1.1 Physical quantities and measurement

Name: _____ Class: _____ Date: _____ **Total: 29 marks**

0 Vocabulary

Word	Example
ruler /'ru:lə/ 直尺	Use the marks on a **ruler** to measure length. 利用**直尺**上的刻度测量长度。
stopwatch /'stɒpwɒtʃ/ 秒表	A **stopwatch** measures how long a race takes. **秒表**可以测量一场比赛所用的时间。
digital timer /'dɪdʒɪtl 'taɪmə/ 数字计时器	A **digital timer** shows the time as numbers. **数字计时器**用数字显示时间。
reaction time /rɪ'ækʃn taɪm/ 反应时间	Your **reaction time** is the delay before you press the stopwatch. 你的**反应时间**是按下秒表之前的延迟时间。
measure many and divide 测多个再相除 /'meʒə 'meni ænd dɪ'vaɪd/	**Measure many and divide**: time ten swings and divide by ten. **测多个再相除**：测量摆动十次的时间，再除以十。
pendulum /'pendjʊləm/ 摆	A **pendulum** swings back and forth. **单摆**来回摆动。
period /'pɪərɪəd/ 周期	The **period** of the wave is 0.02 s. 这个波的**周期**是 0.02 s。
uncertainty /ʌn'sɜ:tənti/ 不确定度	The length is 25.0 cm with an **uncertainty** of 0.1 cm. 长度为 25.0 cm，**不确定度**为 0.1 cm。
parallax /'pærəlæks/ 视差	Look straight at the scale to avoid **parallax** errors. 正对刻度读数，以避免**视差**造成的误差。
zero error /'zɪərəʊ 'erə/ 零点误差	The meter shows 0.2 V with nothing connected: a **zero error**. 没有连接任何东西时，电表显示 0.2 V：这是**零点误差**。

Word	Example
anomalous result 异常值 /əˈnɒmələs rɪˈzʌlt/	Repeat the treatment before deciding how to handle an **anomalous result**. 在决定如何处理**异常值**之前，先重复该处理。
line of best fit 最佳拟合线 /laɪn ɒv best fɪt/	Draw a **line of best fit** through the points. 根据这些点画一条**最佳拟合直线**。
scalar quantity 标量 /ˈskeɪlə ˈkwɒntɪti/	Mass is a **scalar quantity**: it has size but no direction. 质量是**标量**：它有大小，但没有方向。
vector quantity 矢量 /ˈvektə ˈkwɒntɪti/	Force is a **vector quantity**: it has size and direction. 力是**矢量**：它既有大小，也有方向。
resultant /rɪˈzʌltənt/ 合矢量	The **resultant** of 3 N and 4 N at right angles is 5 N. 大小为 3 N 和 4 N 且互相垂直的两个矢量，其**合矢量**的大小为 5 N。
resultant force 合力 /rɪˈzʌltənt fɔːs/	If the **resultant force** is zero, the speed does not change. 如果**合力**为零，速率就不会改变。

1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later: follow the steps and you can do the Practice and Exam-style questions yourself.

■ Instruments and how to read them

quantity	instrument	good practice
length	ruler, tape measure	eye level with the mark (no **parallax** 视差)
diameter of a ball	ruler and two blocks	blocks touch the ball; read the gap
volume of a liquid	measuring cylinder	read the bottom of the meniscus at eye level
time	stopwatch, digital timer	time many repeats and divide

A hand-started **stopwatch** 秒表 carries a **reaction time** 反应时间 error of about 0.2 s at the start and stop. Time a **long** interval, or many swings, so this error is a small fraction of the total.

Worked example 1: a period from timer readings

A timer reads 0 min 40 s as a pendulum passes a marker. The pendulum passes the marker 16 more times from the same direction, and on the last pass the timer reads 1 min 28 s. Find the period.

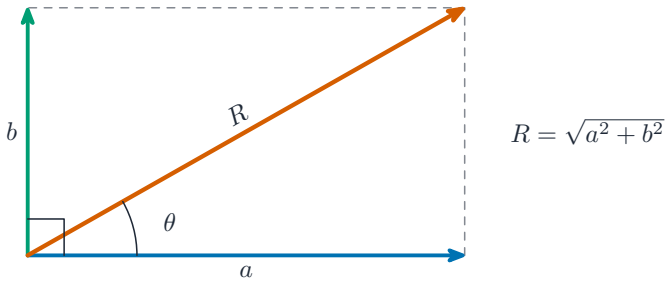
1. Each pass from the same direction is one complete swing, so 16 more passes is 16 swings (not 17).
2. Total time: $88\ \text{s} - 40\ \text{s} = 48\ \text{s}$.
3. Period is the time for one swing, $T = \dfrac{\text{total time}}{\text{number of swings}}$:

$$T = \frac{48\ \text{s}}{16} = \mathbf{3.0}\ \text{s}$$

The same idea gives a small length: 100 sheets of paper measuring 9.0 mm give 0.090 mm per sheet.

Scalars and vectors

- A **scalar** has size only: distance, speed, time, mass, energy, temperature.
- A **vector** has size **and** direction: force, weight, velocity, acceleration, momentum, electric field strength, gravitational field strength.



$R = \sqrt{a^2 + b^2}$

Two vectors at right angles add to a resultant R, the diagonal of the rectangle

Worked example 2: resultant of two perpendicular vectors

A boat is driven north at $4.0\ \frac{\text{m}}{\text{s}}$ across a river flowing east at $3.0\ \frac{\text{m}}{\text{s}}$. Find its resultant velocity.

1. The two velocities are at right angles, so they form two sides of a right-angled triangle and the resultant is the hypotenuse: Pythagoras.

$$v = \sqrt{v_1^2 + v_2^2} = \sqrt{(4.0\ \tfrac{\text{m}}{\text{s}})^2 + (3.0\ \tfrac{\text{m}}{\text{s}})^2} = \mathbf{5.0}\ \frac{\text{m}}{\text{s}}$$

2. A vector also needs its direction. The angle θ east of north has $\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}}$:

$$\theta = \tan^{-1}\left(\frac{3.0\ \frac{\text{m}}{\text{s}}}{4.0\ \frac{\text{m}}{\text{s}}}\right) = \mathbf{37}^\circ \text{ east of north}$$

By scale drawing: choose a scale (for example 1 cm = 1 $\frac{\text{m}}{\text{s}}$), draw the two arrows head to tail at right angles, and join tail to head. Measure the length and convert with the scale, then measure the angle with a protractor.

2 Practice

2.1 State the difference between a scalar and a vector. [1]

scalar vector

2.2 From this list, write down the vectors: mass, weight, energy, velocity, temperature, momentum, gravitational field strength. [2]

mass weight energy velocity

temperature momentum gravitational field strength

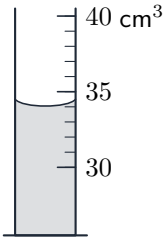
2.3 A student measures the time for 20 swings of a pendulum as 30 s. Find the period (time for one swing). [2]



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2.4 The diagram shows water in a measuring cylinder.

(a) Write down the volume of the water. [1]



(b) State where the student's eye should be when reading the scale. [1]

3 Exam-style questions

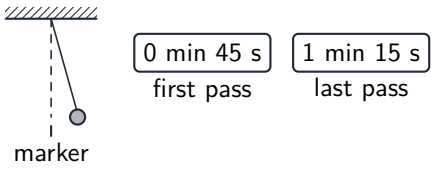
3.1 Which is a vector quantity? [1]

- ☐ **A** mass
- **B** energy
- **C** velocity
- **D** temperature

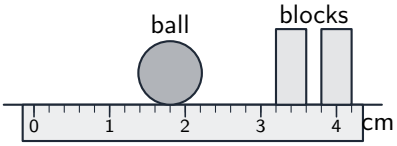
vector quantity

3.2 When a pendulum passes a marker, a timer reads 0 min 45 s. The pendulum passes the marker 15 more times from the same direction. On the final pass the timer reads 1 min 15 s. What is the period of the pendulum? [1]

- ☐ **A** 1.9 s
- **B** 2.0 s
- **C** 3.0 s
- **D** 5.0 s



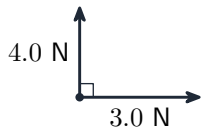
3.3 A student uses a ruler and two wooden blocks to measure the diameter of a metal ball. Describe how she uses them to get an accurate value. [2]



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3.4 Two forces of 3.0 N and 4.0 N act at right angles on a point.

(a) Calculate the magnitude of the resultant force. [2]

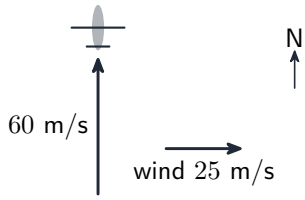


(b) Calculate the angle between the resultant force and the 3.0 N force. [2]

3.5 A small aircraft flies with a velocity of 60 $\frac{\text{m}}{\text{s}}$ due north. A wind blows due east at 25 $\frac{\text{m}}{\text{s}}$.

(a) Explain why velocity is a vector quantity. [1]

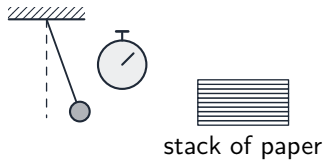
(b) Determine the magnitude and direction of the resultant velocity of the aircraft. [3]



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3.6 A student measures the period of a pendulum and the thickness of a sheet of paper.

(a) Describe how she should measure the period accurately, naming the instrument she uses. [3]



(b) She times 20 swings as 25.6 s. Calculate the period. [2]

(c) Explain why her method reduces the effect of her reaction time. [2]

(d) She measures a stack of 100 sheets of paper as 9.0 mm thick. Calculate the thickness of one sheet in mm, and state why she did not measure one sheet directly. [3]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- a scalar has size only; a vector has size **and** direction

2.2

- weight, velocity, momentum, gravitational field strength

2.3

- period = total time / number of swings

$$T = \frac{30\ \text{s}}{20} = \mathbf{1.5}\ \text{s}$$

2.4

(a)

- **34** cm^3, read at the bottom of the meniscus

(b)

- level with the bottom of the meniscus, looking horizontally at the scale

3.1 C

- velocity has both size and direction

3.2 B

- 15 more passes from the same direction is 15 swings; total time $75\ \text{s} - 45\ \text{s} = 30\ \text{s}$

$$T = \frac{30\ \text{s}}{15} = 2.0\ \text{s}$$

- A divides by 16 (counting passes, not swings); D divides the final reading by 15

3.3

- place the ball on the bench against the ruler, with a block touching each side of the ball, the blocks' faces parallel
- read the ruler at each block face at eye level and subtract (or repeat for different diameters and average)

3.4

(a)

- the forces are perpendicular, so use Pythagoras

$$F_{\text{res}} = \sqrt{F_1^2 + F_2^2} = \sqrt{(3.0\ \text{N})^2 + (4.0\ \text{N})^2} = \mathbf{5.0}\ \text{N}$$

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(b)

- $\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}} = \dfrac{4.0\ \text{N}}{3.0\ \text{N}}$

$$\theta = \tan^{-1}\left(\frac{4.0\ \text{N}}{3.0\ \text{N}}\right) = \mathbf{53}^\circ$$

3.5

(a)

- it has a size (speed) and a direction

(b)

- the velocities are perpendicular, so use Pythagoras

$$v = \sqrt{v_1^2 + v_2^2} = \sqrt{(60\ \frac{\text{m}}{\text{s}})^2 + (25\ \frac{\text{m}}{\text{s}})^2} = \mathbf{65}\ \frac{\text{m}}{\text{s}}$$

- direction: $\tan\theta = \dfrac{25\ \frac{\text{m}}{\text{s}}}{60\ \frac{\text{m}}{\text{s}}}$, so

$$\theta = \tan^{-1}\left(\frac{25\ \frac{\text{m}}{\text{s}}}{60\ \frac{\text{m}}{\text{s}}}\right) = \mathbf{23}^\circ \text{ east of north}$$

- a scale drawing within $\pm 2\ \frac{\text{m}}{\text{s}}$ and $\pm 2^\circ$ earns the same marks

3.6

(a)

- use a stopwatch or digital timer
- start it as the pendulum passes the centre of its swing and count from zero
- time 20 complete swings and repeat, then take an average

(b)

- T = total time / number of swings

$$T = \frac{25.6\ \text{s}}{20} = \mathbf{1.28}\ \text{s}$$

(c)

- her reaction time affects the total once, at the start and the stop
- dividing by 20 divides that error by 20 as well, so each period is far more accurate

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(d)

- thickness of one sheet = total thickness / number of sheets

$$\frac{9.0 \text{ mm}}{100} = \mathbf{0.090} \text{ mm}$$

- one sheet is far thinner than the smallest division on the ruler, so measuring it directly would give a very large percentage error

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