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THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
DIPLOMA IN TECHNOLOGY – LEVEL 04

FINAL EXAMINATION 2006/2007

MEX4231/MED2202 – ELEMENTARY MACHINE DESIGN – PAPER II

DATE: 23 April 2007
TIME: 0930 hours to 1330 hours
DURATION: Four hours

READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THE QUESTION PAPER

This question paper has only one question.

Spent 10 to 15 minutes to read and understand the question carefully.

Wherever appropriate, use catalogues, tables, data sheets and charts provided to you at the examination hall.

At the end of the examination, hand over all such literature to the supervisors or an invigilator. Do not write anything on these literatures.

Any missing data may be sensibly and reasonably assumed, provided that such data are clearly stated with reasons to accept them.

Any ideas/opinions presented in the form of neatly drawn sketches are encouraged.

Any results from calculations should be presented with their correct units, unless they are dimensionless. All such answers should be underlined.

It is important the candidates answer all parts of the question listed in that given order in the question.

Question

The figure shows the front elevation and the plan view of a simplified design of a motorized scissor jack, which is proposed for a workshop. This jack is used to raise heavy metal castings from the floor of the workshop to the level of a machine bed and lower the same castings from the level of machine bed back to the floor. The maximum lifting capacity of the jack is **30 kN**.

The motor **A** transmits power to the jack through a belt drive system and a speed reduction gearbox **E.** The motor carries driver pulley **B,** and the power input shaft of the gearbox carries driven pulley **D**. The power output shaft of the gearbox is coupled to the power screw **G** by a double universal joint **H**. This joint allows total **30^0** misalignment of the screw with respect to power output shaft of the gearbox. The power screw drives two identical nuts **K** and the nuts are linked to the platform **J** and the base **M** as shown in the figure. The base, platform and the two nuts are connected by eight identical metal links **L**. The base is mounted on four rollers guided by rails of U-shape, so that these guides confine the movement of the base parallel to the axis of the screw for a limited distance. The base is located **120 mm** below the level of the workshop floor. The jack starts its vertical motion from a position, where the top surface of the platform aligns with the floor level. At this position each link makes an angle of **11^0** to the horizontal. When the platform comes into rest at the upper position (ie. the level of the machine bed) this angle is **80^0.** In this arrangement the platform never moves below the floor level.

When the motor is switched on, the platform carrying the load of castings accelerates vertically through a height of **150 mm** for **3 seconds** and then maintains a uniform velocity through next **300 mm** for **4 seconds**. Finally it decelerates through **50 mm** during **3 seconds** and reaches the level of the machine bed. The reverse wheel in the gear train is manually engaged for downward motion of the platform. The forward and reverse motions are monitored and controlled by a set of sensors and actuators connected in the form of electrical/electronic circuit.

In order to check the feasibility of the design, answer the following questions.

1. Calculate the power requirement, and hence select a suitable motor. A motor with 900-1200 rpm from the provided motor catalogue is recommended for this system.

   [10 marks]

2. Design the power screw and one of the nuts by specifying the pitch and helix angle of the thread, screw diameter, minimum height and outer diameter of the nut, and length of the power screw. [12 marks]

3. If the belt drive system is V-Belt type, approximated center distance is 500 mm and recommended speed ratio of the belt is 1.5, decide the parameters of the belt and the pulleys. [12 marks]

4. Design gearwheels 2 and 6 completely from the standpoint of their strength, dynamic force and wear. [18 marks]

5. Decide the gear train and diameters of the wheels with single-speed reducer for forward direction and reverse direction. Gearwheels **2** and **3** make a compound wheel, which can be mounted on a splined shaft. Gear wheel **4** is an idler wheel, which meshes with wheels **3** and **5** to provide the reverse motion. Downward velocity of the platform is 1.5 times the upward velocity at the steady conditions. You may assume a suitable ratio between gear wheel **3** and **4**. [10 marks]

6. Determine the dimensions of a link that connect a nut and the platform taking safety factors as 2 and breadth to width ratio is 4. [6 marks]

7. Design the power output shaft for its strength. If the gear wheel ***6*** is keyed to the shaft, propose the key dimensions. [10 marks]

8. Propose a pair of suitable bearings, which support the power output shaft.

   [10 marks]

9. Suggest at least two improvements to the proposed design depending on the features given in the drawing. [12 marks]

Following information are provided

- For simplicity, assume vertical maximum velocity of the platform equals twice as the linear velocity of a nut at any moment.

- Assume following transmission efficiencies.

Spur Gears	94%
Belt Drive	90%
Power screw	95%

- For all shafts, power screw and the nut following information are given.

  Power screw has square threads with double start and maintains self-locking condition.

  Material and their mechanical properties

	Material	Ultimate Tensile/Compressive Strength (Mpa)	Shear Stress (MPa)	Factor of Safety
Screw	Steel	800	340	4
Nut	Phosphor Bronze	552	260	5

Bearing stress for steel and Phosphor Bronze combination = 0.5 x S_{ut}

When there are no key ways for power transmission shafts whose steels have definite specifications, the design stresses are as follows.

Design value of the shear stress = 0.3 x yield stress in tension
= 0.18 x ultimate stress in tension, or
whichever smaller.

Design value of the normal stress = 0.36 x ultimate stress in tension, or
= 0.6 x yield stress in tension
whichever smaller.

For steel Young's Modulus = 200 GPa

Select one of the following steels for the shaft materials

AISI Number	Yield strength (MN/m²)	Ultimate tensile Strength MN/m²
1010	303	366
1018	373	442
1045	532	626
4340	683	766

If key ways are present then above values are to be reduced by 25%

Design of shafts should be made according to the ASME code equation.

A shaft having a diameter *d* when subjected to combined bending and torsion, the equivalent bending and torsional stresses at any point on the shaft are,

$$\sigma_{eq} = \frac{16}{\pi d^3}\left[K_b M + \sqrt{(K_b M)^2 + (K_t T)^2}\right]$$

$$\text{and} \quad \tau_{eq} = \frac{16}{\pi d^3}\left[(K_b M)^2 + (K_t T)^2\right]^{1/2}$$

Coefficient of friction between screws and nut is 0.05 and allowable tensile and shear stresses of the threaded shaft being 120 MN/m² and 70 MN/m² respectively.

- Link mechanism

  Each link is made of steel with rectangular cross section and having following mechanical properties.

  Shear stress (Yield) - 40 Mpa

  Direct stress (Tensile of Compressive) – 75 Mpa

  Rankine formula for buckling of struts is:

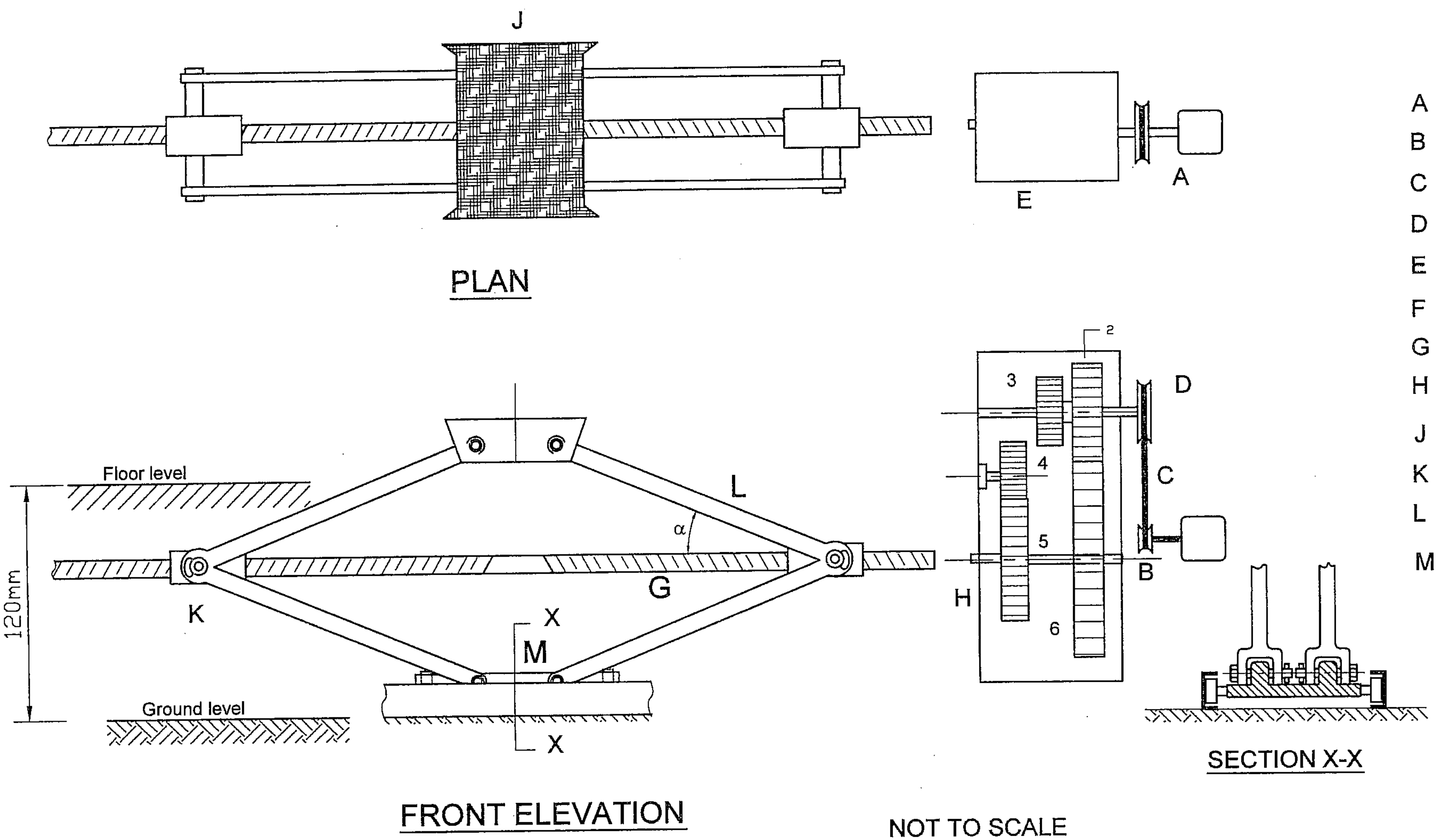
$$F = \frac{\sigma A}{1 + a\left(\frac{L}{K}\right)^2}$$, where F is the buckling load when σ is the buckling stress, A area of cross section, *a* (constant) = *1/7,500* for steel and in usual notations

$$K = \sqrt{\frac{I}{A}}$$

- Neglect energy loss due to friction between rollers of the base and the guides of the floor.

  - **Use the given Catalogues, Charts and tables to extract information required whenever necessary.**

SCISSOR JACK



NOT TO SCALE

LEGEND

A MOTOR
B DRIVING PULLEY
C BELT/S
D DRIVEN PULLEY
E SPEED REDUCER
F BEARINGS
G POWER SCREW
H COUPLING
J PLATFORM
K NUT
L LINK
M BASE