

Mechanical Design 2
7145



CAMEROON GENERAL CERTIFICATE OF EDUCATION BOARD

Technical and Vocational Education Examination

JUNEXXXX

ADVANCED LEVEL

Specialty Name (Specialty Code)	MAME, HBMA, MWIP, AM-LV, AM-HD
Subject Title	Mechanical Design
Paper No.	2
Subject Code No.	7145

Three hours

INSTRUCTIONS TO CANDIDATES

- The paper comprises four compulsory sections :
 - Section A (STATICS): Candidate should attempt ALL questions
 - Section B (KINEMATICS): Candidate should attempt only ONE question
 - Section C (DYNAMICS): Candidate should attempt All questions
 - Section D (STRENGTH OF MATERIALS): Candidate should attempt only ONE question
- Illustrate your answers with neat sketches wherever necessary.
- Preferably, write the answers in sequential order.
- Use of non-programmable calculator is permissible
- This paper carries 35% of the total marks.
- The candidates will write the answers to the questions asked on the documents "answer sheets" pages 8 to 18. All the answer sheets documents even blanked are to be given at the end of the test.

You are reminded of the necessity for good English and orderly presentation in your answers.

You are advised to read carefully through the question paper, before you begin your answers.

Turn Over

SECTION A: STATICS/ marks

Attempt ALL the following questions:

QUESTION 1:

THEME: SELF LOCKING DEVICE

❖ DESCRIPTION AND FUNCTIONING

Figure 1 below represents a self-locking device used in a machining mounting. It is made of a stand **1**, completely linked on a machine table, an operating lever **2**, a connecting rod **3**, a lever **4**, a tappet **5**. Those different elements are linked by the following linkages:

- Pivot link without adherence: **1-2**, **2-3**, **3-4** and **4-1**; of respective axes: **(K, z)**, **(J, z)**, **(I, z)** and **(E, z)**.
- Linear linkage without adherence: **2-7** at **L** and **4-5** at **D**.
- Sliding pivot linkage with adherence **5-1** of axis **(D, x)**.
- Plane stopped linkage with adherence **5-6** at point **A**.

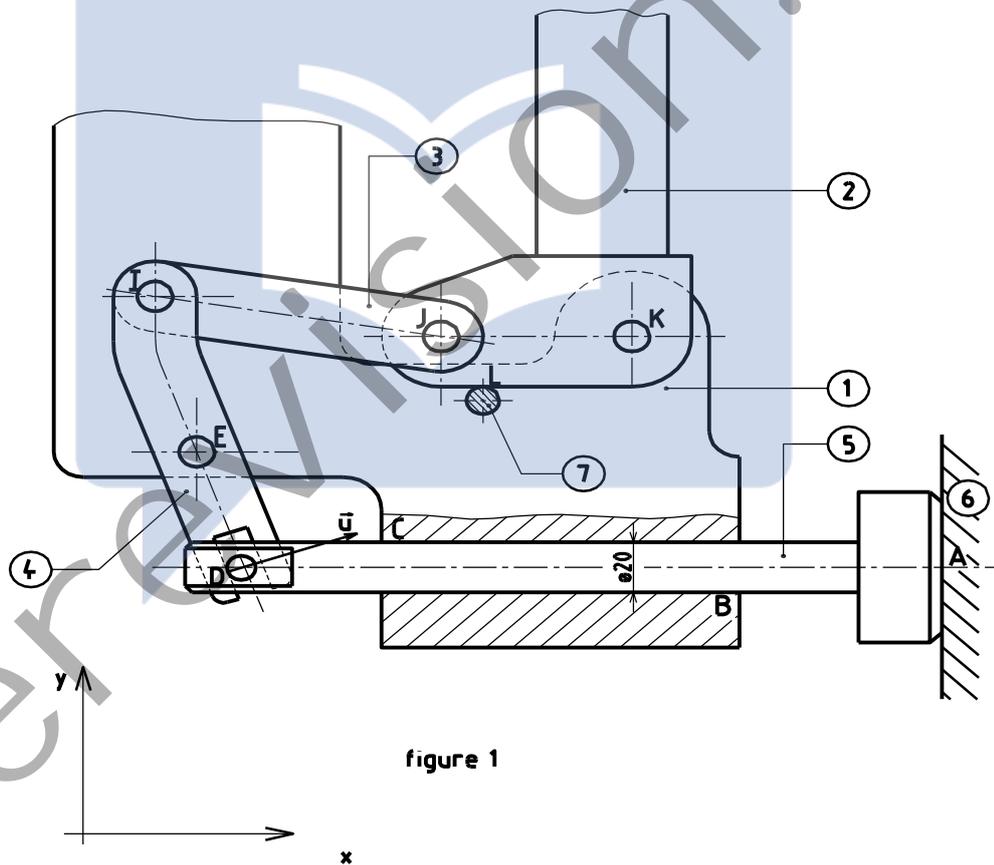


figure 1

Aims: To determine the clamping force $\vec{K}_{1/2}$ exerted by the lever **2**

Hypotheses and data

- The whole system has as plane of symmetry **O, x, y** as indicated in the drawing.
- The weight of pieces is neglected.
- The contact action of link **5-1** is located at points **B** and **C**.
- The coefficient of adherence at **B** and **C** is $f = \text{tg } \varphi = 0.2$

-Under the contact action $\vec{A}_{5/6}$, the rod **5** tends to move toward the left.

-We are at the strict equilibrium.

Data: $\|\vec{A}_{5/6}\| = 6000N$;

The links shall be considered as perfect except at points B and C

1- Study of the equilibrium of the rod **5**.

1.1 Fill the table bill of external forces.

I.2 Apply the fundamental principle of statics.

I.3 Determine graphically the mechanical actions at **B**, **C** and **D**.

2. Study of the equilibrium of the connecting rod **3**.

II- 1 write the condition of equilibrium and deduce the line support of the forces $\vec{I}_{4/3}$ and $\vec{J}_{2/3}$

3 –Study of the equilibrium of the lever **4**.

3- 1Fill the table of bill of external forces

3.2 Apply the fundamental principle of statics.

3.3 Determine graphically the mechanical actions at points **E** and **I**.

Take $\|\vec{D}_{5/4}\| = 7000N$.

4- Study of the equilibrium of the operating lever **2**.

4-1 - Fill the table bill of external forces.

4- 2- Apply the fundamental principle of statics.

4- 3- Determine graphically the mechanical actions at **K** and **L**. Take $\|\vec{J}_{3/2}\| = 5700N$.

QUESTION 2:/10 marks

THEME: GRADING CRUST BRAKER

A – Presentation.

The mechanism in figures 2 (page 4) represents a grading device placed at the back of a grader and used to break the crusts of soil during operations.

B - Description.

This device is made of:

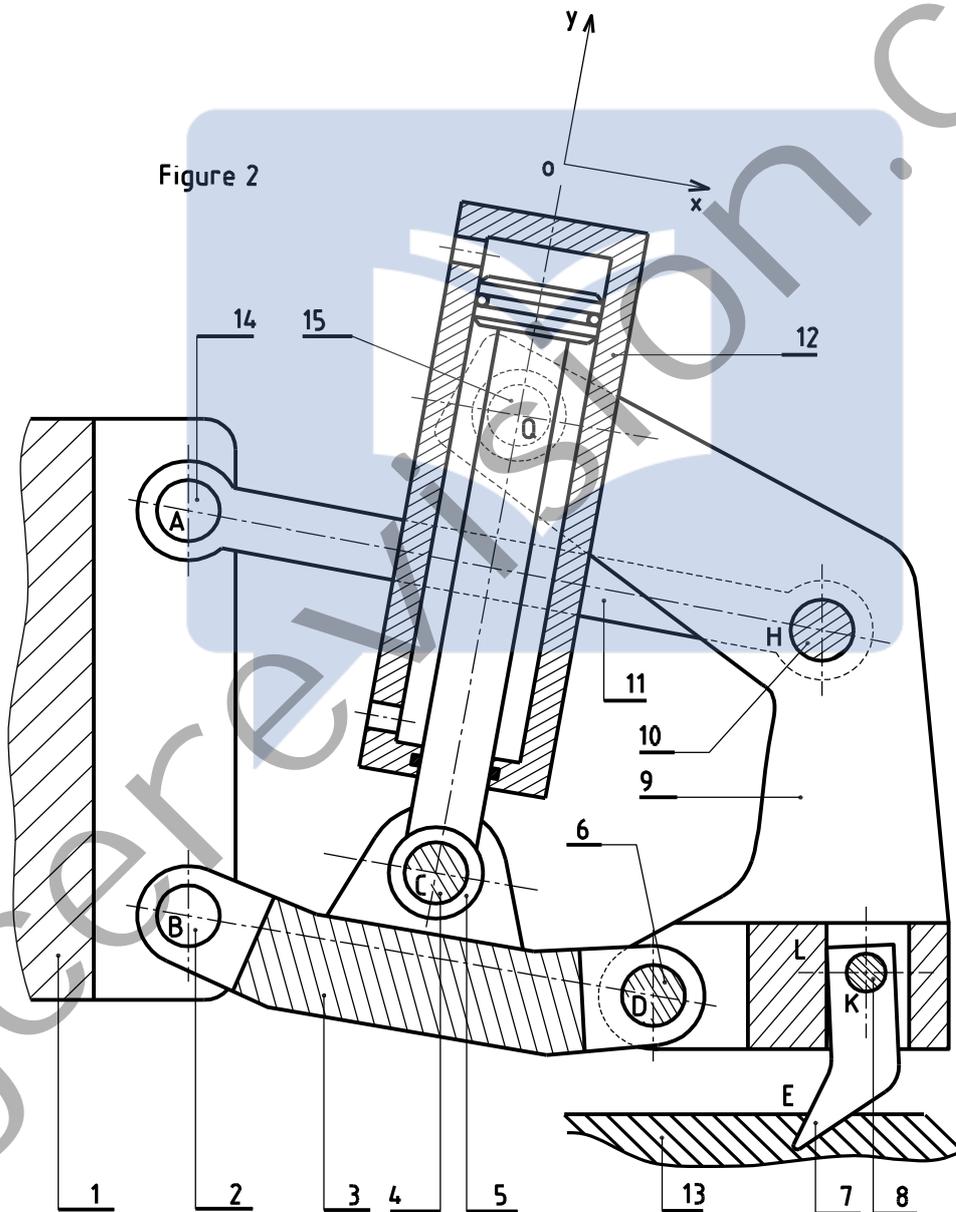
-A jack (**5+12**), articulated at C on the lever (**3**) with the help of the axle (**4**), at Q on the tool holder (**9**)with the help of the axle (**15**).

-The bend lever (**3**) articulated at B on the grader (**1**)with the help of the axle (**2**), at D on the tool holder (**9**)with the help of the axle (**6**).

- The tool (7) articulated on the tool holder (9) at K with the help of the axle (8) and rests on the same tool holder (9) at point L.
- A connecting rod (11) articulated at A on (1) with the help of the axle (14), at H on (9) with the help of the axle (10). The same connecting rod (11) permits to avoid the tipping of the assembly (3+5+9+12) around the point B linked to the grader (1).

Hypothesis :

- . The weight of all the pieces is neglected,
- . The study is done in the plane of symmetry of the mechanism (see page below),
- . All the mechanical actions are situated in that plane,
- . The axles (14), (2), (4), (6), (8), (10) and (15) are coincident with the respective points A, B, C, D, K, H and Q.



Aim: To determine the mechanical actions necessary for the functioning of the pieces 3, 5, 9 and 11.

1 –Study of the equilibrium of jack (5+12) and connecting rod 11.

1-1 - write the condition of equilibrium of jack (5+12) and the connecting rod 11.

1-2 - Deduce the support of the mechanical actions at C and Q, then at A and H.

2 – Study of the equilibrium of the system (3, 4, 5, 6, 7, 8, 9, 12, and 15).

Take. $\|\vec{E}_{13/7}\| = 800daN$.

2-1 –Determine point **I** of concurrency between $\vec{E}_{13/7}$ and $\vec{H}_{11/9}$

2- 2- write the equations of equilibrium of the system (3, 4, 5, 6, 7, 8, 9, 12, 15), deduce the line support of $\vec{B}_{1/3}$

2-3 Using graphic method, determine the magnitude of $\vec{B}_{1/3}$ and $\vec{H}_{11/9}$.

Scale of forces: 1mm \equiv 10daN

3– Study of the equilibrium of the bend lever 3.

Hypothesis and data: We consider that the weight of the bend lever 3 is applied at G.

Data: $\|\vec{B}_{1/3}\| = 500daN$. and $\|\vec{P}_3\| = 100daN$.

Scale: 1mm \equiv 10daN

3.1 – Using the polygon of force method and equilibrium polygon method determine the magnitudes of $\vec{C}_{5/3}$ and $\vec{D}_{9/3}$

3.2 –Determine the magnitudes of $\vec{C}_{5/3}$ and $\vec{D}_{9/3}$

SECTION B: KINEMATICS / marks

QUESTION 3:

- DESCRIPTION AND FUNCTIONING

The **figure 3** below represents a self-locking device used in a manufacturing workshop

Aim: To determine the locking velocity at point **A** during the operation.

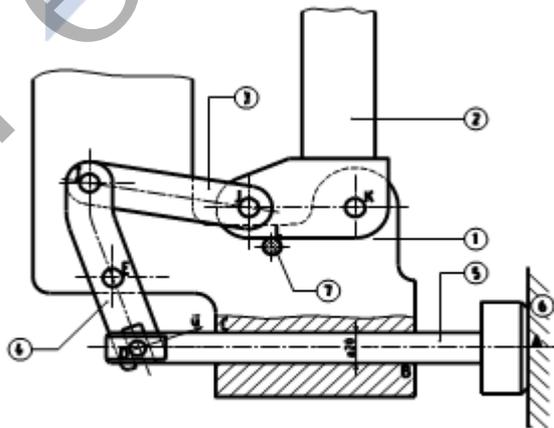


Figure 3

Hypotheses and data

- The system occupies the position in the figure 3 above.
- All the motions of the mobile parts are done in the plane of the sheet.
- The plate has a constant rotation speed.

Data: $\|\vec{V}_{J2/1}\| = 120\text{mm/s}$ Scale of velocities: 1mm = 4mm/s

- I-** Study of the motion of **2**.
- 1.1** Give the nature of the motion of the piece **2** compared with the body **1**
 - 1.2** Deduce the line support and represent the velocity $\vec{V}_{J2/1}$.
 - 1.3** Compare the velocities $\vec{V}_{J2/1}$ and $\vec{V}_{J3/1}$
- II-** Study of the motion of the arm {**3 + 4**}.
- II .1** Give the motion of the arm **3** compared with **1**
 - II .2** Give the nature of the motion of the lever **4** compared with **1**
 - II .3** Deduce the line support of the velocity $\vec{V}_{I4/1}$
 - II .4** Determine graphically the instantaneous centre of rotation of the arm **3** compared with **1**
 - II.5** Justify this equality $\vec{V}_{I4/1} = \vec{V}_{I3/1}$
- II.6** Using the triangle method, determine the velocity $\vec{V}_{I4/1}$

QUESTION 4:

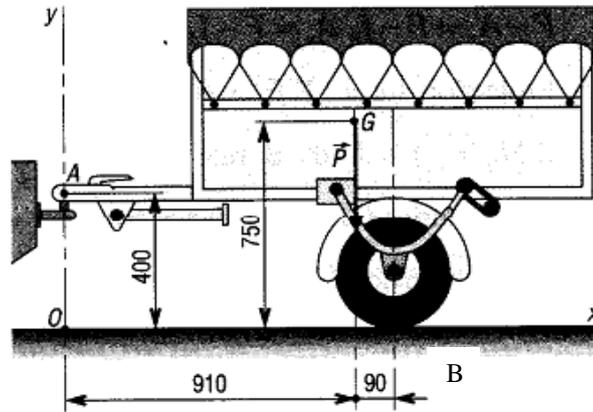
The duration of the starting of an engine is **2** seconds. The rotational velocity of the engine is **1500 rev/min**.

1. Determine the angular acceleration of the engine,
2. Determine the velocity of a point situated at $R = 50\text{mm}$ in $t = 1\text{s}$
3. Determine the components of the acceleration γ_T and γ_N .
4. Deduce the linear acceleration γ knowing that $\gamma^2 = \gamma_T^2 + \gamma_N^2$

SECTION C: DYNAMICS

QUESTION 5: /10 marks

A trailer of weight $P = 3000\text{N}$ applied at G being its center of gravity is drawn by the tractor in A (swivel connection) as shown on the figure below. The set (car + trailer) leaves the rest position and attain a constant speed of 72km/h in 100m with a uniformly rectilinear varied motion. Take $g = 10\text{ m/s}^2$



1 -write equations of fundamental principle of dynamics

2- Determine the acceleration of the movement.

3- Determine the exerted force at point A (between the car and tractor) and at point B (between the wheel of the tractor and the ground).

SECTION D: STRENGTH OF MATERIALS

QUESTION 6: /10 Marks

A panel of triangular shape (isosceles triangle with base 1050mm and height 900mm ; centre of gravity B), supports a load \vec{F} which is resultant of the mechanical actions exerted by the wind. This panel is embedded on the beam AB in the shape of the tube with the external diameter $D = 80\text{ mm}$ and internal diameter $d = 74\text{mm}$.

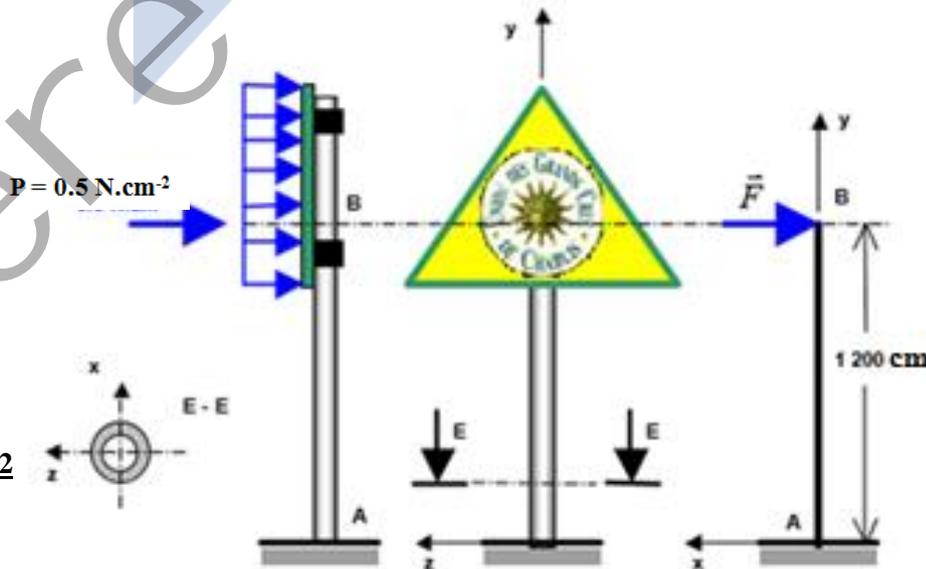


Figure 2

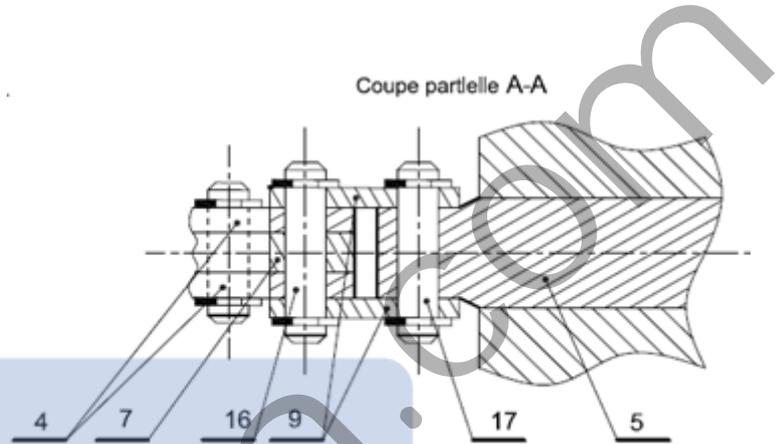
- 1- Determine the force \vec{F} and the embedded effort \vec{R}_A at **A**.
- 2- Determine the shearing efforts and plot the diagram of the shearing efforts. Take $\|\vec{F}\| = \|\vec{R}_A\| = 2400\text{N}$
- 3- Determine the bending moment and plot the diagram of the bending moment.
- 4- Deduce the maximum bending moment in the beam **AB**.

QUESTION 7: /10 marks

Aim: To verify the resistance of the pin **17**.

Hypotheses and data :

- Pin 17 is cylindrical with diameter $D = 12\text{mm}$.
- $\|\vec{T}_{5/17}\| = 8000\text{ N}$
- Coefficient of security $s = 5$
- $R_{eg} = 100\text{ daN/mm}^2$



1—Study of pin 17:

- 1-1-Give the nature of the stress in this pin
- 1-2-Identify the sheared section (s), in the above figure
- 1-3-Calculate the stress in the pin **17**:
- 1-4- Verify the resistance condition of the pin

SECTION A: STATICS

QUESTION 1:

I - Equilibrium of the rod 5:

I.1 Table bill of external forces:

Forces	P.A.	Line of action	Sense	Magnitude

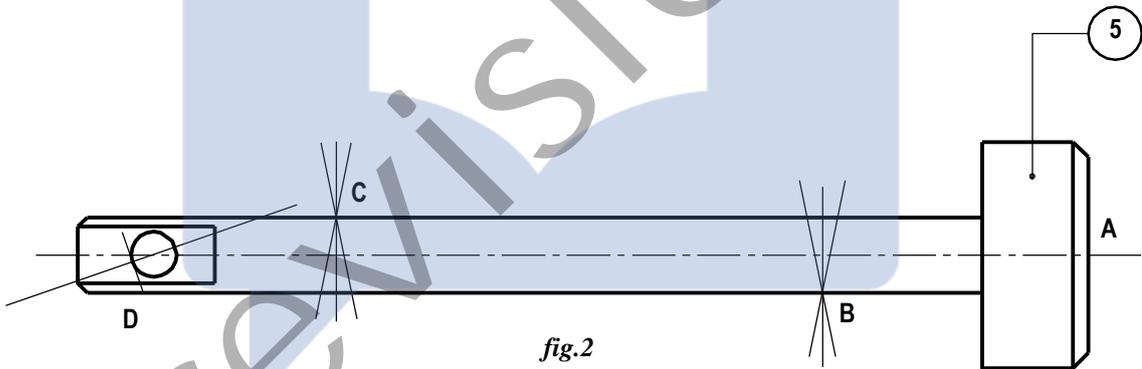
I.2 Fundamental principle of statics:

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I.3 Graphic determination of the mechanical actions at B, C and D:



$$\| \vec{B}_{1/5} \| = \dots \dots \dots \| \vec{D}_{4/5} \| = \dots \dots \dots \| \vec{C}_{1/5} \| = \dots \dots \dots$$

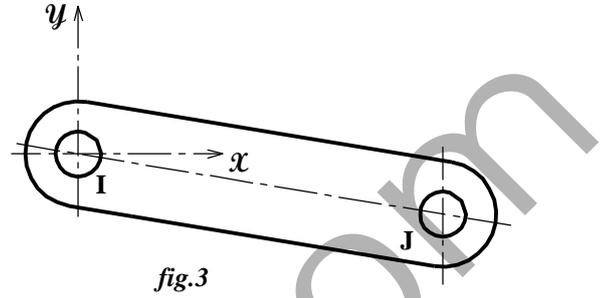
ANSWER SHEETS

II- Equilibrium of the connecting rod 3:

II- 1 Equilibrium equations and deduction of the line support of forces $\vec{I}_{4/3}$ and $\vec{J}_{2/3}$

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Line support :



III –Study of the equilibrium of lever 4:

III- 1 Table of bill of external forces:

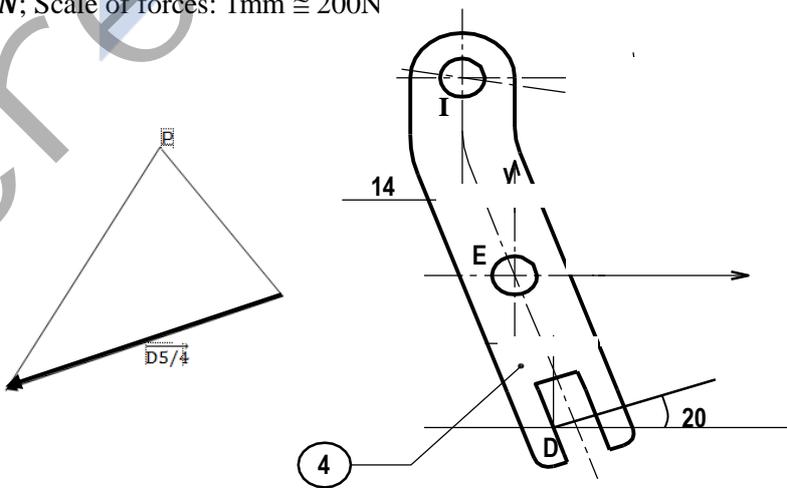
Force	P.A.	Line of action.	Sense	Magnitude

III.2 Apply the fundamental principle of statics.

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III.3 Determine graphically the mechanical actions at **E** and **I**.

Take $\|\vec{D}_{5/4}\| = 7000N$; Scale of forces: 1mm \cong 200N



$\|\vec{E}_{1/4}\| = \dots \dots \dots \|\vec{I}_{3/4}\| = \dots \dots \dots$

11
ANSWER SHEETS

IV - Study of the equilibrium of the operating lever 2.

IV-1 - Fill the table bill of external forces.

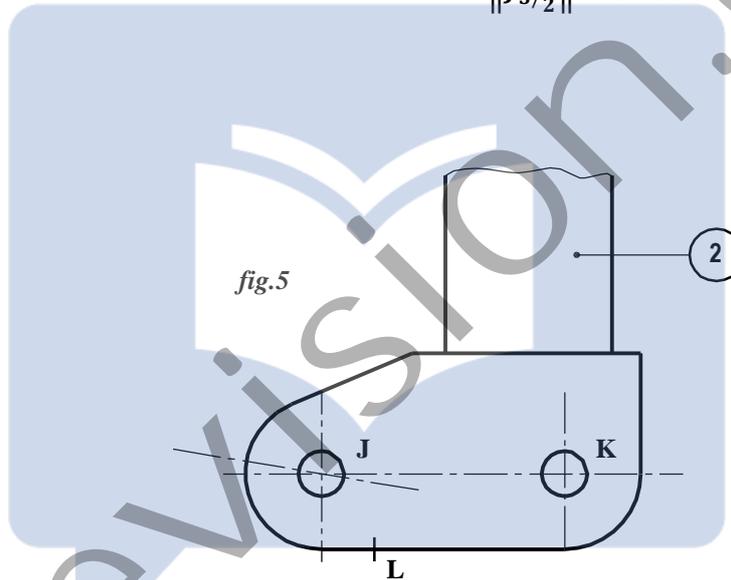
Force	P.A.	Line of action.	Sense	Magnitude

IV- 2- Apply the fundamental principle of statics.

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IV- 3 - Determine graphically the mechanical actions at **K** and **L**. Take $\|\vec{J}_{3/2}\| = 5700N$

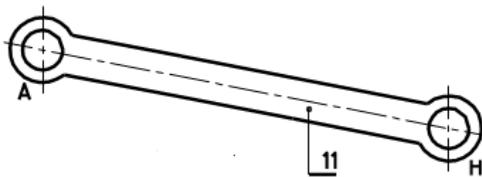


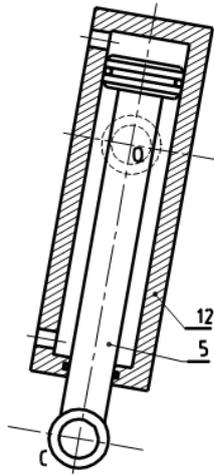
QUESTION 2:

1 - Study of the equilibrium of the jack (5+12) and the connecting rod **11**.

1-1 - write the condition of equilibrium of jack (5+12) and the connecting rod **11**.

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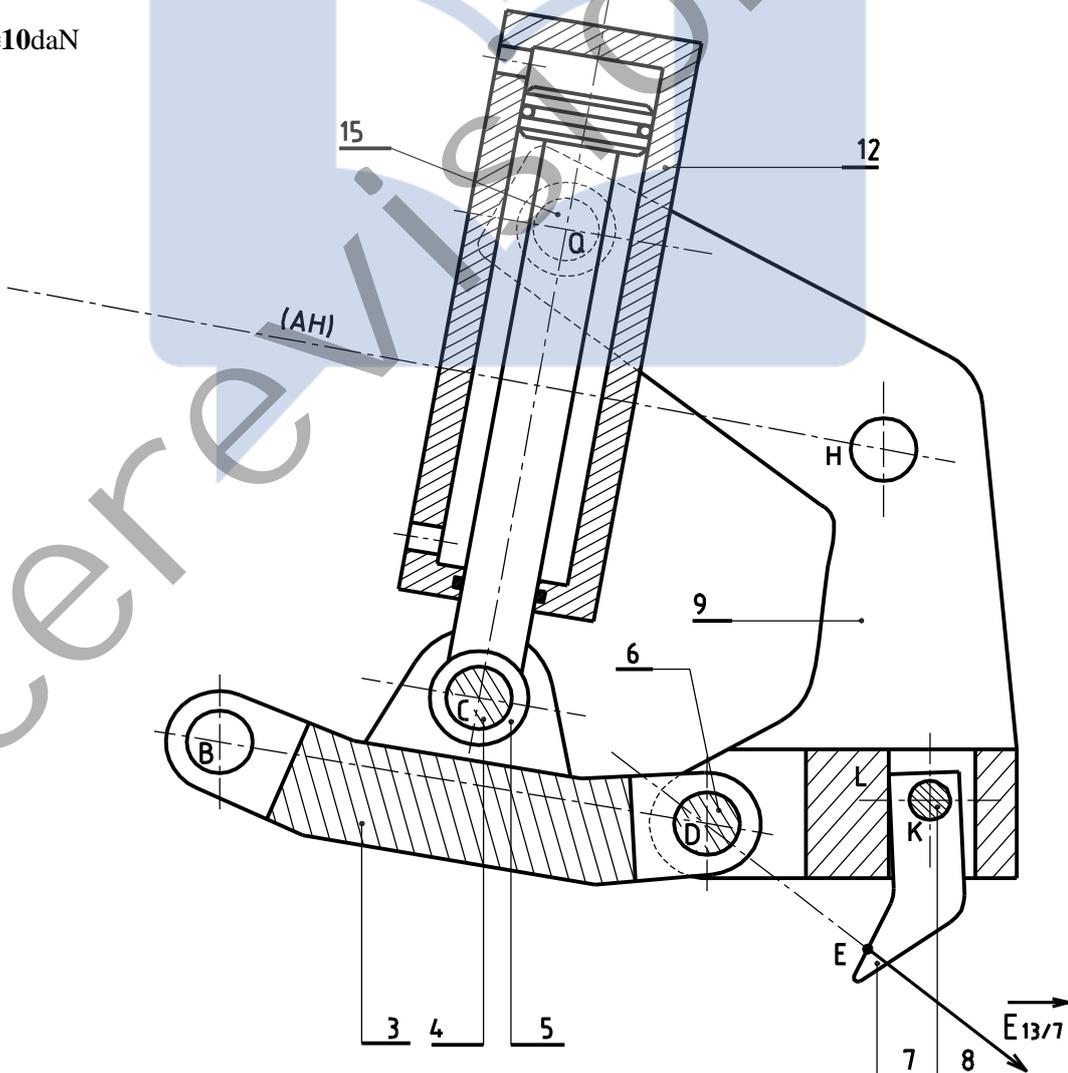


1-2 Deduce the line support of the mechanical actions at C and Q, then at A and H.

2 – Study of the equilibrium of the system (3,4,5,6, 7, 8, 9, 12, and 15).

Take. $\|\vec{E}_{13/7}\| = 800 \text{ daN}$.

-Scale: 1mm \equiv 10daN



ANSWER SHEETS

3.1 Determination of the magnitudes of $\vec{C}_{5/3}$ and $\vec{D}_{9/3}$:

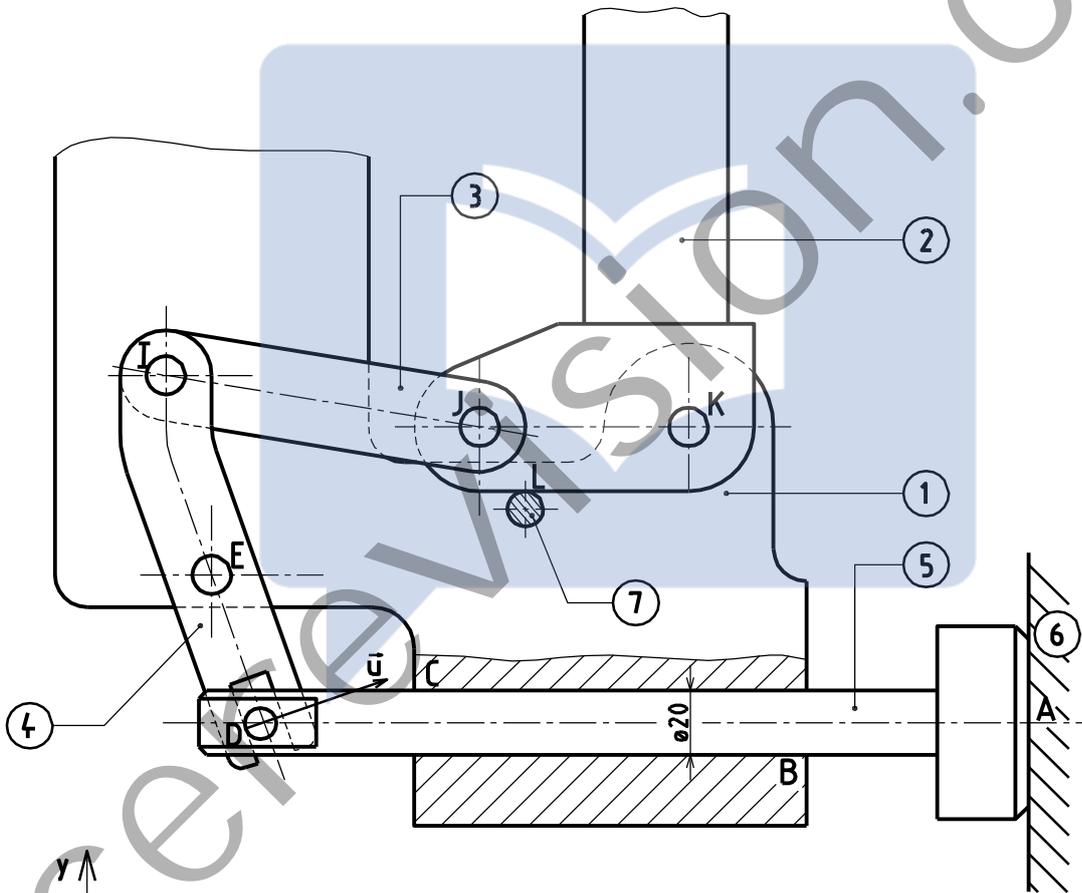
$$\|\vec{C}_{5/3}\| = \underline{\hspace{2cm}} \quad \|\vec{D}_{9/3}\| = \underline{\hspace{2cm}}$$

SECTION B: KINEMATICS

QUESTION 3:

Data: $\|\vec{V}_{J2/1}\| = 120\text{mm/s}$

Scale of velocities: $1\text{mm} \approx 4\text{mm/s}$



Scale: 1:2

Figure 7

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ANSWER SHEETS

III- Study of the motion of **2**.

1.4 Nature of the motion of the piece **2** compared with the body **1**.

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1.5 Deduce the line support and represent the velocity $\vec{V}_{2/1}$.

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1.6 Comparison of the velocities $\vec{V}_{2/1}$ and $\vec{V}_{3/1}$

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II- Study of the motion of the arm **3** and **4**:

II .1 Motion of the arm **3** compared with the **1**:

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II .2 Nature of the motion of the lever **4** compared with **1**:

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II .3 Support of the velocity $\vec{V}_{I4/1}$:

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II .4 Graphic determination of the instantaneous centre of rotation of the arm **3** compared with **1**:

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II.5 Justification of the equality $\vec{V}_{I4/1} = \vec{V}_{I3/1}$:

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II.6 Determination of the velocity $\vec{V}_{I4/1}$:

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QUESTION 4:

The duration of the starting of an engine is 2 seconds; the rotational velocity of the engine is 1500 rev/min.

1. Determination of the angular acceleration of the engine:

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ANSWER SHEETS

2. Determination of the velocity of a point situated at $R= 50\text{mm}$ in $t=1\text{s}$

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3. Determine the components of the acceleration γ_T and γ_N .

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4. Deduce the linear acceleration γ knowing that $\gamma^2 = \gamma_T + \gamma_N$

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SECTION C: DYNAMICS

QUESTION 5:

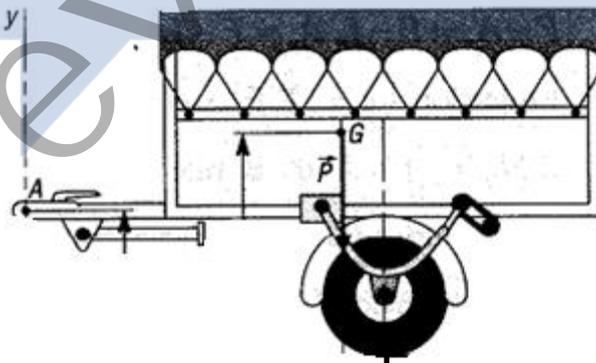
1 -State the equation of fundamental principle of dynamics

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2- Determination of the acceleration of the movement:

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3- Determination of the exerted force at points A and B:



B

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SECTION D: STRENGTH OF MATERIALS

QUESTION 6:

1- Determination of force \vec{F} and embedded effort \vec{R}_A at point A of the beam:

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2- Determination of the shearing efforts and plotting of the diagram of the shearing efforts.

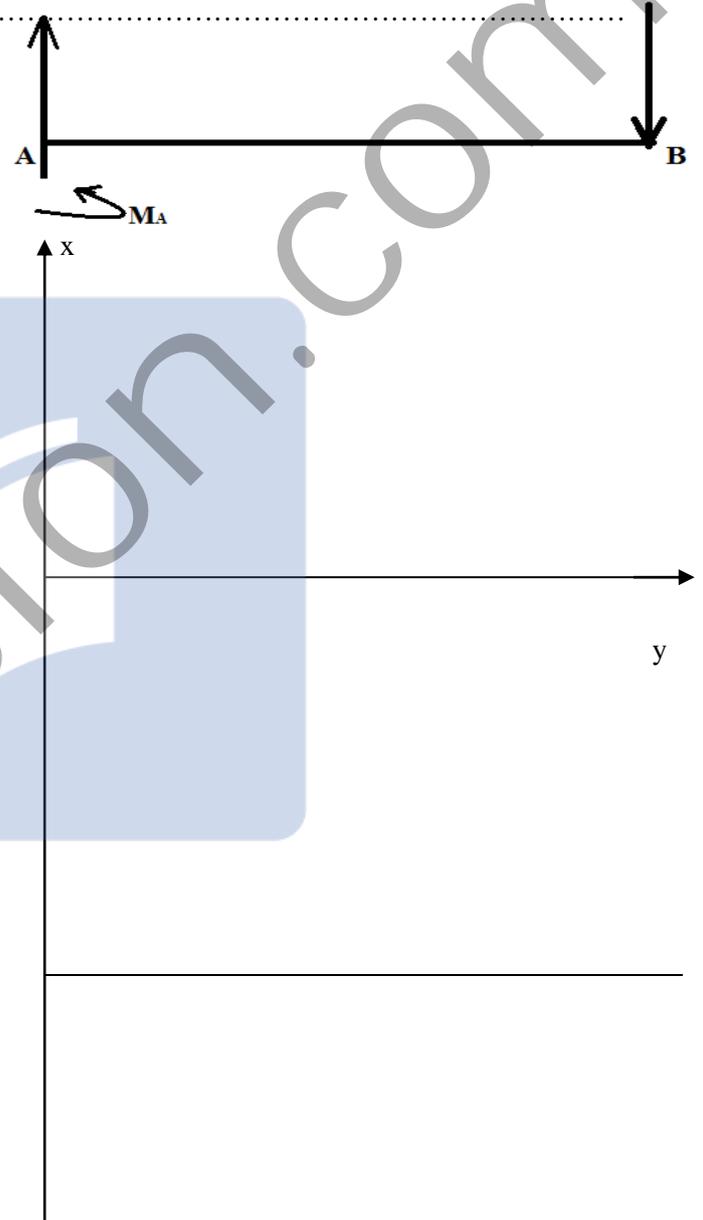
Take $\|\vec{F}\| = \|\vec{R}_A\| = 2400\text{N}$

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3- Determination of the bending moment and plotting of the diagram of the bending moments.

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4. $M_{f_{zmax}} =$



ANSWER SHEETS

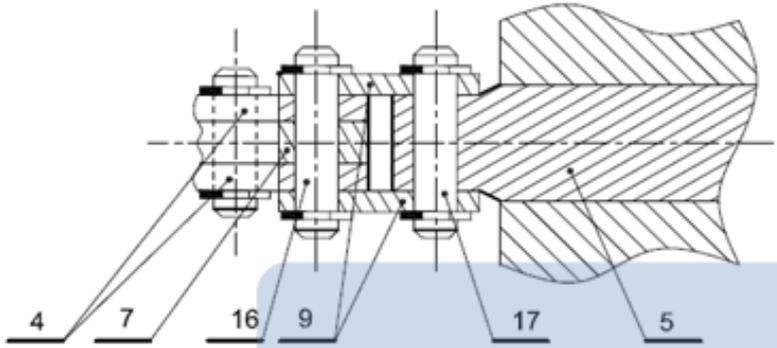
QUESTION7:

1—Study of the articulation pin17:

1-1-Nature of the stress in the pin:

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1-2-Identification of sheared section (s) in the figure below:



1-3-Calculation of the stress in the pin 17:

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1-4- Verification of the resistance condition of the pin:

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