Motion on an inclined plane: Student notes

Introduction

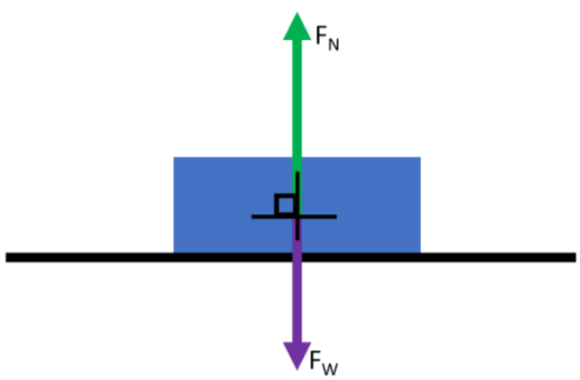
When an object is placed on a flat surface, it will sit still on the surface and won't move unless an outside force causes it to move. However, when the object is placed on an inclined surface, the object will start to slide down the surface due to gravitational forces. These inclined surfaces surround us everywhere. Such examples include when a car is on a hill and when a skateboard is rolling down a ramp. In this experiment, students will utilise their knowledge of acceleration and velocity and investigate how varying the angle of the ramp will affect how fast the object will accelerate down the surface.

Key Ideas

What is an Inclined plane?

To understand the inclined plane first we need to look at forces. Consider this object

While the object is stationary on a flat surface there are two forces acting on it. The Weight Force **(F_W)** and the Normal Force **(F_N)**. The Normal Force is always perpendicular to the plane.



The Weight Force **(F_W)** is found by multiplying the weight with gravity (9.81 N kg^{-1}).

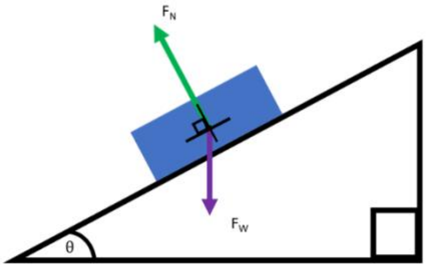
$$\boldsymbol{F_W} = m \times g$$

$$\boldsymbol{F_W} = mg$$

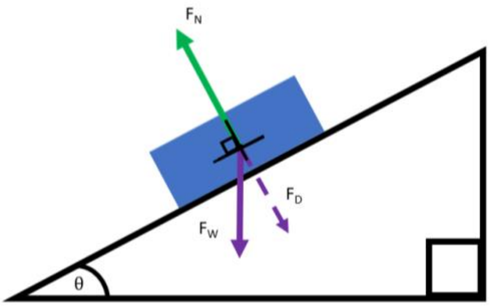
The Normal Force **(F_N)** is equal to Weight Force **(F_W)**. As it is an equal and opposite reaction.

$$\boldsymbol{F_N} = \boldsymbol{F_W}$$

On a flat surface, these two forces are balanced. But if the surface was an incline these forces would become unbalanced.

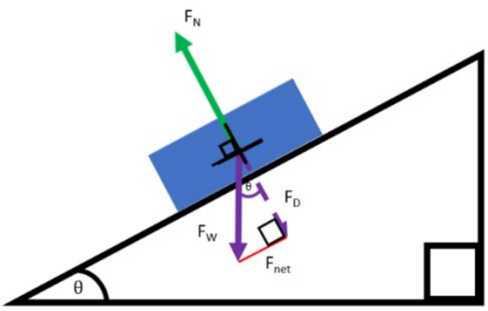


To balance these forces, a force called the Downwards Force **(F_D)** is added.



Combined the Weight Forces **(F_W)** and the Downwards Force **(F_D)** are equal to the normal force

Connecting the Weight Force **(F_W)** and Downward Force **(F_D)** is the Net Force **(F_{net})**. These three forces form a right-angled triangle.



Now that we know all our forces we can calculate the acceleration of the object as it slides down the plane.

To find acceleration we will be using the trigonometry formula

$$\sin\theta = \frac{opposite}{hypotenuse}$$

Each side of the triangle correlation to one of the forces. The hypotenuse is the magnitude of weight force and the opposite is the magnitude of the net force.

To find the magnitude of the Weight Force **(F_W)** we multiple the mass by gravity.

$$\boldsymbol{F_w} = mg$$

Next we rearrange the $\sin\theta$ equation so that the opposite is the subject

$$opposite = \sin\theta \times hypotenuse$$

As the hypotenuse = $\mathbf{F_W}$ and opposite = $\mathbf{F_{net}}$ we substitute them into the equation

$$\boldsymbol{F_{net}} = mg\sin\theta$$

As we know that it is the Net force that is allowing the object to move down the plane, we use newton's second law of motion to make the assumption

$$\boldsymbol{F_{net}} = m \times a$$

Where m = the mass of the object and a = the acceleration of the object down the plane (m/s^2) rearranging the equation gives us

$$a = \frac{\boldsymbol{F_{net}}}{m}$$

Equipment and materials

- Blu-tack
- Stopwatch (or phone timer)
- Spirit level app
- Dynamics cart
- Dynamic plane (MDF board) x 2
- Brick
- Pen or marker
- Sticky note
- Camera with slow-motion (*i*-Phone)

Method

1) Mark both dynamics planes every 20 cm.
2) Attach a sticky note to the dynamics cart and draw a line thick enough to be seen on phone camera.
3) With Blu-tack, stick the stopwatch on top on the dynamics cart.
4) Place the two dynamics planes a row touching and use a brick to elevate one creating a ramp.
5) Using the spirit level app collect the angle of elevation of the plane.
6) Place cart at the top of the ramp and release it without pushing it whilst recording it with the slow-motion camera.
7) Watch the footage and record the time each time the line marked on the cart passes the 20 cm interval.
8) Move the brick to increase the elevation of the ramp and repeat steps 5-7.
9) Put data into an Excel spreadsheet to graph time versus distance and velocity versus time.




Part 1 Scientific Questions

When scientists and engineers ask a scientific question, they make a prediction: ***If this thing is changed, then that is expected to happen***. In testing that prediction, they try to keep all other factors unchanged.

Suggest a couple of scientific questions that you could ask using your experiment equipment and materials:

Some Scientific questions will be more suitable for investigation in a classroom setting. Your teacher will lead a discussion to decide which scientific question will be investigated. Your group will then decide how to investigate that question.

The Scientific question that my group will investigate is:

Our hypothesis is:

Our **Independent** variable is (What you changed):

Our **Dependant** variable is (what you measured):

Our **controlled variables** are (what did you keep the same):

Are there any **safety** issues to consider?

Part 2 Testing our scientific question

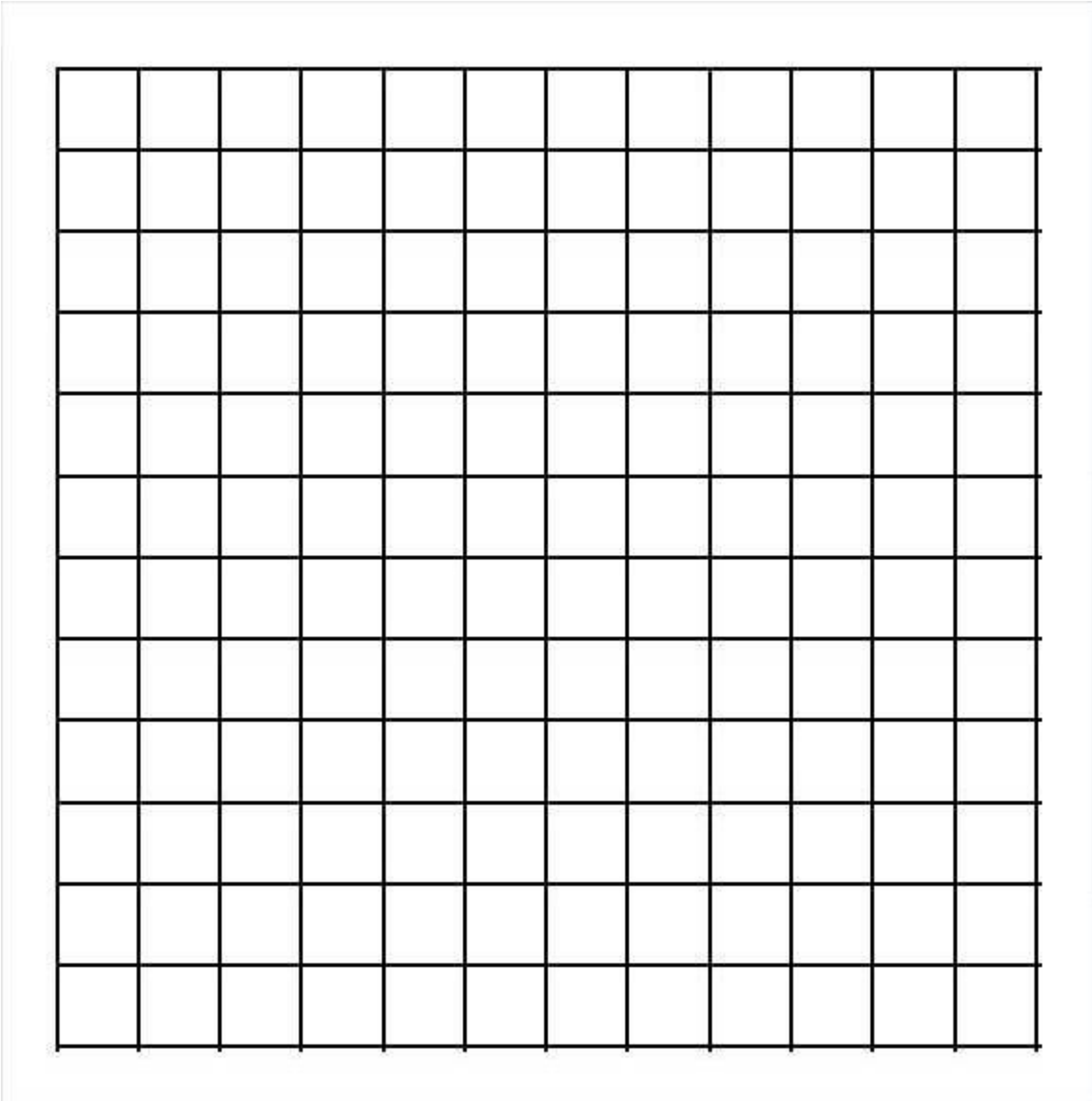
Get approval from your teacher of your plans (Part 1) before starting Part 2.

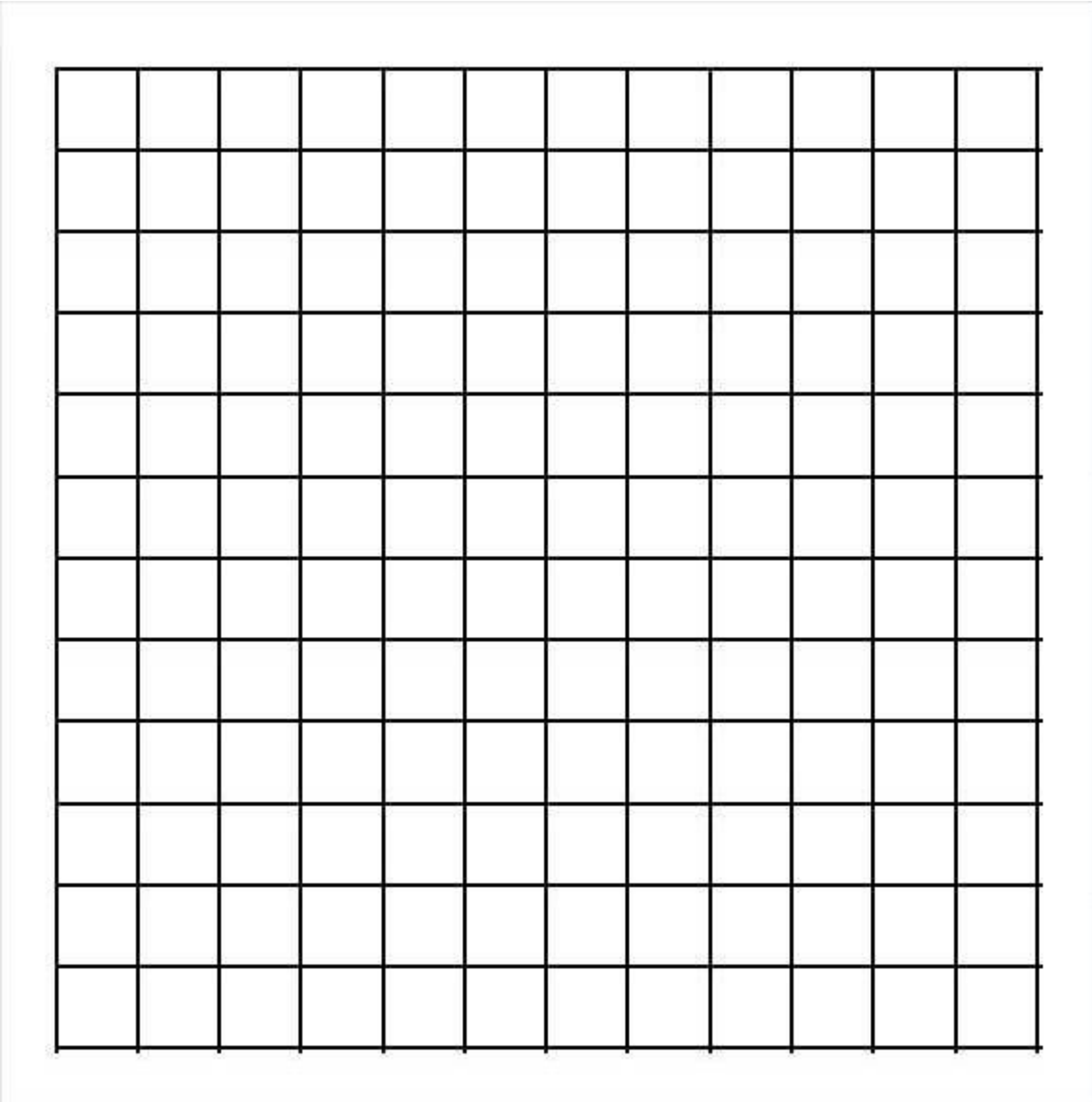
Results

Angle 1:

Time (s)	Distance (m)	Velocity (m/s)

Angle 1:

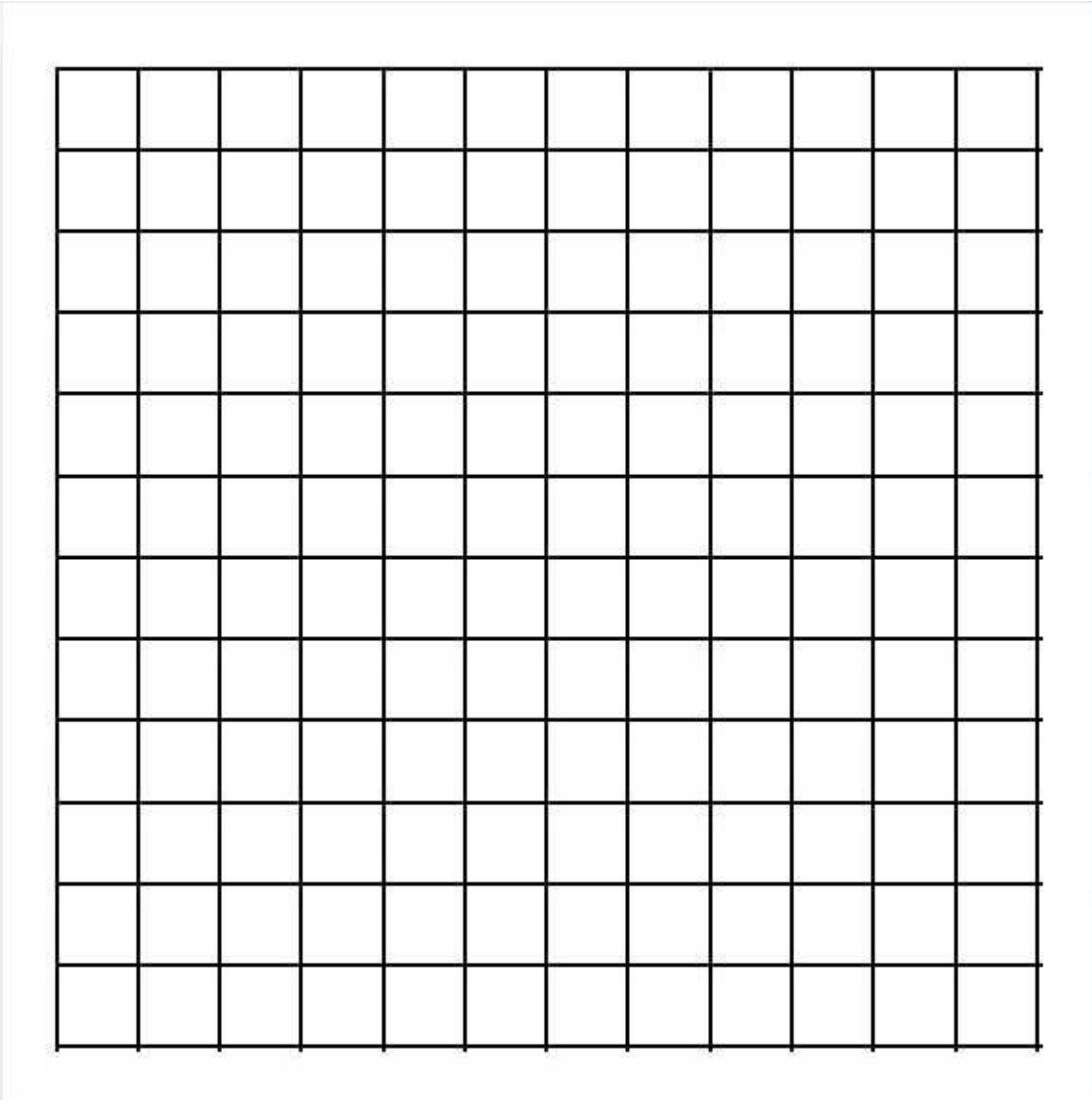


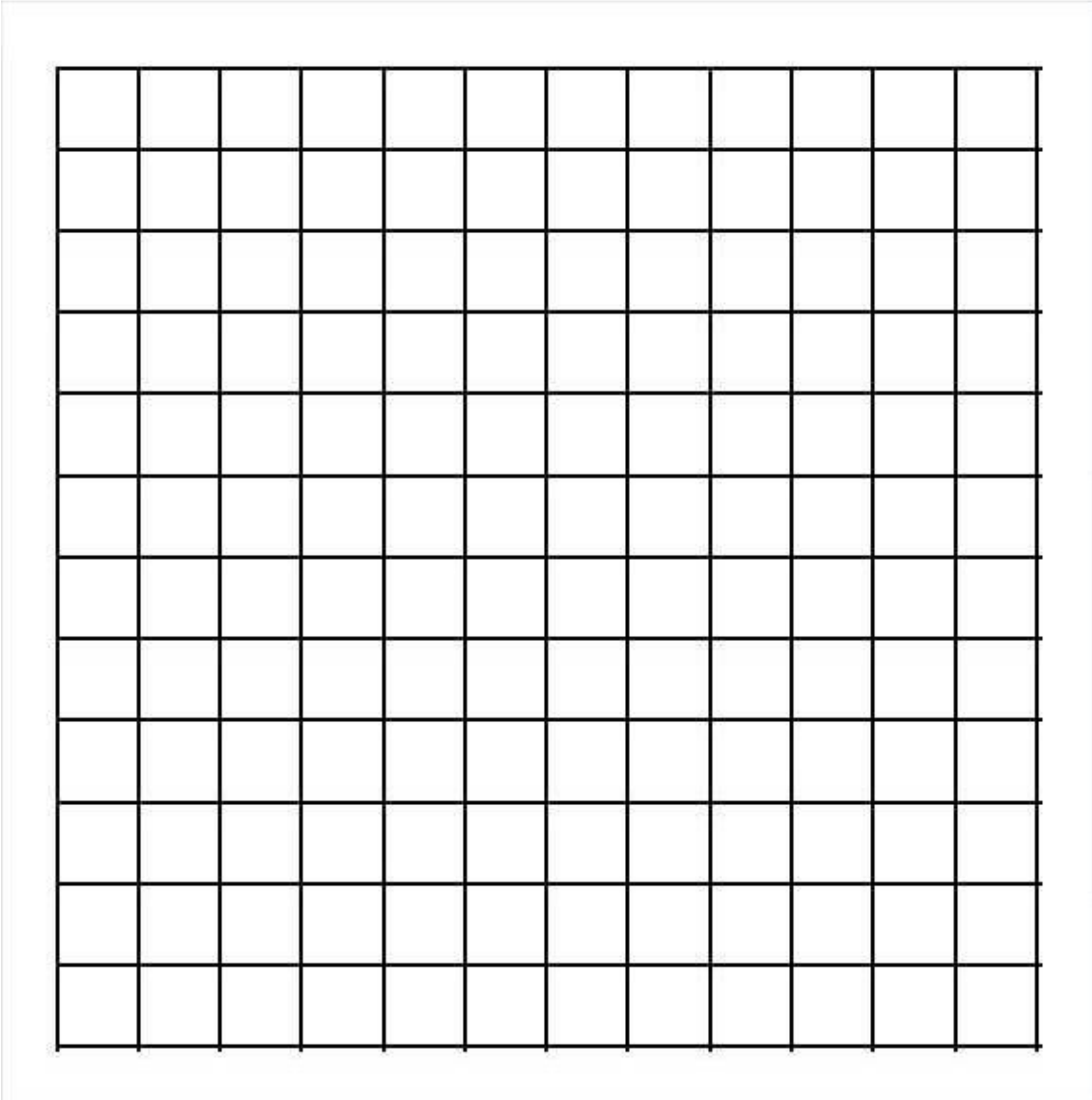


Angle 2:

Time (s)	**Distance (m)**	**Velocity (m/s)**

Angle 2:





Part 3 Forces on an inclined plane

Draw a diagram illustrating the forces on the cart on the plane

Remember to include normal and gravitational force.

Part 4: Calculations & Discussion

Calculations:

Using acceleration = velocity/ time

Angle 1

Calculate the average acceleration for section 1 (slope)

Calculate the average acceleration for section 2 (flat)

Angle 2

Calculate the average acceleration for section 1 (slope)

Calculate the average acceleration for section 2 (flat)

Discussion

What do the trends in the graphs mean?

What do the graphs show about speed in both sections?

How does increasing the slope change the speed?

Why is the acceleration constant in each section?

Extension:

Using $a = g \times \sin\theta$ where θ = angle of slope

Can you work out g?

What could cause your answer to differ from the accepted value of gravity of 9.8 m/s^2?

Part 5: Reflection

Did your observations or measurements agree with your expectations and prediction? Can you explain why?

Did you encounter any problems?

What changes could you have made to this experiment?

What did you discover for this experiment?

Conclusion:

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