ANSWER SHEET

A. Understanding of magnetic fields (1.0 pt)

1. Understanding of magnetic field created by a circular coil

A.1 (0.5 pt)
$k =$

A.2 (0.5 pt)
$B_\beta =$

B. Investigation of the GMR effect using a GMR magnetic sensor (7.0 pt)

1. Determination of resistance of GMR elements

a. Resistance of the elements at $B = 0$.

B.1 (1.25 pt)
Diagrams of the experiment and expressions for calculating the resistance of each element *a*, *b*, *c* and *d*.

B.2 (1.25 pt)
For $B = 0$:
$a =$

$b =$

$c =$

$d =$

b. Resistance of the elements at maximum external magnetic field

B.3 (0.5 pt)
$a =$

$b =$

$c =$

$d =$

c. Properties of the elements

B.4 (0.25 pt)
Elements sensitive to the magnetic field are:

2. Characteristics of a GMR element

B.5 $(0.75\ \mathrm{pt})$
The name of the chosen element:
Diagrams of the experiment and expressions for calculating $\delta(B)$.

B.6 (1.25 pt)
Table for determining $\delta(B)$

I	***B***				$\delta(B)$

B.7 $(0.5\ \text{pt})$
Graph 1- Graph of the relative change of resistance $\delta(B)$

B.8 $(0.25\ \text{pt})$
The average slope

$\alpha =$

B.9 $(0.25\ \text{pt})$
The GMR coefficient

$\delta = \frac{\triangle R_{\text{max}}}{R(0)} =$

B.10 $(0.75\ \text{pt})$
R and *r* of the GMR element

$r =$

$R =$

$\gamma = \frac{r}{R} =$

C. Study of GMR magnetic sensor (6 points)

1. Characteristics of sensor output signal

C.1 (1.0 pt)
Table with the values of *S* corresponding to the values of the current I in the coil and the magnetic field *B*.

I	B	S	I	B	S

C.2 $(1.0\ \text{pt})$
Graph 2 - Graph $S(B)$ of the output signal *S* as a function of the applied magnetic field *B*.

C.3 $(0.5\ \text{pt})$

1. Circle the region of saturation in the curve $S(B)$ and label it with "S".	0.25pt
2. Circle the region of linearity in the curve $S(B)$ and lable it with "L". For this region, find the average value of the slope $m = \frac{\Delta S}{\Delta B}$.	0.25pt

C.4 $(0.5\ \text{pt})$
The coercive field is
$B_c =$

2. Dependence of the output signal on the supply voltage

C.5 $(0.25\ \text{pt})$
Table with the values of S corresponding to the values of *E*.

E	***S***

C.6 $(0.25\ \text{pt})$
Graph 3 - Graph of S as a function of E

C.7 $(0.5\ \text{pt})$

$S =$

C.8 (1.0 pt)

1.The magnetic field used in this experiment. Put a cross in the appropriate box.	0.25 pt

a. The field of the circular coil carrying an electric current	
b. The field of the flat coil carrying an electric current	
c. The plate of permanent magnet	
d. The magnetic field of the Earth	

2.Diagrams of the experiment and expressions to determine the value of n.	0.75 pt

C.9 (0.5 pt)
Table to find B/B_0 for different values of L_1.

L_1				B/B_0

C.10 (0.5 pt)
Graph 4 - Graph of B/B_0 as a function of an appropriate variable to determine the value of n.
$n =$

D. Applications of GMR magnetic sensors (6 points)

1. Measuring the Earth's magnetic field

a. Magnitude of the horizontal component of the Earth's magnetic field

D.1 $(0.5\ \text{pt})$
Diagrams of the experiment and expressions for calculating B_h.

D.2 $(0.25\ \text{pt})$
$B_h =$

b. Magnitude of the Earth's magnetic field and magnetic inclination

D.3 $(0.75\ \mathrm{pt})$
Diagrams of the experiment and expressions for calculating B_{Earth} and θ.

D.4 (0.5 pt)

$B_{Earth} =$

$\theta =$

2. DC wattmeter

D.5 (0.5 pt)
Diagram of the wattmeter circuit together with the load and the multimeters.

D.6 $(0.75\ \text{pt})$
Table with the values of the sensor output signal *S* corresponding to the values of I and *U*, and of $P = I \bullet U$.

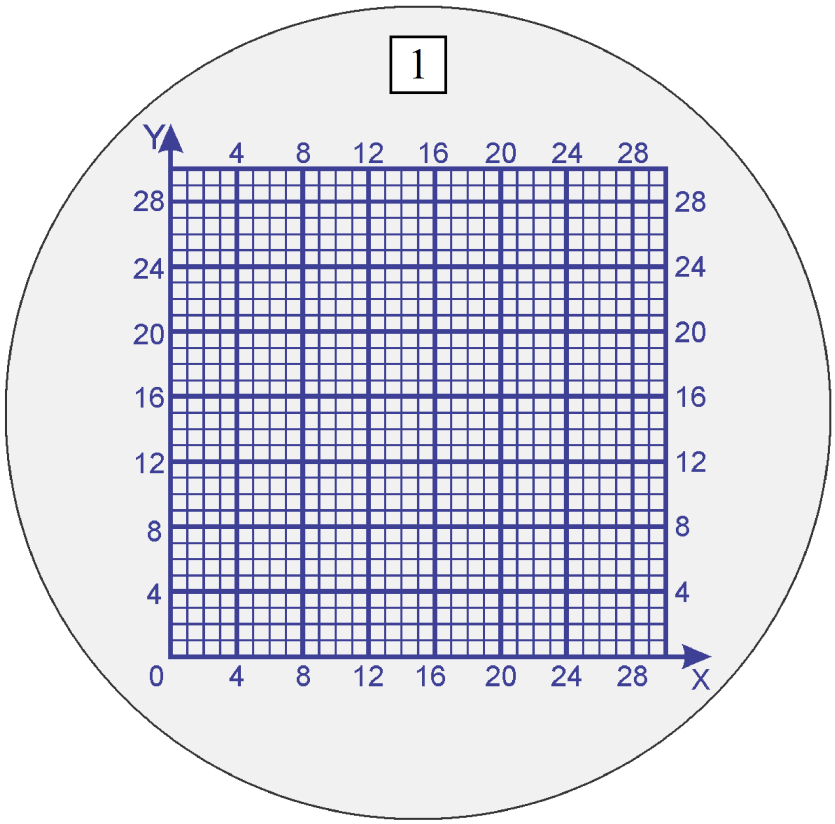
I	*U*	*P*	*S*

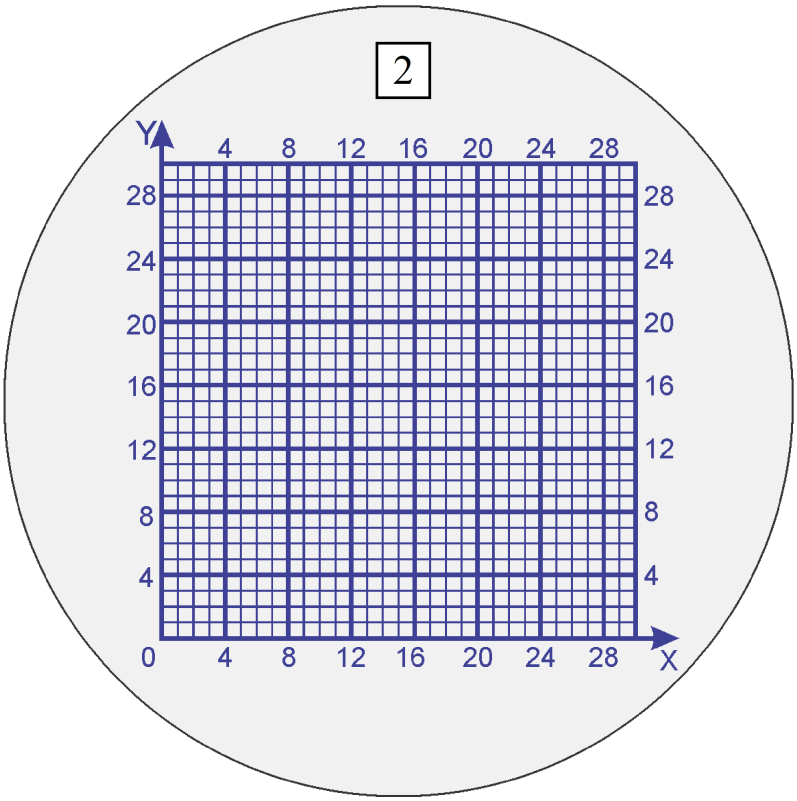
D.7 $(0.5\ \text{pt})$
Graph 5 – Graph of $P = f(S)$

D.8 $(0.25\ \text{pt})$
The expression of the function:
The coefficient(s):

3. Detection of buried electrical circuits

D.9 (2.0 pt)

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A1-16

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A1-19

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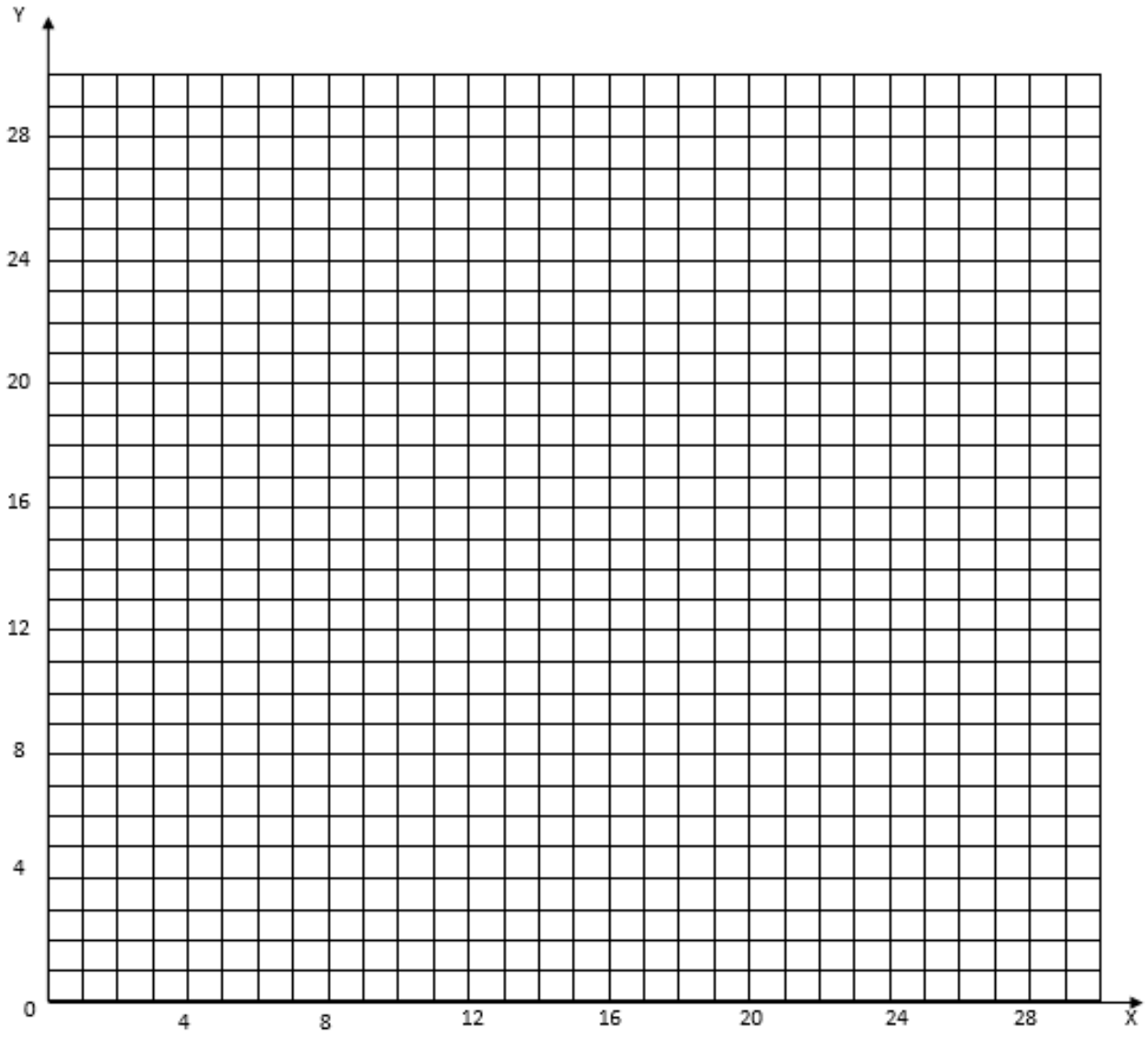
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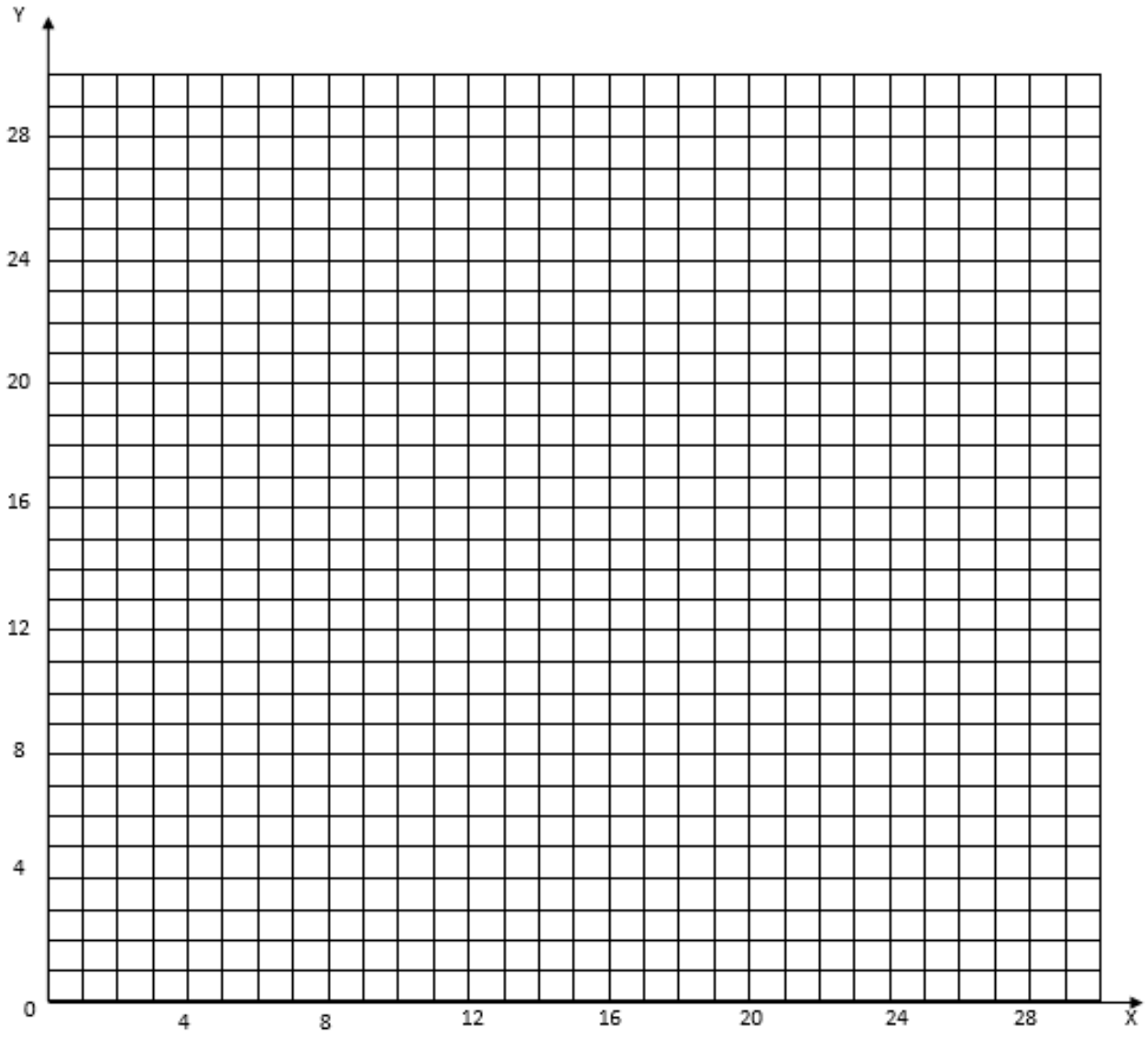

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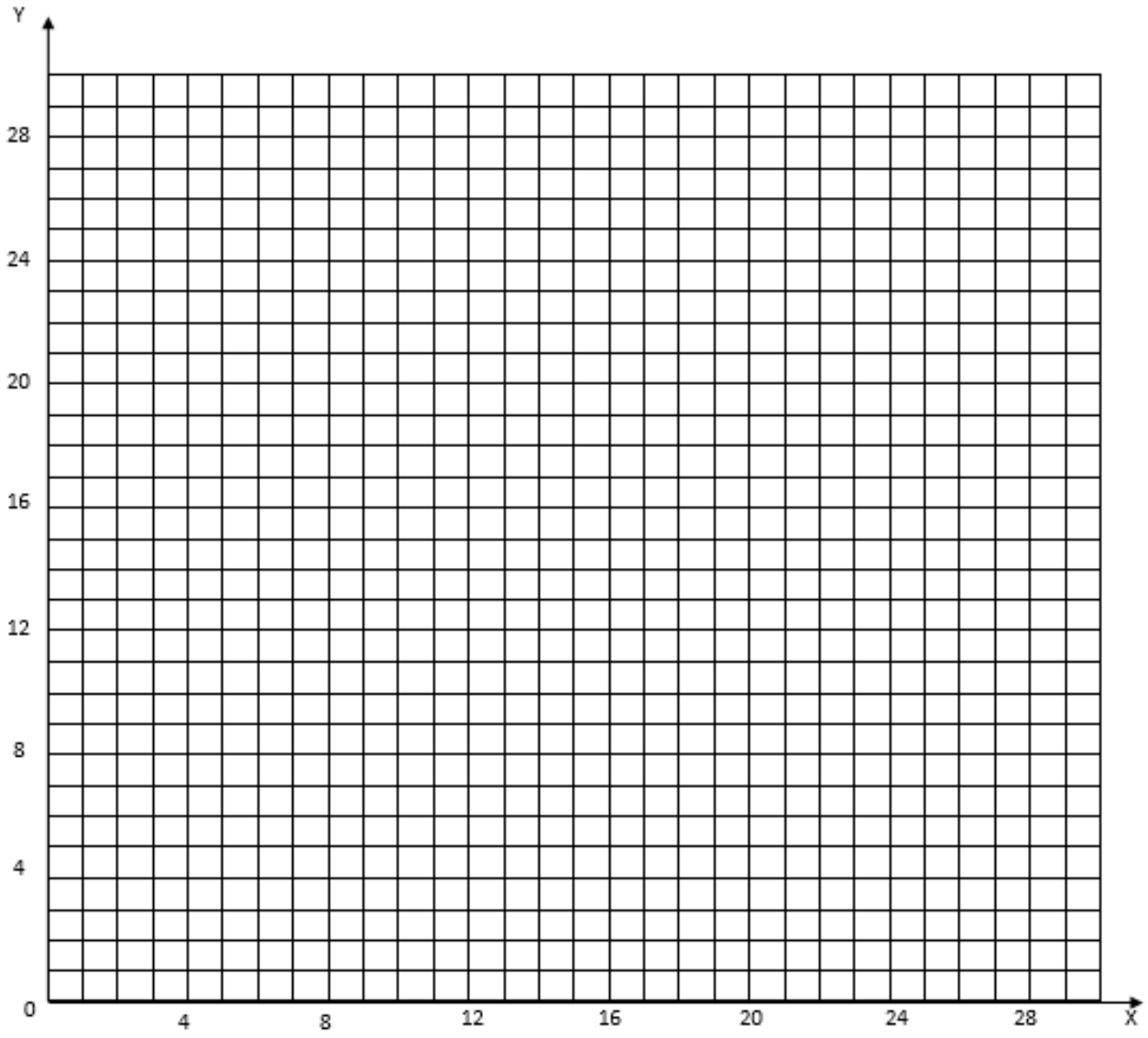

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