KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechanical Engineering

B. Sc. Engineering 3rd Year 1st Term Examination, 2024

ME 3109

(Engineering Mechanics III)

Time: 3 Hours | Total Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.
iii) Assume reasonable data if any are missing.

SECTION-A

1(a) Interpret the conditions for considering an equivalent dynamical system. Also, illustrate a qualitative turning moment diagram of a four-stroke cycle internal combustion engine. 10

1(b) Define the coefficient of fluctuation of energy. Deduce the expression for the mass of a flywheel required for a reciprocating engine. 12

1(c) The crank-pin circle radius of a horizontal engine is 300 mm. The mass of the reciprocating parts is 250 kg. When the crank has travelled 60° from inner dead center, the difference between the driving and the back pressures is 0.35 N/mm². The connecting-rod length between centres is 1.2 m, and the cylinder bore is 0.5 m. If the engine runs at 250 r.p.m. and if the effect of piston-rod diameter is neglected, calculate (i) the pressure on slide bars, (ii) the thrust in the connecting rod, (iii) the tangent force on the crank-pin, and (iv) the turning moment on the crankshaft. 13

2(a) Interpret the differences of a governor over a flywheel. When a governor is said to be stable, hunt, and isochronous? – Explain. 10

2(b) Derive an expression for the height of a Proell governor by the instantaneous centre method. Also, prove that the sensitiveness of a Proell governor is greater than that of a Porter governor. 12

2(c) A Porter governor has equal arms, each 250 mm long and pivoted on the axis of rotation. Each ball has a mass of 5 kg, and the mass of the central load on the sleeve is 25 kg. The radius of rotation of the balls is 150 mm when the governor begins to lift and 200 mm when the governor is at maximum speed. If the friction at the sleeve is equivalent to 10 N, calculate (i) the range of speed, (ii) the sleeve lift, (iii) the governor effort and power of the governor, and (iv) the coefficient of insensitiveness. 13

3(a) State and prove the law of gearing. Also, discuss different types of gear trains. 18

3(b) In an epicyclic gear train, the internal wheels A and B, and the compound wheels C and D, rotate independently about axis O. The wheels E and F rotate on pins fixed to the arm G. E gears with A and C, and F gears with B and D. All the wheels have the same module, and the numbers of teeth are: $T_C = 28, T_D = 26, T_E = T_F = 18$, 17

(i) Sketch the arrangement.
(ii) Find the number of teeth on wheels A and B.
(iii) If the arm G makes 100 r.p.m. clockwise and A is fixed, find the speed of B.

4(a) List out the conditions for static and dynamic balancing. Explain the method of balancing of a single rotating mass by two masses rotating in different planes. 10

4(b) Interpret the reasons why only part of the unbalanced force due to reciprocating masses is balanced by revolving masses. Also, explain the swaying couple and hammer blow. 12

4(c) A shaft carries five masses A, B, C, D, and E, which revolve at the same radius in planes that are equidistant from one another. The magnitudes of the masses in planes A, C, and D are 60 kg, 45 kg, and 80 kg, respectively. The angle between A and C is 90°, and that between C and D is 135°. Determine the magnitudes of the masses in planes B and E and their angular positions to put the shaft in complete rotating balance. 13

SECTION-B

5(a) Interpret different types of motion with which a flower can move. Also, mention the classification of cam. 10

5(b) If a cam is to be designed for a knife-edge follower with the following data: 25

i) Cam lift = 40 mm during 90° of cam rotation with simple harmonic motion.
ii) Dwell for the next 30°.
iii) During the next 60° of cam rotation, the follower returns to its original position with simple harmonic motion.
iv) Dwell during the remaining 180°.

Draw the motion of the follower and the profile of the cam when the line of stroke of the follower passes through the axis of the cam shaft.
Assume the radius of the base circle is 40 mm.

6(a) Interpret the causes and effects of vibrations on mechanical machineries. Also, draw the spring systems from the following differential equations: 10

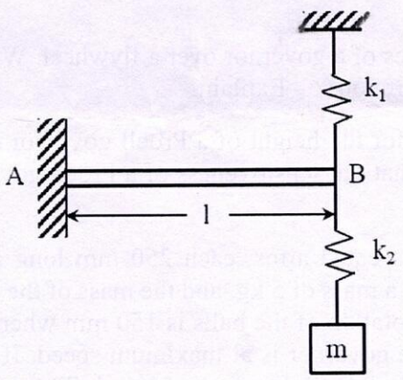
(i) $m\ddot{x} + k_1x + k_2x = 0,$

(ii) $m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + \left(\frac{k_1k_2}{k_1+k_2}\right)x=0$, and

(iii) $m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = F\cos\omega t.$

6(b) Show that the critical speed or whirling speed of shaft is the same as the natural frequency of transverse vibration. 10

6(c) Determine the natural frequency of the vibration of the system as shown in the figure. Assume the AB bar to be rigid and weightless. 15



7(a) What is meant by logarithmic decrement? Deduce the expression of logarithmic decrement. 12

7(b) Explain the terms underdamping, overdamping, and critical damping. 09

7(c) A mass of 10 kg is supported by a spring of stiffness 10 kN/m. In addition, the motion of the mass is controlled by a damper whose resistance is proportional to velocity. The amplitude of vibration reduced to 1/10th of the initial amplitude after five complete cycles. Determine the damping force per unit velocity. 14

8(a) Write the short note on the following terms of forced vibration: 12

i) Magnification factor,
ii) Transmissibility, and
iii) Vibration Isolation.

8(b) What is meant by torsional vibration? Determine the expression of the equivalent length of a shaft, which has several steps. 13

8(c) An electric motor rotating at 1200 r.p.m. drives a centrifugal pump at 500 rpm through a single-stage reducing gearing. The moment of inertia of the electric motor and the pump impeller are 400 kg-m^2 and 1400 kg-m^2 respectively. The motor shaft is 45 mm in diameter and 180 mm long. The pump shaft is 90 mm in diameter and 450 mm long. Determine the frequency of torsional oscillations of the system, neglecting the inertia of the gears. The modulus of rigidity of the shaft material is 84 GN/m^2. 10

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ME 3117

(Machine Design I)

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N.B.: i) Answer any THREE questions from each section in separate scripts.
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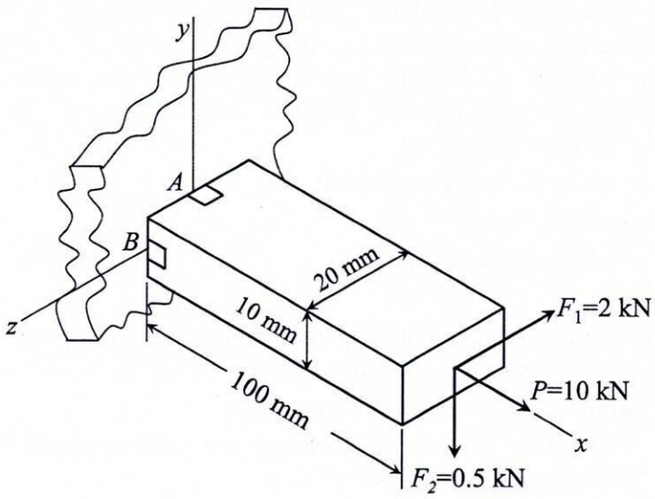
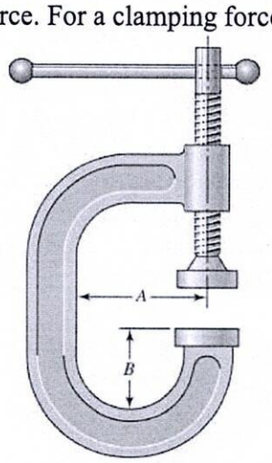
SECTION-A

1 A rectangular bar is subjected to combined loading as shown in the figure. The bar is made of AISI 1006 cold-drawn steel. Find the factor of safety by choosing a suitable failure theory at points *A* and *B*. What would be the factor of safety if the material is ASTM No. 30 cast iron? Which material would you choose and why? 35



2 The C clamp shown in the figure uses a $\frac{3}{4}$ in.-6 Acme thread. The frictional coefficients are 0.15 for the threads and for the collar. The collar, which in this case is the anvil striker's swivel joint, has a friction diameter of 1 in. Calculations are to be based on a maximum force of 8 lbf applied to the handle at a radius of $3\frac{1}{2}$ in. from the screw centerline. Find the clamping force. For a clamping force of 300 lbf, choose a screw. 35



3 A 2-in. steel plate and a 1-in. cast-iron plate are compressed with one bolt and nut. The bolt is $\frac{1}{2}$ in.-13 UNC and one $\frac{1}{2}$ N American standard plain washer under the head of the bolt, and another identical washer under the nut were used. 35

(i) Determine a suitable length for the bolt, rounded up to the nearest $\frac{1}{4}$ in.

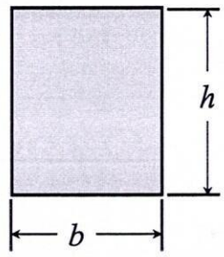
(ii) Determine the bolt stiffness.

(iii) Determine the stiffness of the members.

4) Design a compression spring with a squared end. The spring constant is to be 10 lbf/in, and to close solid when the force is 30 lbf. The spring will be used in a plane where human life matters. 35

SECTION-B

5 A solid rectangular bar ($h = 1.5b$) is cantilevered at one end. The cross-section of the bar is shown in the figure. The bar is 0.8 m long and supports a completely reversing transverse load at the other end of ± 2 kN. The material is AISI 1080 hot-rolled steel. If the bar must support this load for 12000 cycles with a factor of safety of 1.8, what dimension should the rectangular cross-section have? Neglect any stress concentrations at the support end. 35

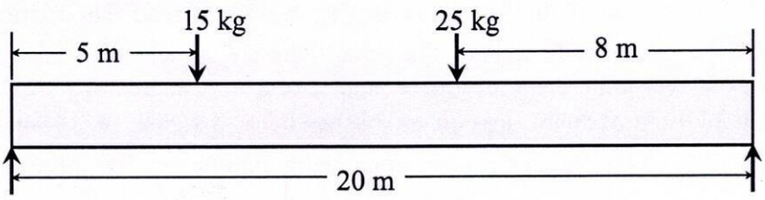


6 A bar of steel has the minimum properties $S_e = 40$ kpsi, $S_y = 60$ kpsi, and $S_{ut} = 80$ kpsi. The bar is subjected to a steady torsional stress of 15 kpsi and an alternating bending stress of 25 kpsi. Find the factor of safety guarding against a static failure, and either the factor of safety guarding against a fatigue failure or the expected life of the part. For the fatigue analysis use: 35

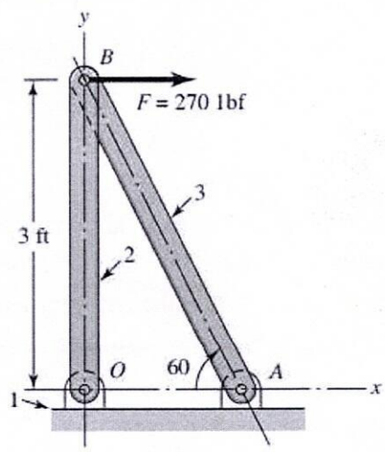
(i) Modified Goodman criterion.
(ii) Gerber criterion.
(iii) ASME-elliptic criterion.

7 Consider a simply supported shaft as shown in the figure with a 30 mm diameter and 20 m span between bearings, carrying two gears weighing 15 kgf and 25 kgf. 35

(i) Find the influence coefficients
(ii) Estimate the first critical speed using Rayleigh's equation, Dunkerley's equation, and superposition.
(iii) Compare and discuss the results found in part (ii).



8(a) Link 3, as shown schematically in the figure, acts as a brace to support the 270-lbf load. For buckling in the plane of the figure, the link may be regarded as pinned at both ends. For out-of-plane buckling, the ends are fixed. Select a suitable material and a method of manufacture, such as forging, casting, stamping, or machining, for casual applications of the brace in oil-field machinery. Specify the dimensions of the cross-section as well as the ends so as to obtain a strong, safe, well-made, and economical brace. 20



8(b) A UNS G10350 steel shaft, heat-treated to a minimum yield strength of 100 kpsi, has a diameter of $1\frac{7}{16}$ in. The shaft rotates at 1000 rev/min and transmits 50 hp through a gear. Select an appropriate key for the gear, with a design factor of 2.0. 15