

Topic Tests: Expert Tests – Set A

For A Level Year 2 AQA

Statistics and Mechanics

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Teacher's Introduction

Content

This pack contains 6 expert level topic tests and solutions for the AQA Applied Mathematics Year 2 A Level content.

These topic tests have been **fully cross-referenced** to the Pearson, Hodder and Collins textbooks for your convenience (see reference sheet on page 2). Each test has been designed to reflect the specification fully.

About the expert tests

These **expert** tests have been designed to **prepare your students** for success in their exam. 25% of the marks come from questions similar in style to our fundamentals and challenge tests, giving all of your students a chance to show what they can do. The other 75% of the marks come from examination-style material, including compound and multistep questions that bring all parts of the topic together.

Each test comes with fully worked solutions, containing helpful tips, hints, and technique boxes to help students who may have made a mistake or who are struggling on a particular question.

Timings

The recommended times for students to complete each test are given at the top of individual tests.

Calculator use

The effective use of a calculator is one of the objectives of the new specification and is encouraged for all the enclosed tests. In particular, students should be comfortable using the statistical functions on their calculator.

The large data set

As part of their assessment, students will be tested on data from the **large data set** provided by AQA. This data set contains data on household food and drink purchases from various locations in England between 2001 and 2014. Familiarity with the large data set is assumed in these topic tests, but a copy of it is not needed to take the tests themselves.

Also available from ZigZag Education

The perfect starting point for students of all abilities are our **fundamentals** tests. These isolate and test the core skills in each topic so that your students can show what they can do. They get a confidence boost and you can see at a glance where each student's weaknesses lie.

For students who have mastered the fundamentals, a complete set of **challenge** tests are available. 50% of the marks in these tests come from concepts covered in the fundamentals tests in order to reinforce learning and boost students' confidence, while the other 50% increases in difficulty and combines and extends the concepts covered.

For each collection of Set A tests we also offer a corresponding collection of Set B duplicated tests with the same styles of questions but different numbers. This allows for a variety of **flexible** uses including:

- **Test → Homework:** Students use test B as a homework to consolidate on areas of weakness identified from completing test A under test conditions in class.
- **Homework → Test:** Students revise as homework using test A before doing test B in class under test conditions.
- **Test → Classwork:** Students work through test B with teacher input to consolidate on areas of weakness identified from completing test A under test conditions in class.
- **Classwork → Test:** Students work through test A with teacher input, before checking their learning by completing test B under test conditions.

For total flexibility, the Set A and Set B tests of all three levels can be run on a rolling basis, using the fundamentals tests as starters, with a time interval between them, leaving one expert level test to use at the end of the course for topic revision.

Free Updates!

Register your email address to receive any future free updates* made to this resource or other Maths resources your school has purchased, and details of any promotions for your subject.

* resulting from minor specification changes, suggestions from teachers and peer reviews, or occasional errors reported by customers

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Cross-referencing Grid

Topic	AQA spec. points	Sub-topics
Regression and Correlation	L2, O1	Exponential models, measuring correlation, hypothesis testing for zero correlation
Conditional Probability	M1–M3	Set notation, conditional probability, conditional probabilities in Venn diagrams, probability formulae, tree diagrams
The Normal Distribution	N2–N3, O3	The normal distribution, finding probabilities, the inverse normal distribution, the standard normal distribution, finding μ and σ , approximating a binomial distribution, hypothesis testing with the normal distribution
Moments	P1, S1	Moments, resultant moments, equilibrium, centres of mass, tilting
Forces and Friction	R2, R4–R6	Resolving forces, inclined planes, friction, modelling with statics, friction and static particles, dynamics and inclined planes, connected particles
Kinematics and Projectiles	Q1, Q3–Q5	Horizontal projection, projection at any angle, projection motion formulae, vectors in kinematics, variable acceleration in one dimension, differentiating vectors, integrating vectors

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Forces and Friction – Test A (65 mins)

Subtopics: resolving forces, inclined planes, friction, modelling with statics, friction dynamics and inclined planes, connected particles

1. A block of mass m kg is placed on a slope that is inclined at an angle of 30° to the horizontal. The frictional force opposing the block's motion down the slope is F .
 - a) By modelling the block as a particle, draw a force diagram showing the forces acting on the block in directions **perpendicular** and **parallel** to the slope. The block lies in a state of limiting equilibrium.
 - b) Show that the **coefficient of friction** between the block and the slope is $\frac{1}{2}$.

2. Two particles A and B are connected by a light, inextensible string that passes over a smooth pulley. Particle A has mass 5 kg and is held on a smooth slope inclined at an angle θ to the horizontal, where $\tan \theta = \frac{3}{4}$. The string lies over a line of best fit on the slope. The system is in equilibrium.

When particle A is released from rest, it moves up the slope with acceleration a m s⁻².

 - a) Find the **exact** tension in the string. You should assume $g = 10$ m s⁻².
 - b) After A has travelled up the slope for 0.4 seconds, the string snaps.
 - c) Find the magnitude of particle A 's **acceleration** down the slope after the string snaps.
 - d) Hence determine how long it takes from the time the string snaps for particle A to reach the bottom point.

3. A particle of mass m kg is acted on by the forces $5\mathbf{i} + 2\mathbf{j}$ N, $x\mathbf{i} + 2\mathbf{j}$ N and $y\mathbf{i} + z\mathbf{j}$ N. These forces produce an acceleration of $3\mathbf{i} + 4\mathbf{j}$ m s⁻² on the particle.
 - a) Find expressions for x and y in terms of m .
 - b) A fourth force of $(-4x + y + z)\mathbf{i} + (y - 2z)\mathbf{j}$ N is applied to the particle. Find the new acceleration of the particle in terms of m .
 - c) Hence determine the value of m if the new acceleration is $4\mathbf{i} + 10\mathbf{j}$ m s⁻².

4. Two particles P and Q are held on different sides of a block that is in the shape of an isosceles triangle (see right). The side of the triangle that particle P is on is **rough**, with coefficient of friction μ . The side of the triangle that particle Q is on is **smooth**. The two particles are joined by a light, inextensible string that passes over a smooth pulley. Particle P has mass m_1 kg and particle Q has mass m_2 kg. Assume for this question that $g = 10$ m s⁻².

When the system is released, particle Q moves up the side of the block.

 - a) By considering the motion of Q , show that the tension in the string is $\frac{5m_2}{2}$ N.
 - b) Hence, by considering the motion of P , show that $\frac{m_1}{m_2} = \frac{5}{1 - 4\mu}$.

5. A scientist has a metallic block of mass 2.9 kg, and wants to know what metal it is made of. She releases the block from rest from the top of a 2.5 m long steel slope that is inclined at an angle of θ to the horizontal, where $\tan \theta = \frac{20}{21}$. The block reaches the bottom of the slope with velocity 4.1 m s⁻¹. Using the table to the right, which shows the coefficient of friction μ between various metals and steel, determine what metal the block is made of. **State any modelling assumptions** you make. In this question you should take $g = 9.8$ m s⁻².

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Preview of Questions Ends Here

This is a limited inspection copy. Sample of questions ends here to avoid students previewing questions before they are set. See contents page for details of the rest of the resource.

Solutions to Kinematics and Projectiles – Test A

1. a) Consider the horizontal and vertical components of velocity separately
Treating downwards as positive, the vertical acceleration of the cork is $g = 9.8 \text{ m s}^{-2}$
Acceleration is constant, so we can use $v = u + at$ with $u = 0 \text{ m s}^{-1}$, $a = 9.8 \text{ m s}^{-2}$ and $t = \frac{5}{7} \text{ s}$

$$v = 0 + 9.8 \times \frac{5}{7} \quad \text{M1}$$

$$= 7 \text{ m s}^{-1} \quad \text{A1}$$

Treating the direction of projection as positive, the horizontal acceleration of the cork is 0
So the horizontal velocity of the cork does not change from its initial value, $U \text{ m s}^{-1}$
So the cork's velocity after $\frac{5}{7}$ seconds has horizontal component $U \text{ m s}^{-1}$ and vertical component 7 m s^{-1} , and its speed is 25 m s^{-1} (see right)

By Pythagoras' theorem:

$$U^2 = 25^2 - 7^2 = 576 \quad \text{M1}$$

$$\therefore U = \sqrt{576} = 24 \text{ m s}^{-1} \quad \text{A1}$$

- b) Cork takes $\frac{6}{7} \text{ s}$ to drop from the bottle to the water with downward acceleration constant, so can use $s = ut + \frac{1}{2}at^2$ with $u = 0 \text{ m s}^{-1}$, $t = \frac{6}{7} \text{ s}$ and $a = 9.8 \text{ m s}^{-2}$

$$s = 0 \times \frac{6}{7} + \frac{1}{2} \times 9.8 \times \left(\frac{6}{7}\right)^2 \quad \text{M1}$$

$$= 3.6 \text{ m} \quad \text{A1}$$

- c) We need the vertical component of the velocity at the instant when the cork hits the water happens at $t = \frac{6}{7} \text{ s}$.

In the air:

Acceleration is constant, so use $v = u + at$ with $u = 0 \text{ m s}^{-1}$, $a = 9.8 \text{ m s}^{-2}$ and $t = \frac{6}{7} \text{ s}$

$$v = 0 + 9.8 \times \frac{6}{7} \quad \text{M1}$$

$$= 8.4 \text{ m s}^{-1} \quad \text{A1}$$

In the water:

Cork now accelerates upwards at 2.4 m s^{-2} . Set the time when the cork hits the water as $t = 0$

Acceleration is constant, so we can use $s = ut + \frac{1}{2}at^2$ with $s = 0 \text{ m}$, $u = 8.4 \text{ m s}^{-1}$ and $a = -2.4 \text{ m s}^{-2}$

$$0 = 8.4t + \frac{1}{2} \times (-2.4)t^2 = 8.4t - 1.2t^2 = 1.2t(7 - t) \quad \text{M1}$$

So the cork is at the water's surface at $t = 0 \text{ s}$ and $t = 7 \text{ s}$ **M1**

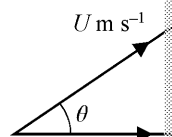
So the time when the cork returns to the surface is $t = 7 \text{ s}$ **A1 [11 Marks]**

2. a) A sketch diagram makes this easier (see right)
The horizontal component of the initial velocity is

$$U \cos \theta \text{ m s}^{-1} \quad \text{A1}$$

The vertical component of the initial velocity is

$$U \sin \theta \text{ m s}^{-1} \quad \text{A1}$$



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b) Show that $R = \frac{U^2 \sin 2\theta}{g}$

Consider vertical component of motion first

Taking upwards as positive, the vertical acceleration of the particle is $-g$

Acceleration is constant, so we can use $s = ut + \frac{1}{2}at^2$ with $s = 0$ m, $u = U \sin \theta$

$$0 = (U \sin \theta)t + \frac{1}{2} \times (-g)t^2 = t \left(U \sin \theta - \frac{gt}{2} \right) \quad \text{M1}$$

So particle is at the ground when $t = 0$ s and when $t = \frac{2U \sin \theta}{g}$ A1

Now consider the horizontal component of motion

Velocity is constant at $U \cos \theta$ m s⁻¹

Distance travelled = $U \cos \theta \times \frac{2U \sin \theta}{g}$ M1

$$= \frac{U^2 \times 2 \sin \theta \cos \theta}{g}$$

$$= \frac{U^2 \sin 2\theta}{g} \text{ m} \quad \text{A1}$$

[6 Marks]

Technique then

Technique angle

3. a) Work with column vectors for easier notation

Acceleration is constant, so we can use $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ with $\mathbf{u} = \begin{pmatrix} -5 \\ 6 \end{pmatrix} \text{ m s}^{-1}$, $\mathbf{a} = \begin{pmatrix} 0.15 \\ -0.12 \end{pmatrix} \text{ m s}^{-2}$

$$\mathbf{v} = \begin{pmatrix} -5 \\ 6 \end{pmatrix} + \begin{pmatrix} 0.15 \\ -0.12 \end{pmatrix} \times 60 \quad \text{M1}$$

$$= \begin{pmatrix} -5 + 0.15 \times 60 \\ 6 - 0.12 \times 60 \end{pmatrix}$$

$$= \begin{pmatrix} 4 \\ -1.2 \end{pmatrix} \text{ m s}^{-1} \quad \text{A1}$$

Tip: You will get 1 mark

- b) The ship is moving north-east when its velocity is of the form $\begin{pmatrix} v \\ v \end{pmatrix} \text{ m s}^{-1}$ for

Use $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ for an unknown $\mathbf{v} = \begin{pmatrix} v \\ v \end{pmatrix} \text{ m s}^{-1}$ and with $\mathbf{u}$ and $\mathbf{a}$ as in part a)

$$\begin{pmatrix} v \\ v \end{pmatrix} = \begin{pmatrix} -5 \\ 6 \end{pmatrix} + \begin{pmatrix} 0.15 \\ -0.12 \end{pmatrix} t = \begin{pmatrix} -5 + 0.15t \\ 6 - 0.12t \end{pmatrix} \quad \text{M1}$$

So we get simultaneous equations:

$$v - 0.15t = -5 \quad (1)$$

$$v + 0.12t = 6 \quad (2) \quad \text{M1}$$

$$(2) - (1):$$

$$0.27t = 11$$

$$\therefore t = \frac{11}{0.27} \quad \text{A1}$$

So the ship is moving north-east at this time

Substituting this into (1):

$$v - 0.15 \times \frac{11}{0.27} = -5$$

$$-5 + 0.15 \times \frac{11}{0.27} = \frac{10}{9} \quad \text{M1}$$

So velocity at this time is $\mathbf{v} = \begin{pmatrix} 10/9 \\ 10/9 \end{pmatrix} \text{ m s}^{-1}$

Speed is the magnitude of this vector, i.e.:

$$\left| \begin{pmatrix} 10/9 \\ 10/9 \end{pmatrix} \right| = \sqrt{\left(\frac{10}{9} \right)^2 + \left(\frac{10}{9} \right)^2} \quad \text{M1}$$

$$= \frac{10\sqrt{2}}{9} \text{ m s}^{-1} \quad \text{A1}$$

Alternative comparison equations: $-5 + 0.15t = v$ for t

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- c) Island's displacement is $\begin{pmatrix} 880 \\ -390 \end{pmatrix}$ m

We need to find ship's position when it has displacement $\begin{pmatrix} 880 \\ y \end{pmatrix}$ m

If $y > -390$ then ship passes north of the island; if $y < -390$ then ship passes south of the island

Use $\mathbf{r} = \mathbf{ut} + \frac{1}{2}\mathbf{at}^2$ with $\mathbf{u}$ and $\mathbf{a}$ as in part a) and $\mathbf{r} = \begin{pmatrix} 880 \\ y \end{pmatrix}$ m

$$\begin{pmatrix} 880 \\ y \end{pmatrix} = \begin{pmatrix} -5 \\ 6 \end{pmatrix}t + \frac{1}{2}\begin{pmatrix} 0.15 \\ -0.12 \end{pmatrix}t^2 = \begin{pmatrix} -5t + 0.075t^2 \\ 6t - 0.06t^2 \end{pmatrix}$$

First component gives the quadratic equation $0.075t^2 - 5t - 880 = 0$ M1

$$\therefore t = \frac{5 \pm \sqrt{(-5)^2 - 4 \times 0.075 \times (-880)}}{2 \times 0.075} = \frac{5 \pm \sqrt{25 + 264}}{0.15} = \frac{5 \pm 17}{0.15}$$
 M1

$$\text{So } t = -80 \text{ s or } t = \frac{440}{3} \text{ s}$$

Sea is in harbour at $t = 0$ s, so need $t \geq 0$, so $t = \frac{440}{3}$ s A1

Now know from the second component of the vector equation above that $y = 6t - 0.06t^2$

$$y = 6 \times \frac{440}{3} - 0.06 \times \left(\frac{440}{3}\right)^2 = -\frac{1232}{3} = -410.666... \text{ M1}$$

So $y < -390$, and hence the ship passes due south of the island A1 [13 M]

4. a) Show that $\dot{\mathbf{r}} = ((4\pi - t)\cos t - \sin t)\mathbf{i} - ((4\pi - t)\sin t + \cos t)\mathbf{j}$ cm s⁻¹

$$\mathbf{r} = (4\pi - t)\sin t \mathbf{i} + (4\pi - t)\cos t \mathbf{j} \text{ cm}$$

$$\therefore \dot{\mathbf{r}} = \frac{d}{dt}((4\pi - t)\sin t \mathbf{i} + (4\pi - t)\cos t \mathbf{j}) \text{ M1}$$

$$= ((4\pi - t)\cos t + (-1)\sin t)\mathbf{i} + ((4\pi - t)(-\sin t) + (-1)\cos t)\mathbf{j}$$

$$= ((4\pi - t)\cos t - \sin t)\mathbf{i} - ((4\pi - t)\sin t + \cos t)\mathbf{j} \text{ A1}$$

- b) Show that when the moth hits the edge of the lamp its speed is $\sqrt{\pi^2 + 1}$ cm s⁻¹

Displacement, $\mathbf{r}$, is measured from centre of lamp, which is a circle with diameter π cm

$$\text{So the moth hits the lamp when } |\mathbf{r}| = \frac{2\pi}{2} = \pi \text{ cm M1}$$

$$\mathbf{r} = (4\pi - t)\sin t \mathbf{i} + (4\pi - t)\cos t \mathbf{j} \text{ cm}$$

$$\therefore |\mathbf{r}| = \sqrt{((4\pi - t)\sin t)^2 + ((4\pi - t)\cos t)^2}$$

$$= \sqrt{(4\pi - t)^2(\sin^2 t + \cos^2 t)}$$

$$= 4\pi - t \text{ M1}$$

So moth hits the lamp when $4\pi - t = \pi$, i.e. when $t = 3\pi$ s M1

Substituting this value of t into the equation for $\dot{\mathbf{r}}$ in part a) gives:

$$\dot{\mathbf{r}} = ((4\pi - 3\pi)\cos 3\pi - \sin 3\pi)\mathbf{i} - ((4\pi - 3\pi)\sin 3\pi + \cos 3\pi)\mathbf{j}$$

$$= -\pi\mathbf{i} + \mathbf{j} \text{ cm s}^{-1}$$

So at this time its speed at this time is:

$$|\dot{\mathbf{r}}| = \sqrt{\pi^2 + 1}$$

$$= \sqrt{\pi^2 + 1} \text{ cm s}^{-1} \text{ A1}$$

Tip: Use the chain rule

Technique: Use the chain rule $\frac{d}{dx}(u \cdot v) = u \frac{dv}{dx} + v \frac{du}{dx}$

Hint: Use the identity $\sin^2 t + \cos^2 t = 1$

Tip: Use the identity $\cos 3\pi = -1$ and $\sin 3\pi = 0$

[7 M]

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5. a) Show that $g_c = \frac{U^2}{2800} \text{ m s}^{-2}$

Model the dust as a particle. Can ignore air resistance since there is no air.

Dust is thrown up at a 45° angle, so the vertical component of initial velocity

Treating upwards as positive, the acceleration of the dust is $-g_c$

Dust reaches its maximum height when vertical velocity is zero

Acceleration is constant, so use $v^2 = u^2 + 2as$ with $v = 0 \text{ m s}^{-1}$, $u = \frac{U\sqrt{2}}{2} \text{ m s}^{-1}$

$$0^2 = \left(\frac{U\sqrt{2}}{2}\right)^2 + 2 \times (-g_c) \times 700 \quad \text{M1}$$

$$\therefore g_c = \frac{2U^2}{4 \times 2 \times 700} = \frac{U^2}{2800} \text{ m s}^{-2} \quad \text{A1}$$

- b) On Earth:

Dust is thrown up at 60° angle, so the vertical component of its initial velocity

Treating upwards as positive, the acceleration of the dust is $-g_E$

Dust reaches its maximum height when vertical velocity is zero

Acceleration is constant, so use $v^2 = u^2 + 2as$ with $v = 0 \text{ m s}^{-1}$, $u = \frac{U\sqrt{3}}{2} \text{ m s}^{-1}$

$$0^2 = \left(\frac{U\sqrt{3}}{2}\right)^2 + 2 \times (-g_E) \times 0.105 \quad \text{M1}$$

$$\therefore g_E = \frac{3U^2}{4 \times 2 \times 0.105} = \frac{25U^2}{7} \text{ m s}^{-2} \quad \text{A1}$$

And so

$$\frac{g_c}{g_E} = \frac{U^2/2800}{25U^2/7} = \frac{7}{25 \times 2800} = \frac{1}{10\,000} \quad \text{A1}$$

[7 Marks]

Tip:
height
10.5

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6. $\mathbf{a} = (20t^3 + 16)\mathbf{i} + (30t^4 - 18t)\mathbf{j} \text{ m s}^{-2}$

$$\mathbf{v} = \int \mathbf{a} \, dt$$

$$= \int [(20t^3 + 16)\mathbf{i} + (30t^4 - 18t)\mathbf{j}] \, dt \quad \text{M1}$$

$$= (5t^4 + 16t + c_1)\mathbf{i} + (6t^5 - 9t^2 + c_2)\mathbf{j} \quad \text{A1}$$

We are told the particle is moving due east when $t = 0$ s, so $\mathbf{v}$ is of the form $a\mathbf{i} \text{ m s}^{-1}$.
At $t = 0$:

$$\mathbf{v} = (5 \times 0^4 + 16 \times 0 + c_1)\mathbf{i} + (6 \times 0^5 - 9 \times 0^2 + c_2)\mathbf{j}$$

$$= c_1\mathbf{i} + c_2\mathbf{j} \text{ m s}^{-1}$$

So $c_1 > 0$ and $c_2 = 0$ **M1**

We are also told that the particle has speed 205 m s^{-1} when $t = 2$ s

Velocity when $t = 2$ s is:

$$\mathbf{v} = (5 \times 2^4 + 16 \times 2 + c_1)\mathbf{i} + (6 \times 2^5 - 9 \times 2^2)\mathbf{j}$$

$$= (112 + c_1)\mathbf{i} + 156\mathbf{j} \text{ m s}^{-1}$$

Speed at $t = 2$ s is the magnitude of this vector, which the question states is 205 m s^{-1} , so

$$205 = \sqrt{(112 + c_1)^2 + 156^2}$$

$$= \sqrt{(112 + c_1)^2 + 156^2}$$

$$\therefore 205^2 = (112 + c_1)^2 + 156^2$$

$$\therefore 112 + c_1 = \pm \sqrt{205^2 - 156^2} = \pm 133$$

$$\text{So } c_1 = 133 - 112 = 21 \text{ or } c_1 = -133 - 112 = -245$$

But we know $c_1 > 0$ so $c_1 = 21$ **M1**

$$\therefore \mathbf{v} = (5t^4 + 16t + 21)\mathbf{i} + (6t^5 - 9t^2)\mathbf{j} \text{ m s}^{-1} \quad \text{M1}$$

$$\mathbf{r} = \int \mathbf{v} \, dt$$

$$= \int [(5t^4 + 16t + 21)\mathbf{i} + (6t^5 - 9t^2)\mathbf{j}] \, dt \quad \text{M1}$$

$$= (t^5 + 8t^2 + 21t + c_3)\mathbf{i} + (t^6 - 3t^3 + c_4)\mathbf{j} \text{ m} \quad \text{M1}$$

We are told that $\mathbf{r} = 0\mathbf{i} + 0\mathbf{j}$ when $t = 0$, so:

$$(0^5 + 8 \times 0^2 + 21 \times 0 + c_3)\mathbf{i} + (0^6 - 3 \times 0^3 + c_4)\mathbf{j} = 0\mathbf{i} + 0\mathbf{j}$$

and hence $c_3\mathbf{i} + c_4\mathbf{j} = 0\mathbf{i} + 0\mathbf{j}$, so $c_3 = c_4 = 0$ **M1**

$$\text{And so } \mathbf{r} = (t^5 + 8t^2 + 21t)\mathbf{i} + (t^6 - 3t^3)\mathbf{j} \text{ m} \quad \text{A1}$$

[9 Marks]

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