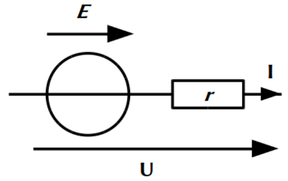
Correction & Marks – Exam 2 (/36)

General comments for all exercises :
- **up to 1 point bonus/penalty for spelling, cleanness and clarity**.
- As indicated in the header of the exam, **no points for any numerical result given without unit**.
- For all **non homogeneous result without any comment**, penalty of -0.5.
- The exam is noted on **36 points + 5.5 points bonus**. The final mark is obtained by **dividing the mark by 1.8**.

Exercise 1 : Plot of an I-V Characteristics (11.5 points + 0.5 pts bonus)

Remark : the point for U<0 could not be obtained with this circuit only.

Elements of correction	**Points**	**/11.5**
1. The I-V curve does not go through (0,0) : active dipole (points for justification)	**0.5**	
Question 2		/ 5
- Drawing of **extreme lines** (D_1) et (D_2) :	**0.5+0.5**	
- **Bonus** : drawing quality : D_1 and D_2 go through all (or almost all) uncertainty boxes		+0.5
- Choice of points for determining the lines' equations : the two points chosen on (D_1) and (D_2) must be specified with their coordinates (and units)	**0.5**	
- **Determination of a_{min}, b_{max} from the equation of** (D_1)	**0.5**	
Points A_1(2 V ;4.2 mA) and B_1(0.42 V ; 18 mA) belong to (D_1).		
$\Rightarrow a_{min} = \frac{18-4.2}{0.42-2} = -8.73$ mA.V^{-1}		
From the coordinates of point B_1 : $b_{max} = 18 + 8.73 \times 0.42 = 21.7$ mA		
- **Determination of a_{max},b_{min} from the equation of** (D_2)	**0.5**	
Points A_2(2 V ;7.4 mA) and B_2(0.22 V ; 18 mA) belong to (D_2).		
$\Rightarrow a_{max} = \frac{18-7.4}{0.22-2} = -5.96$ mA.V^{-1}		
From B_2 : $b_{min} = 18 + 5.96 \times 0.22 = 19.3$ mA		
- **Determination of parameters a and b :**		
2 possible methods :		
- Either : drawing of line (D) of equation $I = aU + b$		
Points A(2 V ;5.8 mA) and B(0.34 V ; 18 mA) belong to (D).		
$\Rightarrow a = \frac{18-5.8}{0.34-2} = -7.4$ mA.V^{-1}	**0.5**	
Then from B : $b = 18 + 7.35 \times 0.34 = 20.5$ mA	**0.5**	
- Or : from a_{min}, a_{max}, b_{min}, b_{max} :	(or	
$a = \frac{a_{max}+a_{min}}{2}$	0.5	
$b = \frac{b_{max}+b_{min}}{2}$	0.5)	
- Uncertainties on a and b :		
$\Delta a = \frac{a_{max}-a_{min}}{2} = \frac{-5.96+8.73}{2} = 1.4$ mA.V^{-1}	**0.5**	
$\Delta b = \frac{b_{max}-b_{min}}{2} = \frac{21.7-19.3}{2} = 1.2$ mA	**0.5**	
- Presentation of the results : $(a = -7.4 \pm 1.4)$ mA.V^{-1} and $b = (20.5 \pm 1.2)$ mA	**0.5**	
No points if no unit		

3. Equivalent circuit scheme		/ 3.5
Scheme of a real voltage source of emf E internal resistance r :	**0.5**	
		
- Define U and I along the same orientation as E on the scheme (active sign convention)	**0.5**	
- Justification for values of r and E :	**0.5**	
<u>either</u> using $U = E - rI$, $I = -\frac{1}{r}U + \frac{E}{r}$, hence $a = -\frac{1}{r}$ and $b = \frac{E}{r}$		
<u>or</u> $a = -\frac{1}{r}$ et $E = U(I = 0)$		
$\Rightarrow r = -\frac{1}{a} = 135\Omega$ and $E = br = 2.8$ V	**0.5**	
- Uncertainties on r and E :		
$r_{min} = -\frac{1}{a_{min}} = \frac{1}{8.73\times10^{-3}} = 114\Omega$, $r_{max} = -\frac{1}{a_{max}} = \frac{1}{5.96\times10^{-3}} = 168\Omega$, $\Delta r = \frac{r_{max}-r_{min}}{2} = 27\Omega$	**0.5**	
$E_{min} = b_{min}r_{min} = 2.2$ V, $E_{max} = b_{max}r_{max} = 3.7$ V, $\Delta E = 0.8$ V	**0.5**	
- Presentation of the results : $r = (135 \pm 27)\Omega$ and $E = (2.8 \pm 0.8)$ V (no unit : no points)	**0.5**	
4. Active sign convention since U and I have the same orientation	**0.5**	
5. Always supplying energy ?		/ 2
Passive role for $U < 0$ and active for $U > 0$	**0.5**	
Justification : in active sign convention, $P = UI$ is the power supplied by the dipole.	**0.5**	
$P = UI < 0 \rightarrow$ passive role, $P = UI > 0 \rightarrow$ active role	**0.5+0.5**	

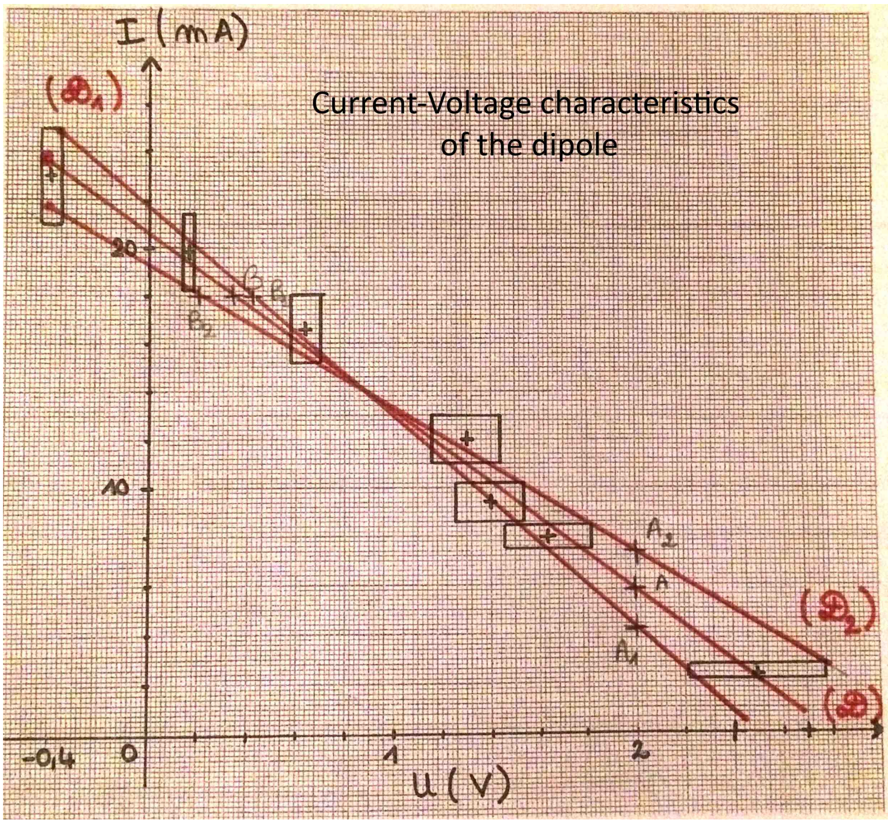


FIGURE 1 – I-V curve of the dipole

Exercise 2 : Galileo's telescope (15 points + 3 pts bonus)

Elements of correction	**Points**	**/15**
1. Optical scheme of Galileo's telescope		8.5
1.1 Afocal system : the image of an object at infinity through the system should be at infinity $\Rightarrow F_1'$ and F_2 are on the same location (1 point for the explanation, 1 point for $F_1' = F_2$)	**2**	
1.2. Determination of d :		/4
$d = \overline{O_1O_2} = \overline{O_1F_1'} + \overline{F_1'O_2} = \overline{O_1F_1'} + \overline{F_2O_2} = f_1' + f_2'$	**1**	
Uncertainty on d :		
$f_1' = (20,0 \pm 0,4)cm$ and $f_2' = (-4,00 \pm 0,08)cm$	**0.5**	
$d_{max} = f_{1max}' + f_{2max}'$=16.5cm	**0.5**	
$d_{min} = f_{1min}' + f_{2min}'$=15.5cm	**0.5**	
Calculation of Δd : $\Delta d = \frac{d_{max} - d_{min}}{2}$	**0.5**	
Numerical application : d=(20,0-4,0=16,0) cm or $d = \frac{d_{max}+d_{min}}{2} = 16,0cm$	**0.5**	
$d = (16,0 \pm 0.5)cm$ (correct rounding, 0 if no unit)	**0.5**	
1.3. Scheme of Galileo's telescope (on doc 2) :		/2.5
Correct positioning of L_2	**0.5**	
Drawing of the ray going through L_1 (obvious) then L_2	**1**	
Determination of the intermediate image	**1**	
Bonus : Drawing accuracy, correct use of full/dotted lines		+0.5
1.4. Bonus : Advantages of Galileo's telescope		+2
The image through the telescope is **upright**	+0.5	
Justification of upright image	+0.5	
Advantage 1 : the image is not reversed	+0.5	
Advantage 2 : the telescope is more **compact** (d smaller)	+0.5	
2. Angular magnification of Galileo's telescope		/3
2.1 $tan\theta = \frac{\overline{A_1B_1}}{\overline{O_1F_1'}} = \frac{\overline{A_1B_1}}{f_1'}$	**0.5**	
$tan\theta' = \frac{\overline{A_1B_1}}{\overline{O_2F_2}} = -\frac{\overline{A_1B_1}}{f_2'}$	**0.5**	
We are in Gauss conditions so $tan\theta \approx \theta$ and $tan\theta' \approx \theta'$	**0.5**	
We have therefore : $G = \frac{\theta'}{\theta} \approx -\frac{f_1'}{f_2'}$		
2.2 Calculation of G : $G_{max} = \frac{f_{1max}'}{f_{2min}'} = \frac{20,4}{3,92} = 5,20$	**0.5**	
$G_{min} = \frac{19,6}{4,08} = 4,80$	**0.5**	
Presentation of the final result : $G = 5,0 \pm 0,2$	**0.5**	
3. Open question		/3.5
-Scheme of the apparent diameter of Copernicus with the naked eye showing clearly the different parameters : d_{cop} : Copernicus diameter, D_{EM} and angle θ_{cop}	**1**	
- $tan\theta_{cop} \approx \theta_{cop} \approx \frac{d_{cop}}{D_{EM}}$ because in Gauss conditions	**0.5**	
- Without telescope : $\theta_{cop} \approx \frac{96}{384000} \approx 2.5 \times 10^{-4}$ rad smaller than the eye angular	**0.5**	
resolution $\Rightarrow$ Copernicus is invisible with the naked eye	**0.5**	
- With the telescope : $\theta_{cop}' = G\theta_{cop} = 1.25 \times 10^{-3}$ rad : Copernicus is visible	**0.5**	
- For Clavius : $\theta_{cla} \approx 6.25 \times 10^{-4}$ rad : Clavius is visible with the naked eye (therefore with the telescope).	**0.5**	
- **Bonus** : Communication and clarity of the reasoning		+0.5

Exercise 3 : Autocollimation (9.5 points + 2 pts bonus)

Elements of correction	**Points**	**/9.5**
1. Construction on document 3 :		/2.5
- Case a : construction of A_1B_1 with prolongation in dotted line	**0.5**	
- Case a : correct position of A_2B_2 (accept the symmetry w.r.t. the mirror plane)	**0.5**	
Bonus : if drawing of rays to get A_2B_2 (case a)		+0.5
Bonus : construction of $A'B'$ (case a)		+0.5
- Case b : drawing of A_1B_1 then A_2B_2 and finally $A'B'$ with at least two rays	**1.5**	
If correct rays until $A'B'$ but without finding A_1B_1 and A_2B_2 : 1 pt/1.5		
2. Position and size of A_1B_1, A_2B_2 and $A'B'$ by calculation :		/4
2.1 For A_1B_1 : $\frac{1}{\overline{OA_1}} - \frac{1}{\overline{OA}} = \frac{1}{f'}$ hence $\overline{OA_1} = \frac{f'\overline{OA}}{f'+\overline{OA}}$	**0.5**	
$\overline{OA_1} = 6$ cm	**0.5**	
Calculation of $\overline{A_1B_1}$: $\gamma = \frac{\overline{A_1B_1}}{\overline{AB}} = \frac{\overline{OA_1}}{\overline{OA}}$.	**0.5**	
We find $\overline{A_1B_1} = -2$ cm	**0.5**	
Since the question mentioned the length, points for answer : $A_1B_1 = 2cm$		
2.2 For A_2B_2 :		
Noting M the intersection between the mirror plane and the optical axis, $\overline{MA_1} = -\overline{MA_2}$	**0.5**	
$\overline{MA_1} = \overline{MO} + \overline{OA_1} = -2+6 = 4cm$ so $\overline{MA_2} = -4cm$	**0.5**	
As a result : $\overline{OA_2} = \overline{OM} + \overline{MA_2} = 2-4 = -2cm$.	**0.5**	
Calculation of $\overline{A_2B_2}$: the mirror magnification is 1 : $\gamma = \frac{\overline{A_2B_2}}{\overline{A_1B_1}} = 1$		
therefore $\overline{A_1B_1} = \overline{A_2B_2} = -2cm$	**0.5**	
Since the question mentioned the length, points for answer : $A_2B_2 = 2cm$		
2.2 **Bonus** : For $A'B'$		
Warning : the direction of propagation of light changed and is now from right to left (rl)		
thus : $\overline{OA_{2rl}} = -\overline{OA_2}$		
$\frac{1}{\overline{OA'_{rl}}} - \frac{1}{\overline{OA_{2rl}}} = \frac{1}{f'}$		+0.5
We find : $\overline{OA'} = -\overline{OA'_{rl}} = -1cm$		
$\gamma = \frac{\overline{A'B'}}{\overline{A_2B_2}} = \frac{\overline{OA'}}{\overline{OA_2}}$. We get $\overline{A'B'} = -1$ cm		+0.5
The question mentioned the length, points for answer : $A'B' = 1cm$		
3.		/1
Moving M in case b) does not change the position of the final image $A' = F$.	**0.5**	
If $A = F$ then A_1 and A_2 are located at infinity on the optical axis, therefore A' is located on F'_{rl} (light propagation from right to left) and so $A = F = F'_{rl}$.	**0.5**	
4.		/ 2
- The method is called **autocollimation**.	**0.5**	
- The experimental setup is that of doc. 3 : object, lens, mirror aligned	**0.5**	
(point for correct scheme or doc 3 correctly referred to)		
- We vary the object/lens distance by moving the lens	**0.5**	
When the final image is formed on the object plane and is of the same size as the object but reversed, we are in case b		
- We then measure $\overline{OA} = -f'$	**0.5**	

Document 2 :

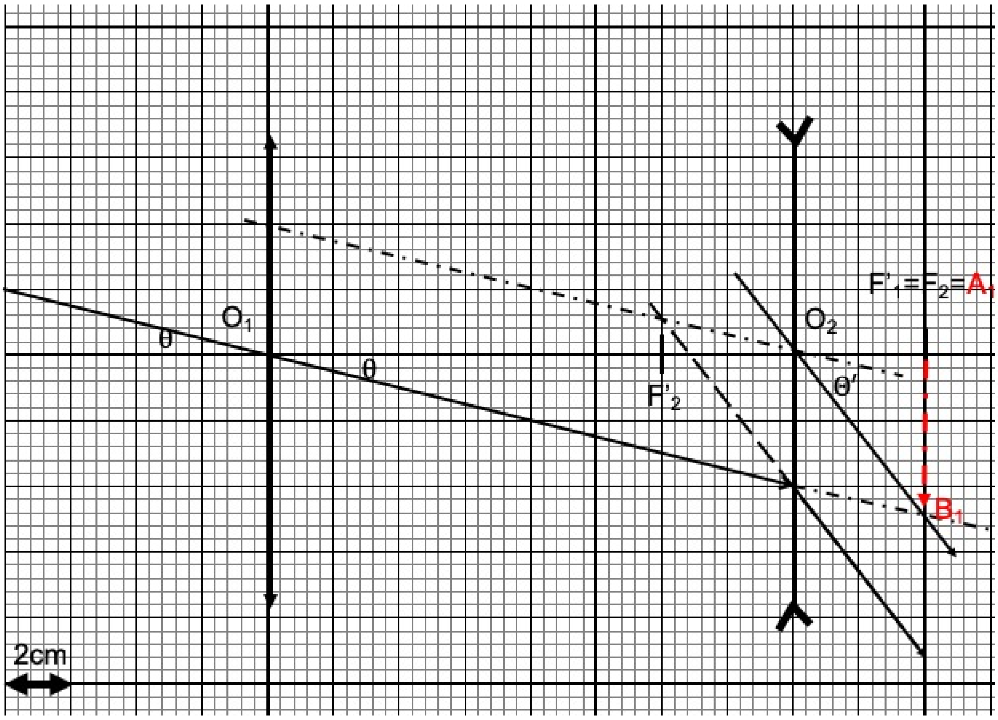
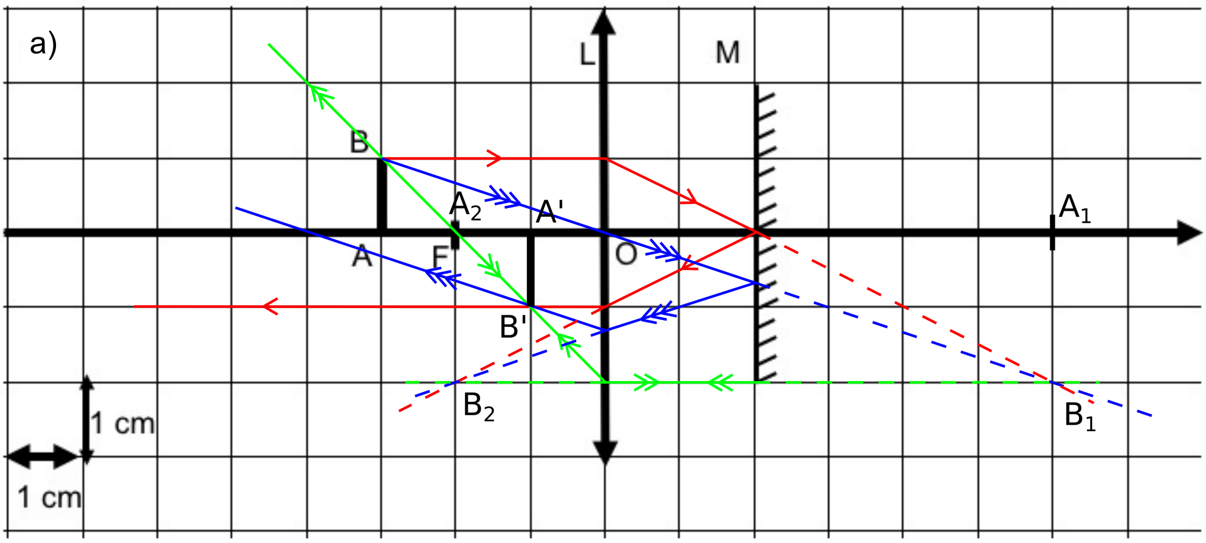
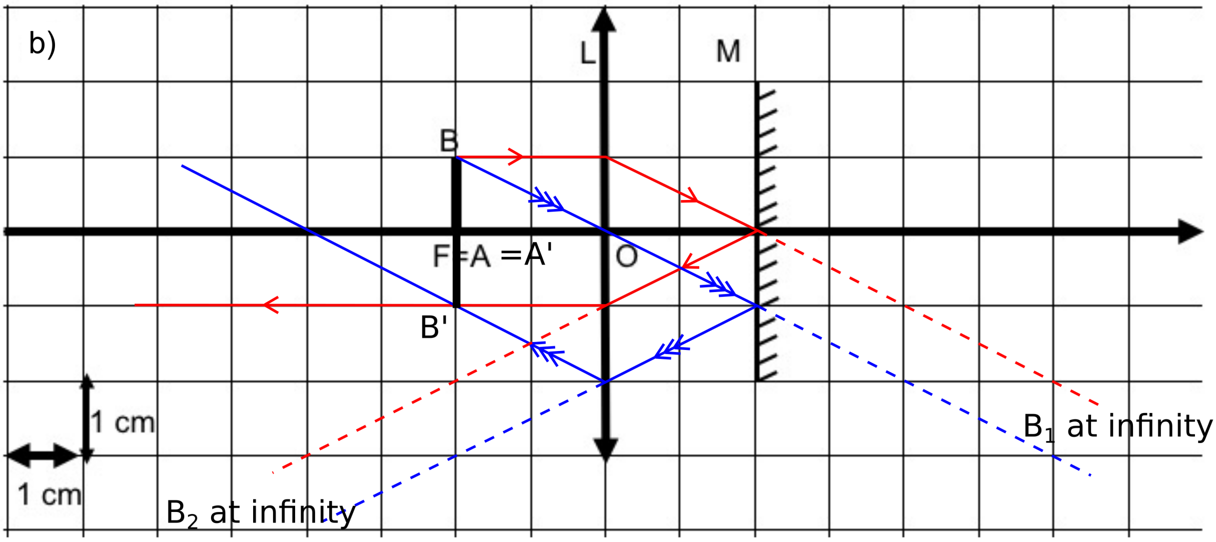


FIGURE 2 – Correction of 1.3 of exercise 2 : B_1 is the intermediate image of an object B at infinity

Document 3 :


a)
L
M
B
A_2
A'
A_1
A
F
O
B'
B_2
B_1
1 cm
1 cm


b)
L
M
B
F=A =A'
O
B'
1 cm
1 cm
B_1 at infinity
B_2 at infinity