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UNIVERSITY OF WALES
Trinity Saint David

LOCATION SWANSEA

LEVEL 6

**EXAMINATION PERIOD
AUGUST 2015**

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LEFEL 6

**CYFNOD ARHOLIADAU
AWST 2015**

MODULE CODE: M3X8820
Competition Engine Design

TIME: 2 HOURS

ANSWER THREE QUESTIONS OUT OF FOUR

Note that in all your answers, marks will be awarded for detailed explanation of the calculation steps.

QUESTION ONE

You are required to carry out the balancing of a 350 cc single cylinder engine. Balancing will be at first order of crankshaft rotation.

Assume that the piston and gudgeon pin mass is 320 gms. Assume that the total con-rod mass is 300 gms and that the stroke is 40 mm. Assume that the total crankshaft mass is 1.8 kg.

- (a) Using diagrams to explain your answers, calculate the total mass moment of the resultant first order forward rotating vector acting on the crankshaft as a result of the piston and con-rod inertia forces. Give the answer in kgm.
(3 marks)
- (b) Explaining your reasoning, calculate the required offset in mm of the crankshaft centre of gravity from its centre-line of rotation to fully balance the forward rotating vector. Sketch the crankshaft to illustrate your answer.
(3 marks)
- (c) Calculate the mass moment of the first order reverse rotating vector in kgm.
(2 marks)
- (d) Explain how you can use a counter-rotating balance shaft to cancel this reverse rotating vector and calculate in mm the required offset of the balance shaft centre of gravity from its centre line of rotation if the balance shaft has a mass of 1.5 kg.
(2 marks)
- (e) If the crankshaft has rotated 90° clockwise from top dead centre, show where the eccentric part of the balance shaft should be pointing. Use a diagram of front view of crankshaft and balance shaft to illustrate your answer.
(2 marks)
- (f) If it is not possible install a balance shaft, explain how the crankshaft can be overbalanced to create a resultant horizontal first order force. Explain your reasoning using suitable vector diagrams. If the overbalanced crankshaft now weighs 2.2 kg, calculate the required offset in mm from its centre line of rotation to obtain this suitable overbalance.
(3 marks)
- (g) If the engine is rotating at 8000 RPM, calculate the amplitude of the resultant horizontal first order shaking force in Newtons if the crankshaft is suitably overbalanced as in question (f).
(2 marks)
- (h) Explain how you could also balance the crankshaft to obtain a resultant vertical first order force and calculate the crankshaft mass moment in kgm to achieve this.
(3 marks)

QUESTION TWO

You are required to carry out an analysis of first and second order vibrations on a 70 degree bank angle vee twin engine. Looking from the front, bank 2 is the right hand bank.

Assume that the piston and gudgeon pin has a mass of 280 gms and each rod a mass of 420 gms. Assume that the stroke is 50 mm and the rod length 130 mm.

- (a) If the con-rods both share a common crankpin, calculate the mass moment in kgm of the resultant first order forward rotating vector using a suitable diagram to explain your reasoning and to show the direction of the resultant first order forward vector relative to the crankpin.

(2 marks)

- (b) Assuming again a common crankpin, calculate the magnitude of the resultant first order reverse rotating vector mass moment in kgm using a suitable diagram to explain your reasoning.

Calculate the angle of the resultant reverse vector relative to bank 1 when the crankpin is along bank 2 and show its position in a suitable diagram.

(2 marks)

- (c) Calculate the magnitude and direction of the resultant second order forward rotating vector when the pin is along bank 1. Give the magnitude as a function of angular velocity squared (ie ω^2).

(3 marks)

- (d) Calculate the magnitude and direction of the resultant second order reverse rotating vector when the pin is along bank 1. Give the magnitude as a function of ω^2 .

(3 marks)

- (e) It is now required to modify the crankshaft to include a crankpin offset for the 2 banks.

Calculate the required crankpin offset angle to reduce the resultant first order reverse rotating vector to zero.

Use a vector diagram with pin 2 along bank 2.

(5 marks)

- (f) Using the offset pin crankshaft calculated in (e) you are required to use a vector diagram with pin 2 along bank 2 and find the directions of the resultant forward and reverse rotating second order vectors.

(5 marks)

QUESTION THREE

You are required to analyse the crankshaft and flywheel on an in-line 2 cylinder 2 stroke engine with crankpins at 180° to each other.

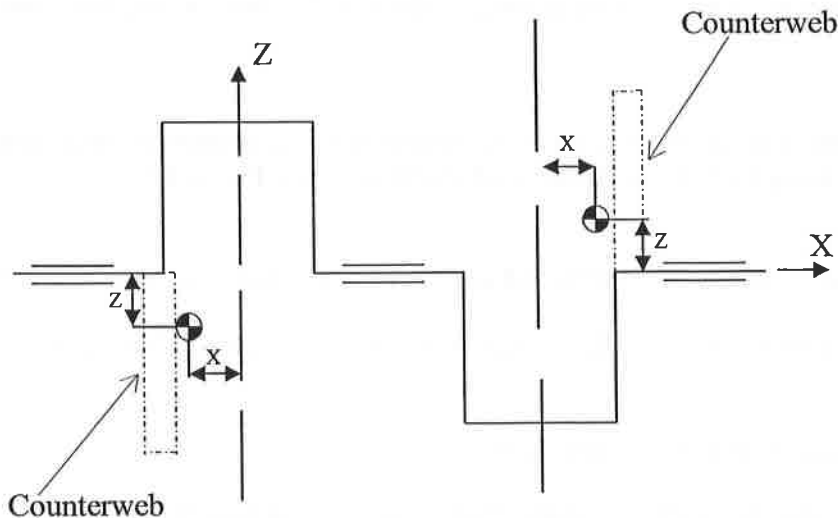
- The engine has 3 main bearings.
- The individual piston and gudgeon pin mass is 340 gms.
- The individual con-rod mass is 390 gms.
- The stroke is 60 mm.
- The bore-centre spacing (pin to pin) is 100 mm.

- (a) Calculate the mass of the required bob-weights which would be needed for balancing the crankshaft on a balancing machine if 100% of the forward rotating vectors are to be balanced.

(3 marks)

- (b) The crankshaft is to be fully balanced using 2 equal counter webs on the outer sides of the 2 respective crankpins.

The diagram shows the x and z coordinate axes for the crankshaft.



If the centre of mass offset z for an individual crankpin is 3 mm, calculate the x offset from the middle of the crankpin to achieve the required balance if the total crankshaft mass is 6 kg.

(5 marks)

- (c) Assuming a maximum mean engine torque of 120 Nm, you are required to calculate the number of M8 bolts of grade 10.9 needed to attach the flywheel to the crankshaft. The PCD (Pitch circle diameter) of the flywheel bolts can be assumed to be 60 mm. Assume a coefficient of friction between flywheel and crankshaft of 0.1 and select a suitable safety factor to withstand shock loads.

(6 marks)

- (d) Assuming that the crankshaft/flywheel assembly has a moment of inertia of 0.08 kgm^2 , calculate the value of the torsional amplitude in degrees at the flywheel at 1000 RPM resulting from the fluctuating applied torque. Assume the mean applied torque is 60 Nm at 1000 RPM.

(6marks)

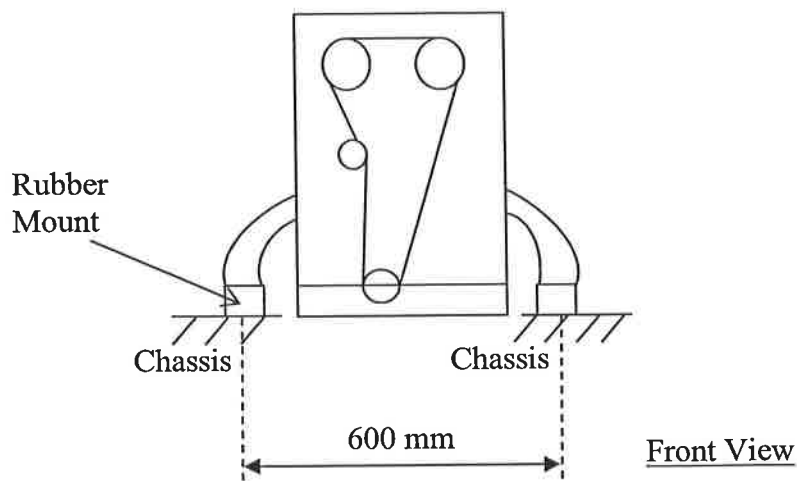
QUESTION FOUR

You are required to develop an engine mounting system for an in-line 4 cylinder 2 litre engine/gearbox unit.

The engine has internals with the following specification:

Piston Mass	=	250 gms
Conrod Mass	=	300 gms
Conrod Length	=	120 mm
Stroke	=	70 mm
Bore	=	70 mm
Mean Torque	=	150 Nm
Instantaneous Peak Torque at 4000 RPM	=	400 Nm
Total Engine Gearbox Mass	=	140 kg

Assume that the engine has 4 rubber engine mounts with identical vertical stiffness. Assume that the mounts are positioned symmetrically around the crankshaft axis as shown in figure below:



- (a) If the maximum vertical deflection over 3g bumps is designed to be 10 mm, calculate the vertical stiffness of each mount in N/m. (2 marks)
- (b) Calculate the amplitude of the resultant vertical second order inertia force as a function of angular velocity squared (ω rads/sec)². (2 marks)
- (c) Derive an equation for the amplitude of the resultant vertical second order displacement amplitude as a function of crankshaft angular velocity. Sketch a graph of displacement amplitude against angular velocity. (6 marks)
- (d) Calculate the crankshaft angular velocity and crankshaft RPM when the engine/gearbox unit is in a vertical resonance on its mounts as a result of the applied vertical second order inertia forces. (2 marks)

- (e) Calculate the displacement amplitude at high RPM. (2 marks)
- (f) Calculate the amplitude of the force (in Newtons) transmitted into the chassis through each engine mount at high RPM. (2 marks)
- (g) Assuming that the engine/gearbox unit has a longitudinal principal axis of rotation along the crankshaft axis and a longitudinal moment of inertia of magnitude $6,4 \text{ kg.m}^2$, calculate the amplitude of the torsional displacement in radians about the crankshaft axis at 4000 RPM. Assume a suitable torque amplitude. Show the principles of the derivation as in part (c). (4 marks)