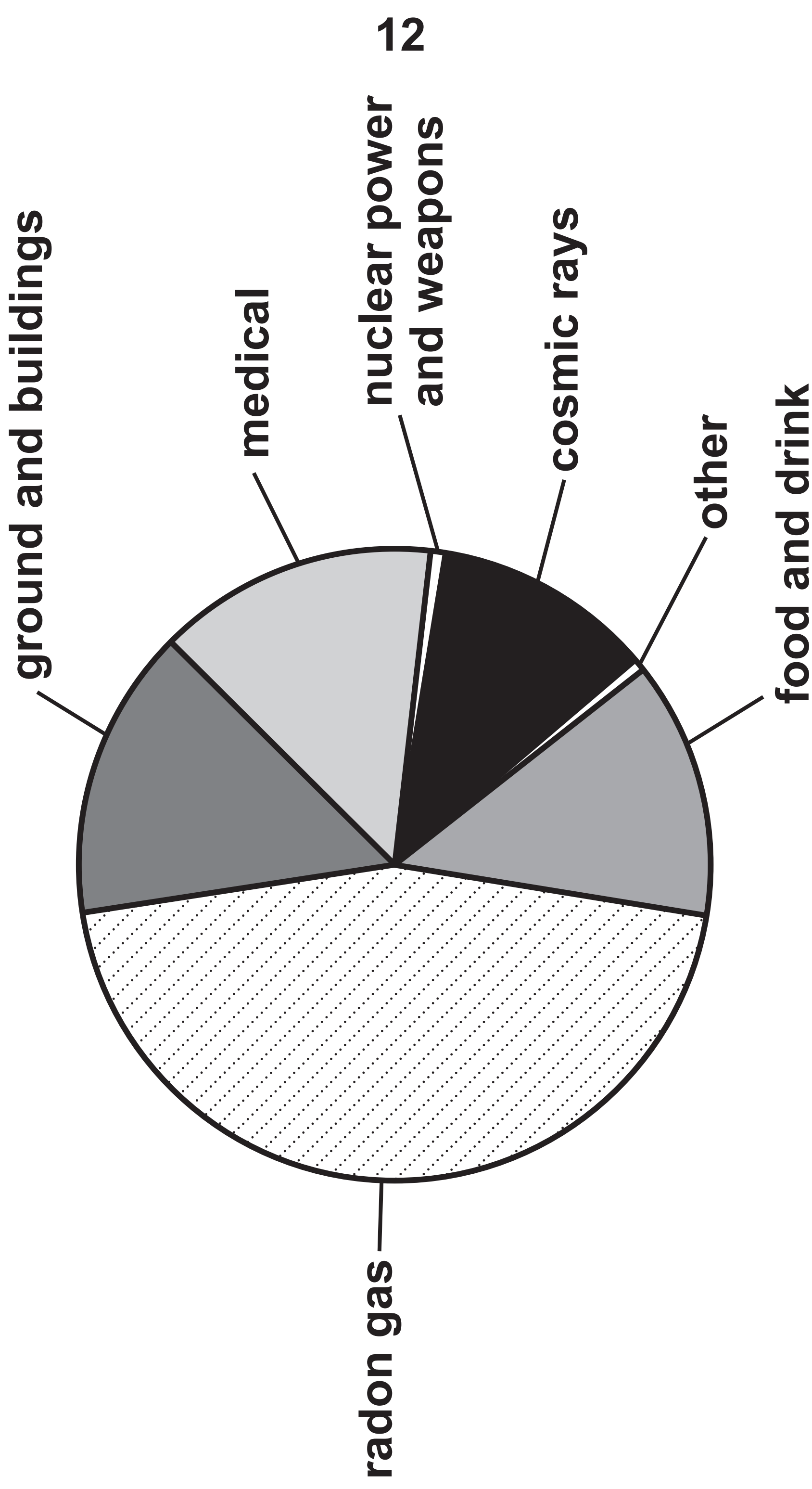
DIAGRAM 7.3



PIE CHART 9.1 – LOCATION A



PIE CHART 9.2 – LOCATION B



PIE CHART 9.3 – LOCATION C

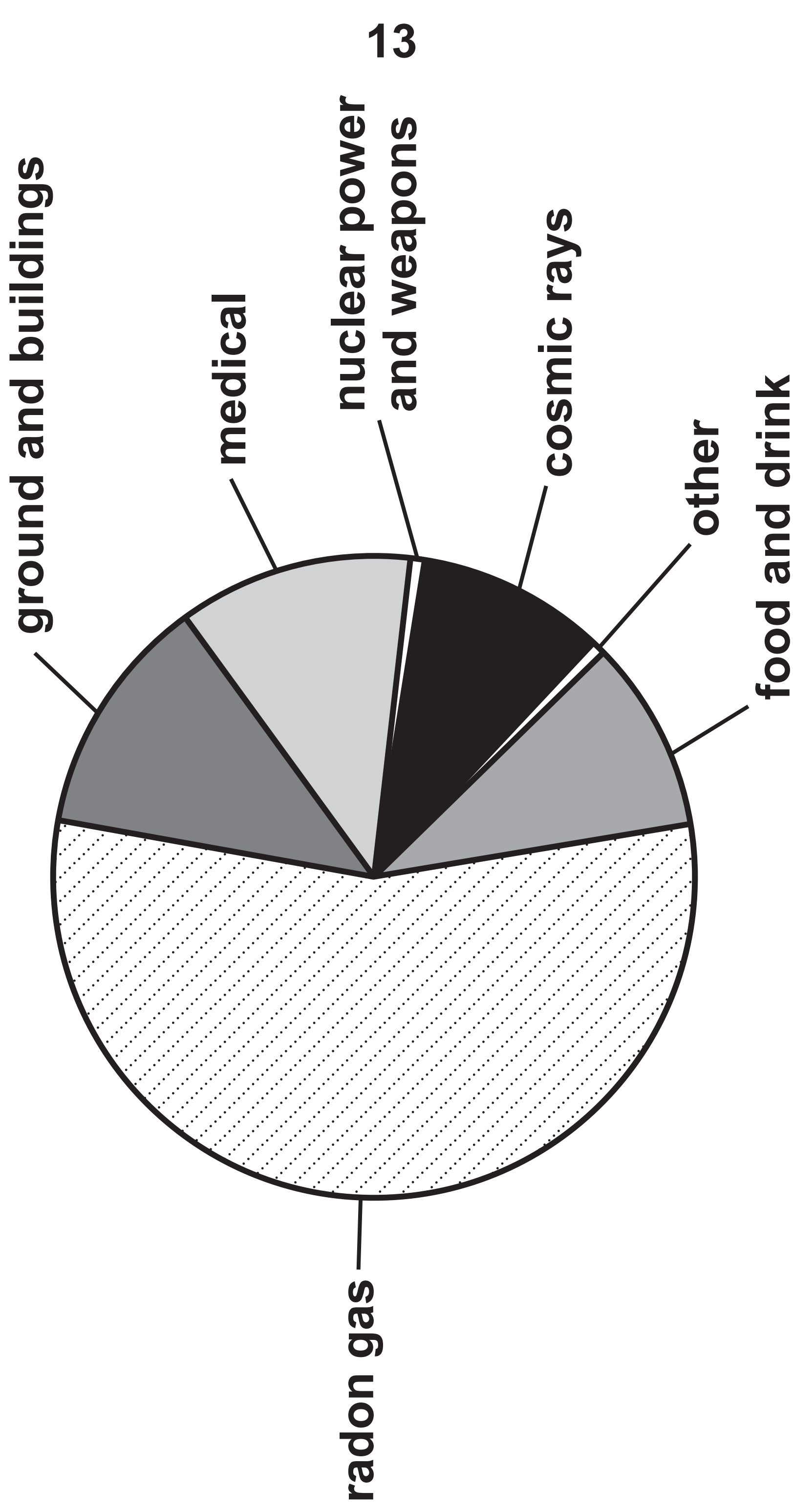


DIAGRAM 9.4

UK RADON LEVELS

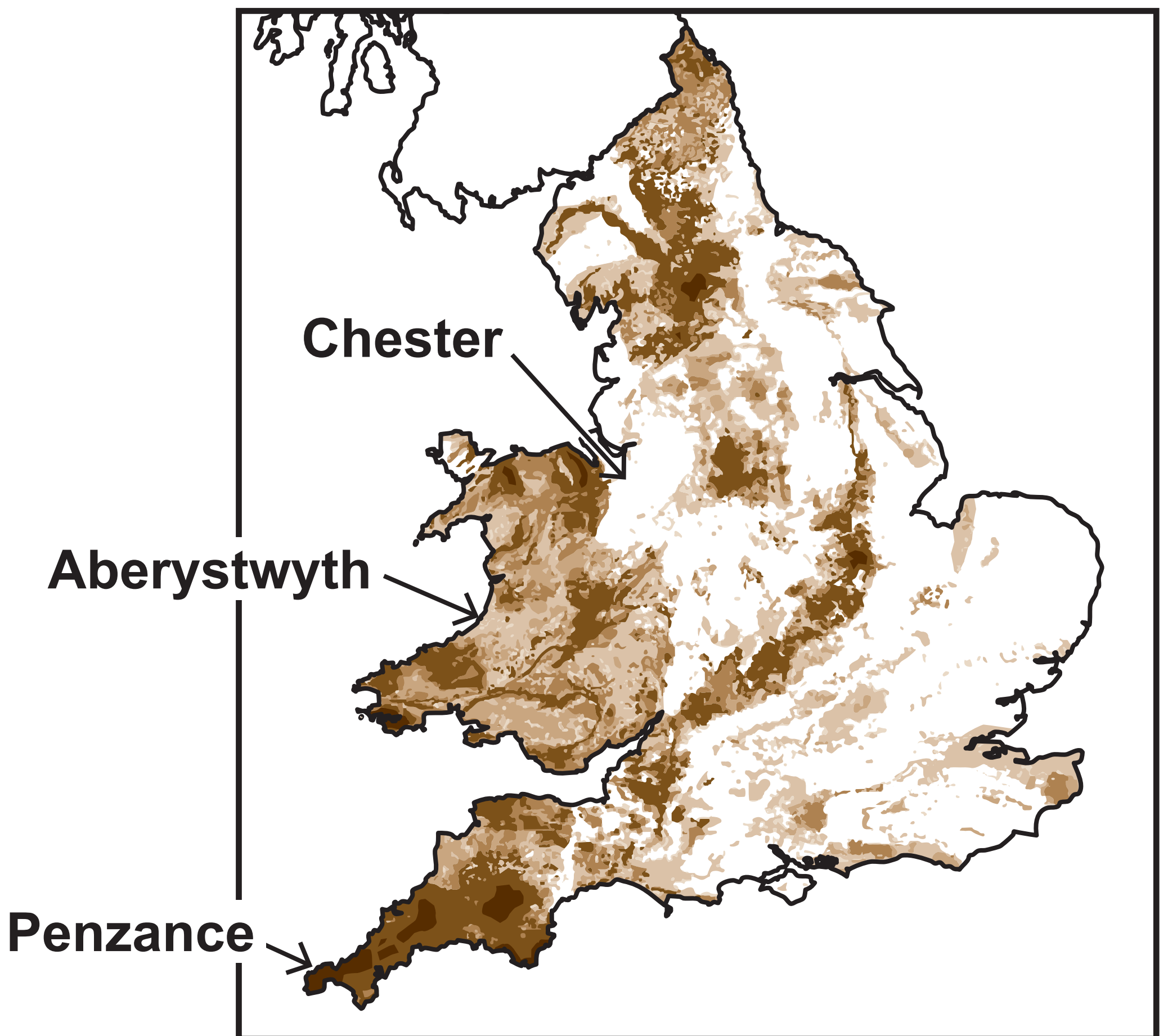


TABLE 9.5

Source of radiation	Radiation received (units)
mean background radiation (per year)	2.7
8 hour flight from London to New York	0.09
dental X-ray	0.005
chest X-ray	0.014
CT scan of head	1.4
CT scan of chest	6.6
worker in a nuclear power station (per year)	0.18

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DIAGRAM 10.1

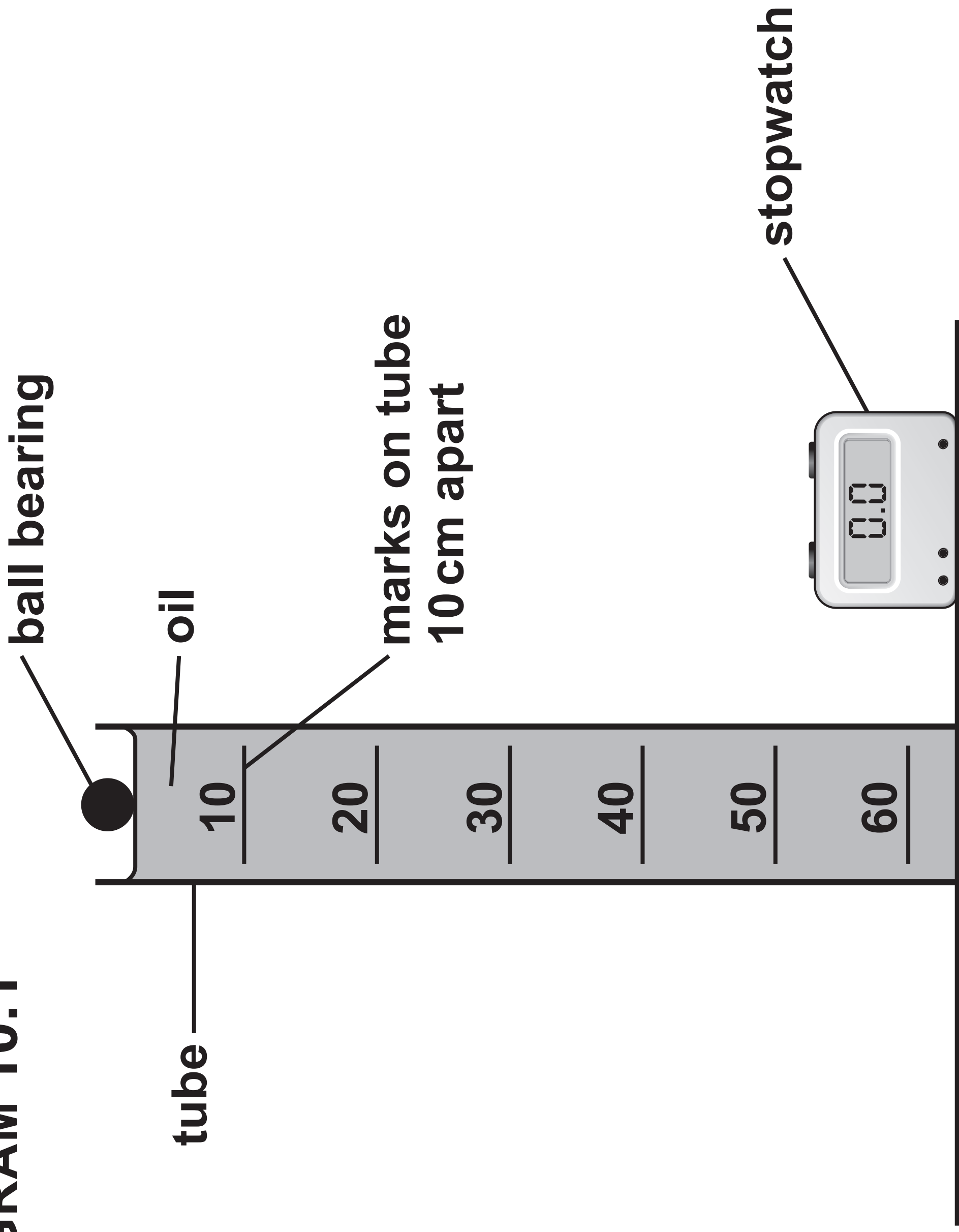
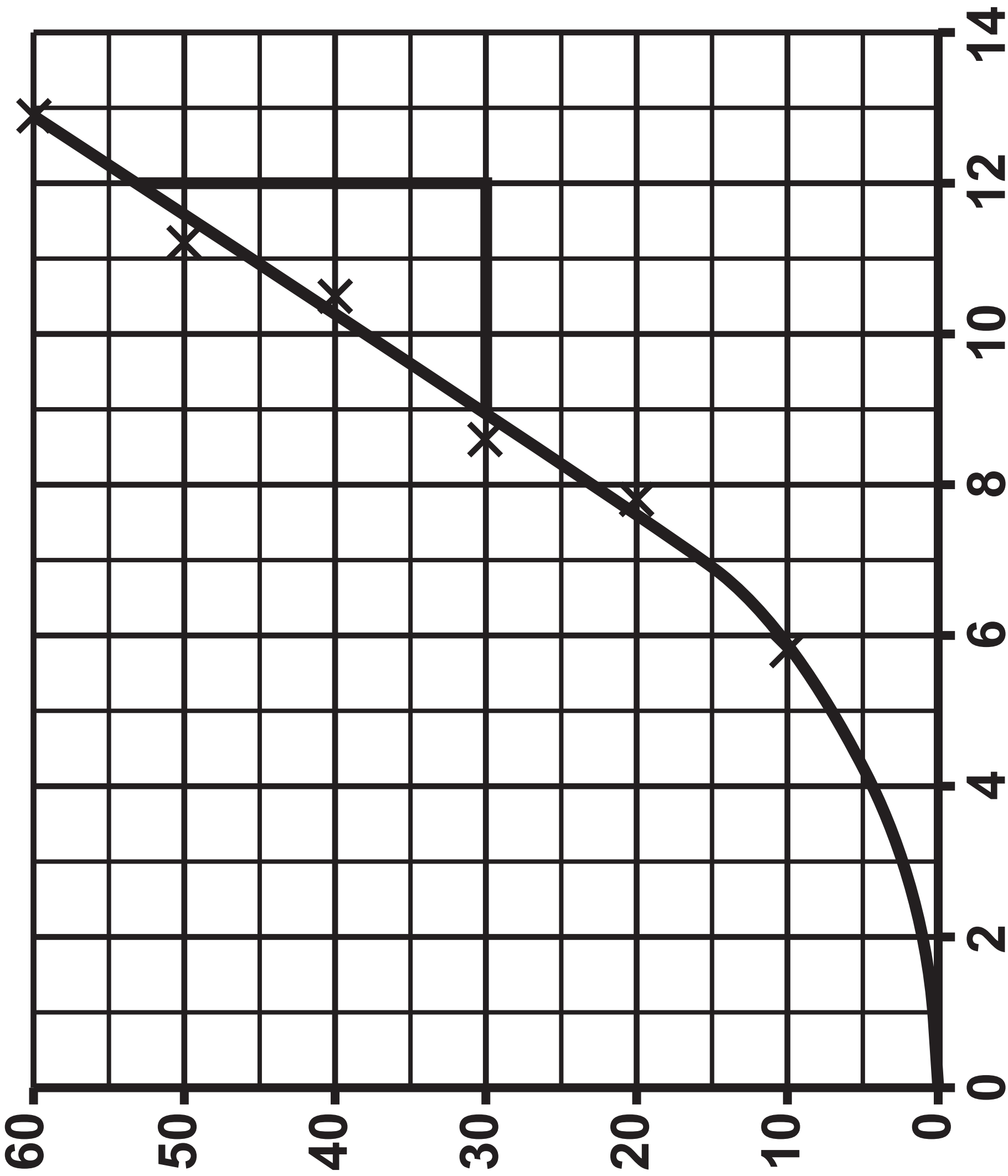


TABLE 10.2

Distance (cm)	Time (s)			
	Trial 1	Trial 2	Trial 3	Mean
10	5.4	6.2	5.8	5.8
20	7.6	4.2	8.0	7.8
30	8.4	9.0	8.3	8.6
40	10.9	10.3	10.4	10.5
50	11.5	11.2	10.8	11.2
60	12.5	13.0	13.2	12.9

GRAPH 10.3

Distance (cm)



Mean time (s)



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FRIDAY, 24 MAY 2024 – MORNING

Data Booklet
PHYSICS – Unit 2:
Forces, Space and Radioactivity
FOUNDATION TIER

Data Booklet
Equations and SI multipliers

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EQUATIONS

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{acceleration [or deceleration]} = \frac{\text{change in velocity}}{\text{time}} \quad a = \frac{\Delta v}{t}$$

$$\text{acceleration} = \text{gradient of a velocity-time graph}$$

$$\text{resultant force} = \text{mass} \times \text{acceleration} \quad F = ma$$

$$\text{weight} = \text{mass} \times \text{gravitational field strength} \quad W = mg$$

$$\text{work} = \text{force} \times \text{distance} \quad W = Fd$$

$$\text{force} = \text{spring constant} \times \text{extension} \quad F = kx$$

$$\text{momentum} = \text{mass} \times \text{velocity} \quad p = mv$$

$$\text{force} = \frac{\text{change in momentum}}{\text{time}} \quad F = \frac{\Delta p}{t}$$

u = initial velocity

v = final velocity

t = time

a = acceleration

x = displacement

$$v = u + at$$

$$x = \frac{u + v}{2} t$$

moment = force $\times$ distance

$$M = Fd$$

SI MULTIPLIERS

Prefix	Symbol	Conversion factor	Multiplier
milli	m	divide by 1000	1×10^{-3}
centi	c	divide by 100	1×10^{-2}
kilo	k	multiply by 1000	1×10^3
mega	M	multiply by 1 000 000	1×10^6