BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

ME/MF F 221: Mechanisms and Machines

SECOND SEMESTER 2021-2022

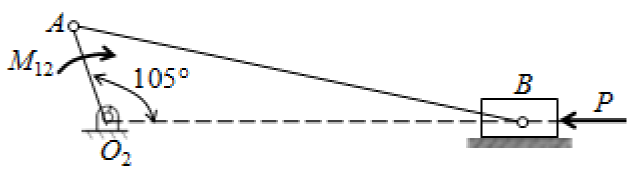
COMPREHENSIVE EXAMINATION

PART-A (CLOSED BOOK)

10th May, 2022 | Max. Marks: 40 (Weightage 20%) | Duration: 90 minutes

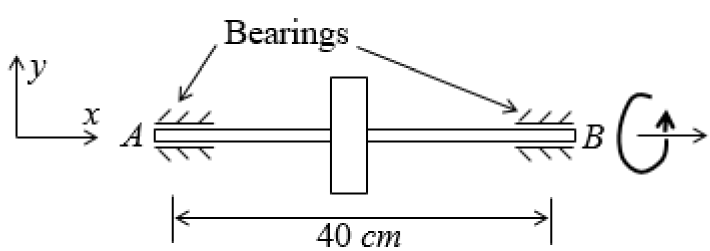
1. The exam is divided into Part-A (Closed-book type) and Part-B (Open-book type). Part-A and Part-B are to be answered in separate answer sheets.
2. Part A and Part-B both have equal weightage and equal time.
3. You have 90 minutes to answer PART-A. Early or late submission of Part-A is allowed.

Q1. Refer **FigQ1**, using the principle of virtual work, derive the expression for P. What force P (kN) is required to maintain static equilibrium if moment M_{12} = 500 N-m (CW) is applied to the crank? (**Given**: link O_2A = 60 mm, AB = 250 mm) **[8M]**



FigQ1

Q2. A uniform disc (diameter d = 20 cm, m = 25 kg) is mounted centrally on a horizontal shaft as shown in **FigQ2**, which runs in bearings (A and B) which are 40 cm apart. The disc spins, in the direction shown in the **FigQ2**, with a uniform speed of 2000 rpm. The shaft precesses with a uniform velocity of 45 rpm in the horizontal plane (i.e. xy plane) in the anti-clockwise direction when looking from top. Determine the total reactions (static + dynamic) at each bearing. Show the static and dynamic reactions with direction on both the bearings. **[10M]**



FigQ2

Q3. A machine punching 38 mm holes in 32 mm thick plate requires 7 N-m of energy per mm^2 of sheared area, and punches 360 holes per hour. Calculate the power of the motor required. The mean speed of the flywheel is 25 meters per second. The punch has a stroke of 100 mm.

Find the mass of the flywheel required, if the total fluctuation of speed is not to exceed 3% of the mean speed. Assume that the motor supplies energy to the machine at uniform rate. **[10M]**

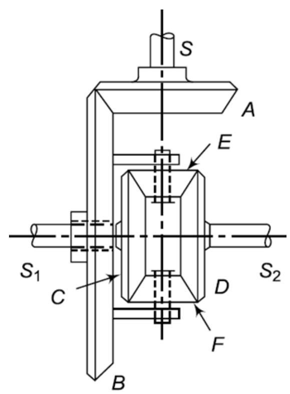
Q4. A vehicle, with the differential shown in **FigQ4**, takes a turn to the left so that the right wheel becomes the outer wheel. The speed of the vehicle is 54 km per hour, and the radius of the turn is 30 m (at the center of the differential). The distance between the centers of the wheels is 2.6 m and the tyres are 40 cm in diameter. The number of teeth on each gear of differential shown in **FigQ4** are $T_A = 18$, $T_B = 84$, $T_C = T_D = 24$ and $T_E = T_F = 18$. **[12M]**

Calculate:

(a) The speed of rotation (rpm) of each rear wheel (i.e. S_1 and S_2)

(b) The rotational speed (rpm) of the ring gear *B* and the drive shaft *S*.

(c) Assume that the vehicle is stopped so that the right wheel sits on a small icy patch and can spin freely while the left wheel does not spin. Determine the angular velocity of the right wheel if the angular speed of the drive shaft *S* is 600 rpm.



FigQ4

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Q1. A vertical, single cylinder, four-stroke gas engine, working on Otto cycle, has a bore of 360 mm and a stroke of 600 mm. The engine runs at 300 rpm.
The compression ratio of the engine is 5.5. The maximum explosion pressure is 4.5 N/mm^2 and expansion follows the law $PV^{1.2}$ = constant. The masses of the piston and connecting rod are 65 kg and 120 kg, respectively. The connecting rod is 1.5 m long with its center of mass at a distance of 0.5 m from the big end (i.e. crank end). The radius of gyration for the connecting rod is 0.4 m. The back pressure is 0.1 N/mm^2.

Calculate the turning moment (T in **kN-m**) on the crankshaft when the crank has turned through 45° from the top dead center during expansion stroke. **[12M]**

Q2. A shaft, rotating at a uniform speed, carries two discs A and B of masses 5 kg and 6 kg, respectively. The CG (center of gravity) of each disc is 3 mm from the axis of rotation, and the angle between the radii containing the centers of gravity is 90°. The shaft has bearings at C and D, between A and B, such that AC = 360 mm, AD = 1080 mm, and AB = 1440 mm. It is desired to make the dynamic forces on the bearings equal and opposite, and to have a minimum value for a given speed by means of a mass in the plane E at a radius of 30 mm. Determine:

(a) the magnitude of the mass to be attached at E and its angular position with respect to that of A
(b) the distance of the plane E from the plane through A
(c) the dynamic force on the bearings with the attached mass in the plane E for a speed of 500 rpm.
(d) Show the relative axial and radial positions of masses with a neat sketch wrt **plane *A***. **[12M]**

Q3. A four-bar mechanism in the vertical plane has the coupler AB a rigid uniform rod of length 50 cm, its mass being 15 kg. The input crank O_2A and output link O_4B are of equal lengths but of negligible mass. In the instantaneous position shown, a torque M acts on the crank O_2A, causing crank to move with ω_2 = 50 rad/s and α_2 = 10 rad/s^2, both in CCW direction. Start with the **loop closure equation** for the mechanism and analytically determine **(a)** the angular velocity (ω_3) and acceleration (α_3) of coupler AB **(b)** the shifted inertia force on coupler AB **(c)** the pin reactions at A and B **[16M]**

Given $\boldsymbol{AB} = \boldsymbol{BO_4} = \boldsymbol{O_2A}$