UNIVERSITY OF LONDON

B.Sc. (ENGINEERING) EXAMINATION 1963

PART I

for Internal and External Students

(3) MECHANICS OF MACHINES

Wednesday 19 June: 2.30 to 5.30

Answer FIVE questions.

It may be assumed that the gravitational acceleration is equal to the standard acceleration.

1. Four rigid links OA, AB, BC and CO are pin-jointed together at O, A, B and C forming a four bar chain as shown in figure 1. Link OC is fixed and link OA rotates with a uniform angular velocity of 210 rev/min. The lengths of the links are as follows: OC 6 in; OA $1\frac{1}{2}$ in; AB $11\frac{1}{2}$ in; BC 8 in.

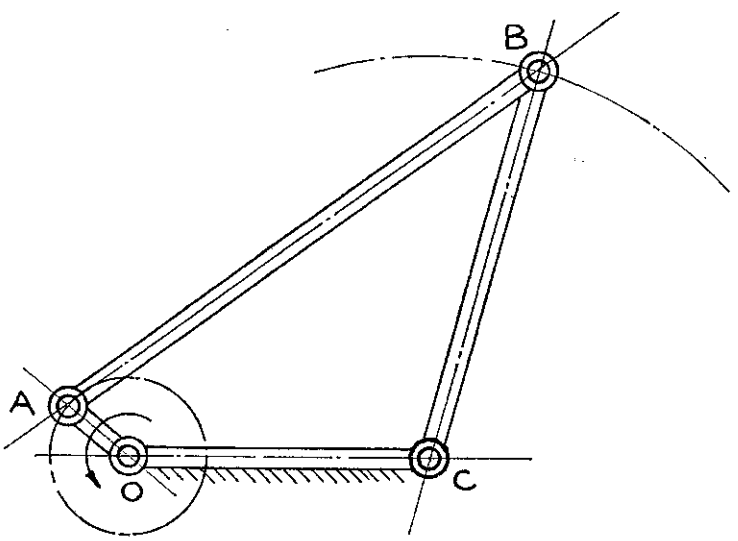

Figure 1

Find (*a*) the included angle between the extreme positions of the oscillating link BC, and
(*b*) the angular acceleration of the link BC at the extreme positions of its travel, stating the direction in each case.

2. Figure 2 shows part of a printing machine in which a light flat belt passes around the four pulleys A, B, C and D. Pulley A is driven anticlockwise at 300 rev/min by an electric motor while pulleys B and C operate devices which require constant torques of 30 and 52 lbf in respectively. Jockey pulley D runs freely in its bearings at E and absorbs no power. The diameters of the pulleys are as follows: A 3 in; B 6 in; C 4 in; D 3 in.

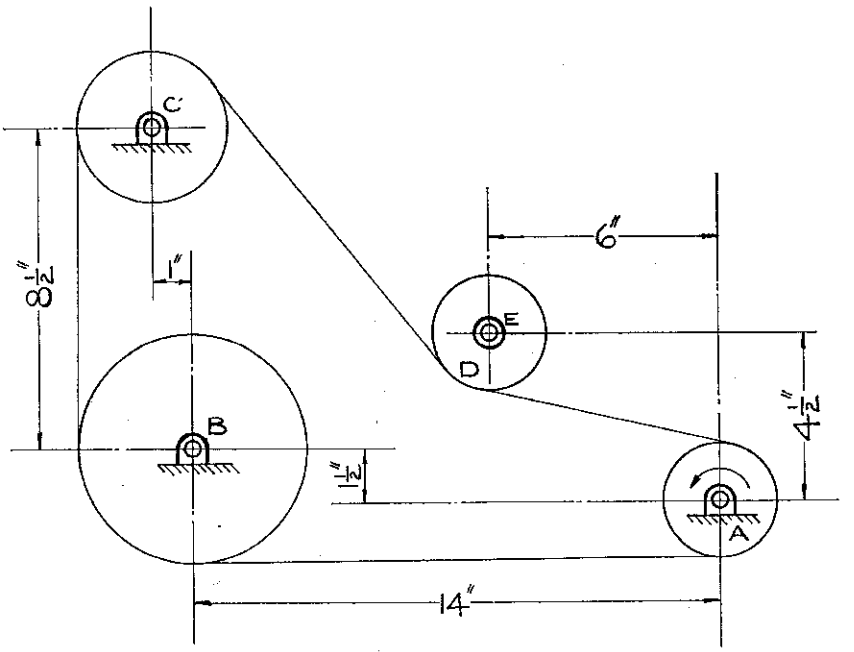

Figure 2

(a) Assuming that there is no slip between the belt and the pulleys find the power of the motor.

(b) Assuming that slip is about to take place between the belt and pulley A only, the coefficient of friction being 0·2, find the belt tension in each section of the drive.

3. The lifting device shown in figure 3 consists of a platform P, a base Q and the crossed links AC and BD which are pin-jointed together at G. Link AC is pin-jointed to the platform at A and to a block at C; this block slides in a slot in the base. Similarly, link BD is pin-jointed to the base at D and to a block at B; this block slides in a slot in the platform. The platform is raised by pumping oil into the cylinder which is hinged to the base at F, the piston rod transmitting the thrust to pin E on link BD.
When the mechanism is in the given configuration the platform supports two loads, each of $\frac{1}{2}$ tonf, as shown in the figure. The effect of friction and the weight of the lifting device itself may be neglected.

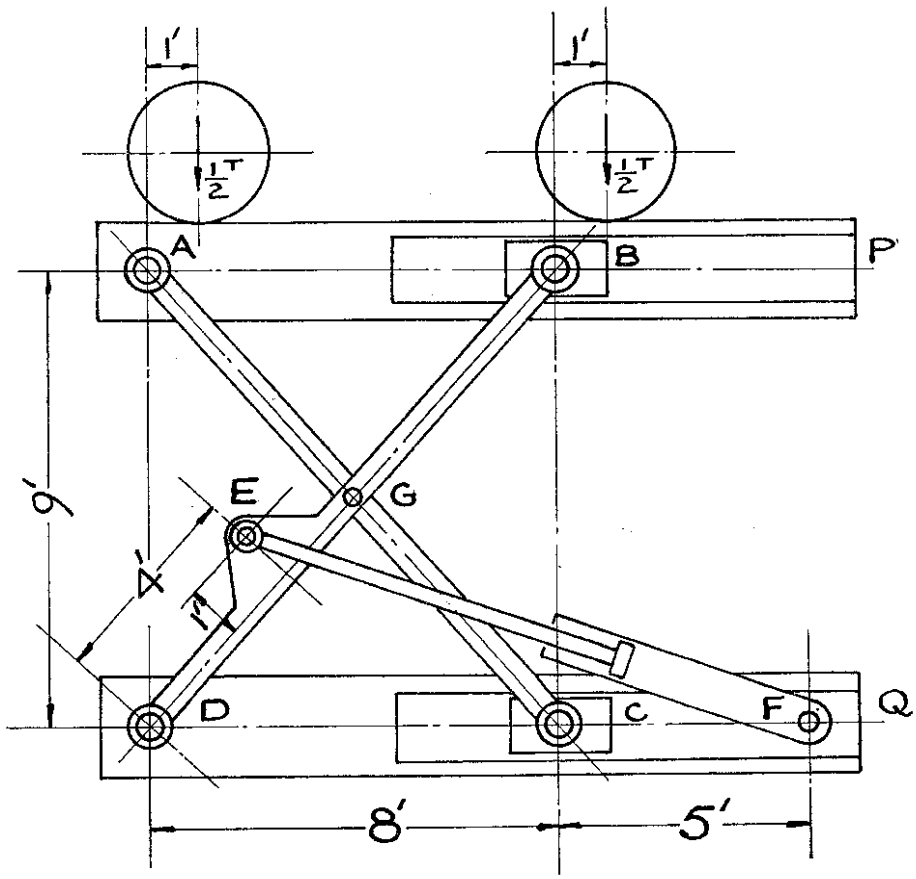

Figure 3

(*a*) Find the forces acting on the link BD at B, at D and at E, and the forces acting on the link AC at A and at C, indicating directions as well as magnitudes.

(*b*) Show that the thrust exerted by the piston rod is independent of the positions of the two $\frac{1}{2}$ tonf loads on the platform.

4. Figure 4 shows an epicyclic gear train which is driven by two electric motors. The gear train consists of an arm A keyed to the shaft of motor M and carrying a spindle S upon which the compound planet BE revolves freely. B meshes with a wheel C which is keyed to the output shaft X and E meshes with the wheel D which is integral with wheel F. The compound wheel DF revolves freely on shaft X and F meshes with wheel G which is keyed to the shaft of motor N. The numbers of teeth, all of which are of the same pitch, are as follows:

D 40; E 40; F 45; G 30.

When viewed in the direction of arrow Y motor M always rotates clockwise and motor N always rotates anticlockwise.

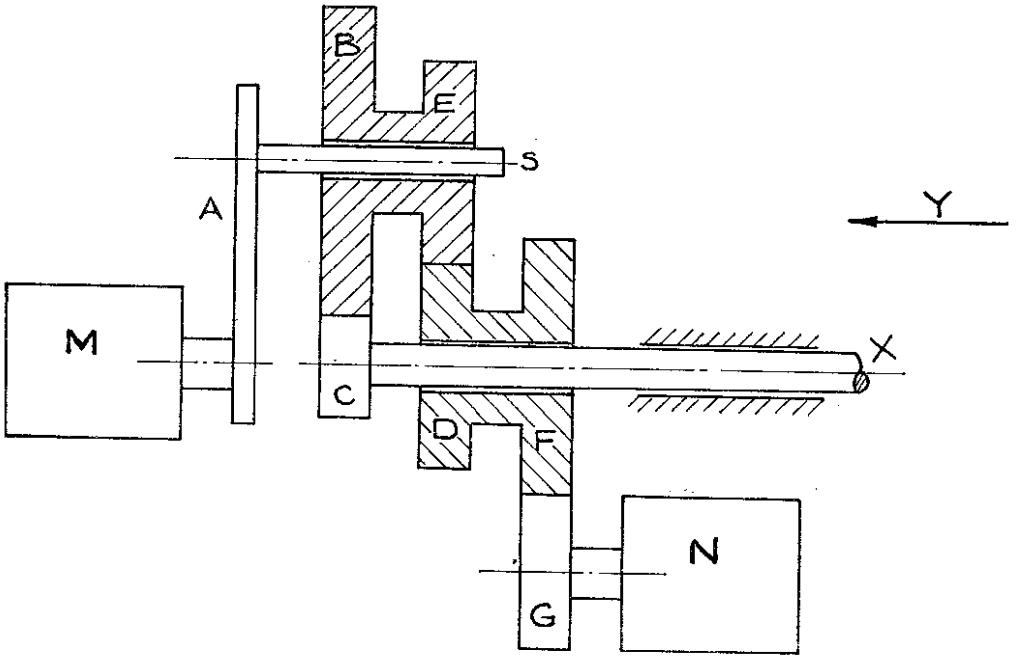

Figure 4

(*a*) Determine the numbers of teeth on wheels B and C if the output shaft X is to be stationary when both motors run at 960 rev/min.

(*b*) With these numbers of teeth, find the speed range of shaft X if motor M continues to run at 960 rev/min while the speed of motor N is varied from 324 to 2874 rev/min.

✓ **5.** A uniform rectangular plate of mass 96 lb is free to rotate in a vertical plane about a horizontal axis through O as shown in figure 5. A body B of mass 16 lb falls freely through a height of 1 ft and strikes the top edge of the plate at a distance of $1\frac{1}{2}$ ft from O. The body B adheres to the plate with its centre of mass coinciding with the top edge of the plate.

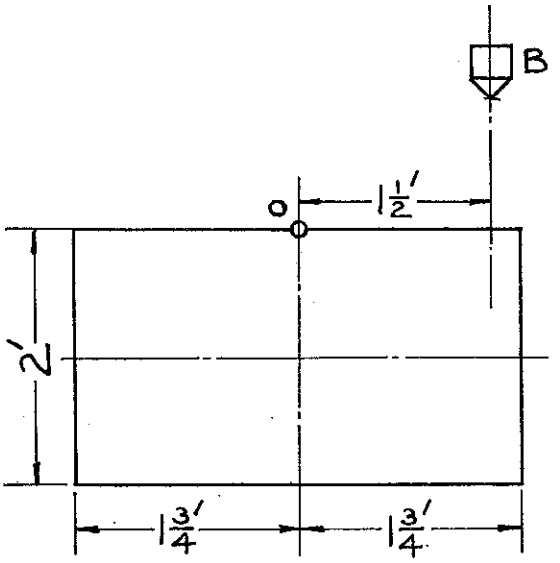

Figure 5

By working from first principles find
(*a*) the angular velocity of the plate immediately after impact,
(*b*) the angle through which the plate tilts before coming to rest for the first time after the impact.

6. A differential lifting machine consists of a wheel of 32 in effective diameter fixed to an axle of 6 in effective diameter, rotating in bearings of negligible friction. The wheel and axle, together with other rotating parts attached to them, have mass 800 lb and radius of gyration 6 in. Body A, of mass 200 lb, hangs by a light rope wrapped round the wheel and body B, of mass 1000 lb, hangs by a light rope wrapped in the opposite direction round the axle, so that as A rises, B falls.
A is to be lifted from rest with uniform acceleration through a height of 10 feet in 3 seconds. Find the driving torque to be applied to the wheel and axle and the maximum power to be supplied.
If, when A has reached this height the power supply is suddenly cut off and a braking torque of 200 lbf ft simultaneously applied to the wheel and axle, find the further height through which A rises before coming to rest. It may be assumed that both ropes remain taut throughout.

16
49
48
113

7. A screw press consists of a fixed frame, with a rotating screw of outside diameter 2 in. The screw thread is square in form, single start, with a lead of $\frac{3}{4}$ in. The screw can be rotated by a bar, of effective length 15 in, projecting at right angles to the axis of the screw. At the lower end of the screw and rotating with it is a collar which bears on a non-rotating pad through which the axial force is transmitted to the work being pressed. The mean diameter of the rubbing surface between the collar and the pad is $3\frac{1}{4}$ in. The coefficient of friction at all rubbing surfaces is 0.07.
Given that the axial force on the work is 1400 lbf, find the tangential force required at the end of the bar (*a*) to tighten the screw, (*b*) to slacken it.

8. A machine is driven directly, at a mean speed of 270 rev/min, by a motor which supplies a constant torque. The resisting torque offered by the machine is given by $T = 1200 \sin^2\theta$ lbf ft, where θ is the angle of rotation of the common shaft, measured from some datum.
   (*a*) Find the mean power developed by the motor.
   (*b*) The speed of the shaft is to be kept within $\pm 2\%$ of the mean speed by means of a cast iron flywheel fitted to it. Calculate the moment of inertia of the flywheel, clearly stating the units employed. Suggest an approximate cross section for the rim, assuming that the rim provides 90% of the total moment of inertia and that the external diameter is not to exceed 3 ft. The density of cast iron is 0·26 lb/in^3.

9. A horizontal shaft DABEC carries eccentric rotors at A, B and C and is supported in bearings at D and E. The relevant distances are DA 20 in; AB 24 in; BE 12 in; EC 16 in. The masses and eccentricities of the rotors are 28 lb, 3 in at A; 18 lb, $2\frac{1}{2}$ in at B; 10 lb, 3 in at C. The rotors are so arranged that when the shaft rotates there is no out-of-balance force on bearing E.
Find the angles, in the end view of the shaft, between the lines joining the centre of the shaft and the centre of mass of each rotor.
With the rotors thus arranged, find the out-of-balance force on bearing D when the shaft rotates at 300 rev/min.
All diagrams must be clearly labelled.

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