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AENG20002 – Mechanisms

Assessed Test – Monday 02 March 2015 - Solutions

Answer all parts of the questions (maximum mark 50) – Time allowed: 50 minutes

1. Considering n the total number of links, f the total number of joints and F the number of degrees of freedom, which formula describes the Gruebler's equation for planar mechanisms? **[Maximum 3 marks]**:

   a. $F = 3(n^2 - 1) + 2f$ ☐0.5

   b. $F = 3(n - 3) + 2f$ ☐1.5

   c. $F = 3(2n - 1) + 3f$ ☐1.5

   d. $F = 3(n - 2) + 2f$ ☐1.5

   e. *none of the above* ☐**3**

2. In a spur gear, what is the standard pressure angle for high load carrying capacity? **[Maximum 3 marks]**:

   a. *16º* ☐0.5

   b. *18º* ☐**1**

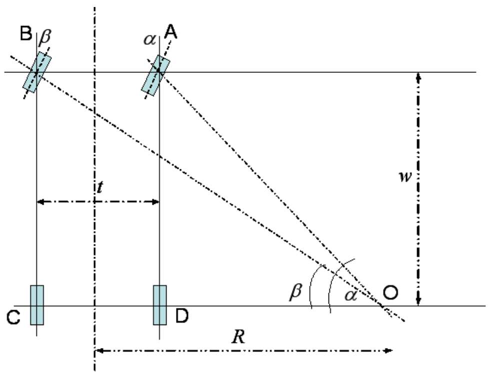
   c. *10º* ☐1

   d. *14.5º* ☐1.5

   e. *none of the above* ☐3

3. The figure below shows a steering mechanism with ratio t/w (track vs. wheel distance) of 0.35. Indicate, providing justification, which answer is correct to avoid the rear wheels of the mechanism skidding. **[6 marks]**.

   <u>Please see the notes</u>



t = track
w = wheel distance
A, B = wheel pivots

   a. $\cot\beta = 2.5 + \cot\alpha$ ☐1.0

   b. $\tan\beta = 1.5 + \cot\alpha$ ☐1.5

   c. $\cot\beta = 0.35 + \tan\alpha$ ☐2.5

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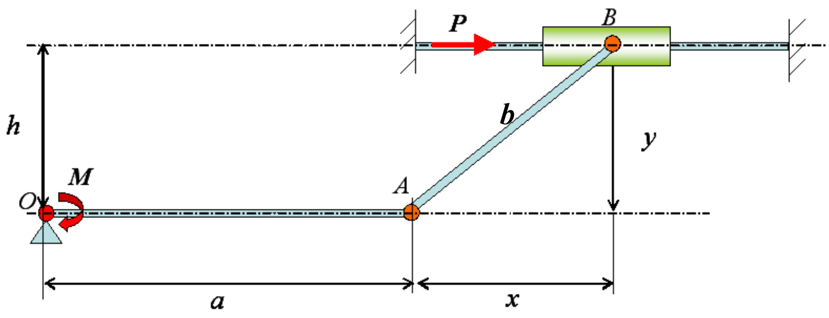
d. $\cot\beta = 0.4 + \tan\alpha$ □1.0

e. *None of the above* □6

4. For link OA in the position shown, determine using the Principle of Virtual Work only the force $\boldsymbol{P}$ on the sliding collar which will prevent OA from rotating under the action of the couple $\boldsymbol{M}$. Neglect the mass of the moving parts. **[Maximum 7 marks]**:



a. $P = \dfrac{Mx^2}{ha}$ □1

b. $P = \dfrac{Mx}{hb}$ □3

c. $P = \dfrac{Mx}{ya^2}$ □1

d. $P = \dfrac{Mx}{hb\tan(y/x)}$ □1

e. *None of the above* □7

Give to crank OA a small clockwise angular movement $\delta\theta \rightarrow \delta y = a\ \delta\theta$. (1)

By inspection one can write: $b^2 = x^2 + y^2$ (2)

Take differential of (2) → $0 = 2x\delta x + 2y\delta y$ → $\delta x = -\dfrac{y}{x}\delta y = -\dfrac{y}{x}a\delta\theta$ (3)

Applying PVW: $M\delta\theta + P\delta x = 0$ Back substituting (3) → $P = \dfrac{Mx}{ha}$

5. Write the trigonometric expression for the rod displacement x in the Ackermann steering mechanism when the tab is moved from the initial position (a) to the final one (b): **[Maximum 8 marks]**.

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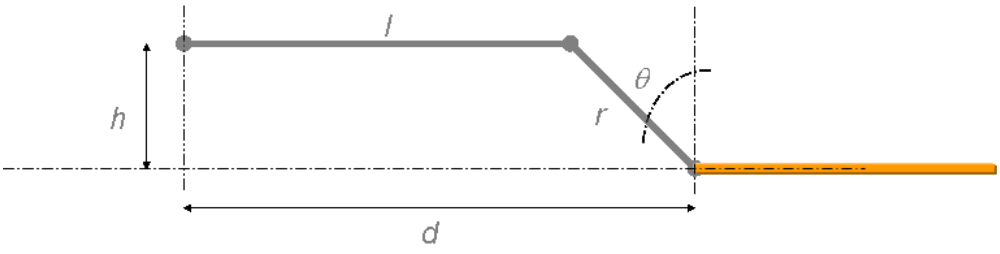
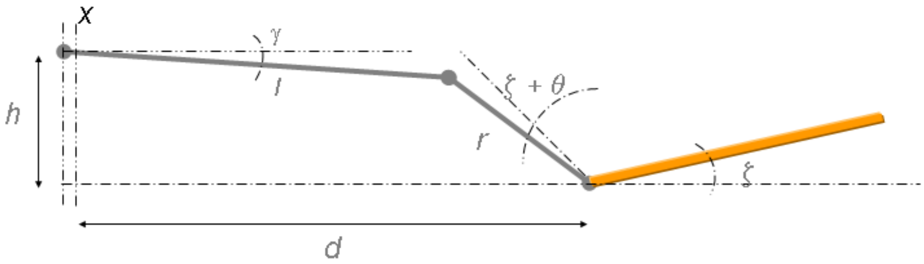


(a)



(b)

The marking will be provided ad hoc for each answer. A possible marking scheme is the following:

Initial position:

$$d = l + r\sin\theta \qquad (1)$$

$$h = r\cos\theta \qquad (2)$$

After control movement x:

$$d + x = l\cos\gamma + r\sin(\theta+\xi) \qquad (3)$$

$$h = l\sin\gamma + r\cos(\theta+\xi) \qquad (4)$$

Back substituting (3), (4) in (1), (2):

$$l\cos\gamma = l + r\sin\theta - r\sin(\theta+\xi) + x \qquad (5)$$

$$l\sin\gamma = r\cos\theta - r\cos(\theta+\xi) \qquad (6)$$

Squaring and adding (5) and 6:

$$l^2 = [l + r\sin\theta - r\sin(\theta+\xi) + x]^2 + [r\cos\theta - r\cos(\theta+\xi)]^2$$

$$\boxed{x = \sqrt{l^2 - [r\cos\theta - r\cos(\theta+\xi)]^2} - l - r\sin\theta + r\sin(\theta+\xi)}$$

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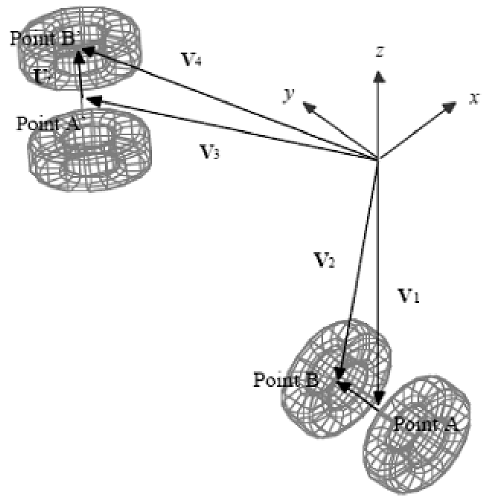
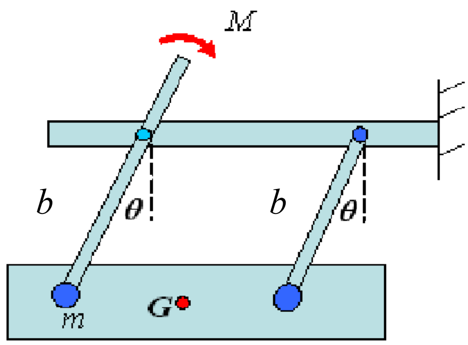
6. Consider the landing gear system in the wing mounted assembly below. Let $\mathbf{V}_1$ and $\mathbf{V}_3$ the vectors related to the positions of the axle/piston centrelines, with components (X_1, Y_1, Z_1) and (X_3, Y_3, Z_3) respectively. Point **B** is located at a unit distance from the centreline along the y-direction. The final position $\mathbf{V}_4$ is defined from $\mathbf{V}_3$ is defined by a vector with components X_U, Y_u, Z_U. If no devices are used to shorten the length of the strut during the retraction, indicate which relation is valid:
[Maximum 6 marks].



a. $X_1^2 + Y_1^2 + Z_1^2 = (X_3 + X_U)^2 + (Y_3 + Y_U)^2 + (Z_3 + Z_U)^2$	**3**
b. $X_1^2 + (Y_1 + 1)^2 + Z_1^2 = (X_3 + X_U)^2 + (Y_3 + Y_U + 1)^2 + (Z_3 + Z_U)^2$	**3.0**
c. $X_U^2 + Y_U^2 + Z_U^3 = 1$	**2.0**
d. $X_1^2 + (Y_1^2 + 1) + Z_1^2 = (X_3 + X_U)^2 + (Y_3 + Y_U)^3 + (Z_3 + Z_U)^2$	**3.0**
e. $X_1^2 + (Y_1 + 1)^2 + Z_1^3 = (X_3 + X_U)^2 + (Y_3 + Y_U + 1)^2 + (Z_3 + Z_U)^2$	**3.0**
f. *none of the above*	**6**

7. The mass m of the following mechanism is brought to an equilibrium position by the application of the couple M to the end of one of the two parallel links hinged as shown. The links have negligible mass, and all friction is assumed to be absent. Using the Principle of Virtual Work, indicate the correct expression for the equilibrium angle θ assumed by the links with the vertical for a given value of M. **[Maximum 7 marks]**:



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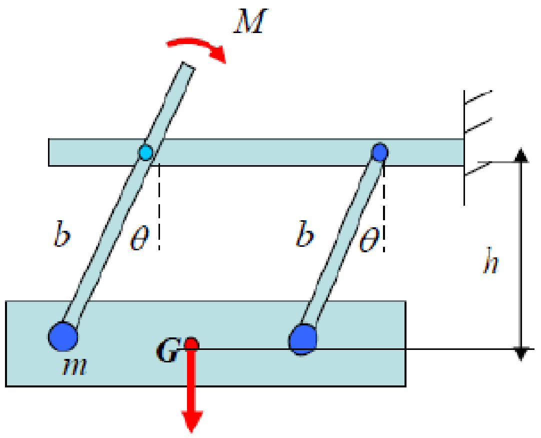


Work done by couple M:

$$\pm M\ \delta\theta$$

Work done by force mg:

$$mg \cdot \delta h = mg \cdot \delta(b\cos\theta) = -mg \cdot b \cdot \sin\theta \cdot \delta\theta$$

PVW:

$$M \cdot \delta\theta + mg \cdot \delta h = 0 \Longrightarrow \boxed{\theta = \sin^{-1}\frac{M}{mgb}}$$

a. $\theta = \sin^{-1}\dfrac{M}{2mgb}$ □**3**

b. $\theta = \tan^{-1}\dfrac{Mg}{mb}$ □**2.5**

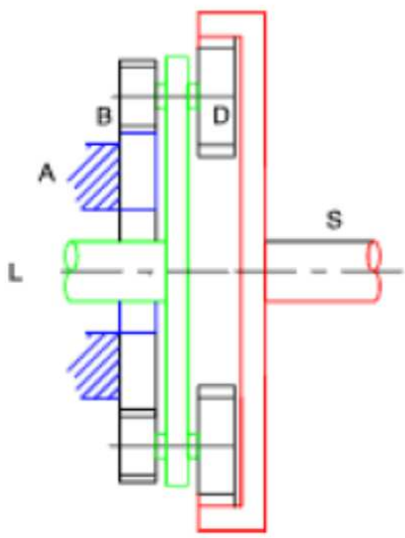
c. $\theta = \sin^{-1}\sqrt{\dfrac{M}{mgb}}$ □**3.0**

d. $\theta = \sec^{-1}\dfrac{Mg}{mb}$ □**2.5**

e. $\theta = \cos^{-1}\dfrac{M}{mgb}$ □**3.0**

f. *None of the above* □**7**

8. In the epicycle gear shown in the figure, the driver is the planetary arm (L). The follower is the sun (S), while the ring gear (A) is fixed. The gear tooth numbers for B, D, S and A are 12, 18, 60 and 30 respectively. Fixing L and giving one counter clockwise rotation to A, indicate the transmission ratio on the shaft S. Give evidence of your results. **[Maximum 10 marks]:**



a. –3.5 2.5

b. +3.5 3

c. – 1.75 3.5

d. + 1.75 10

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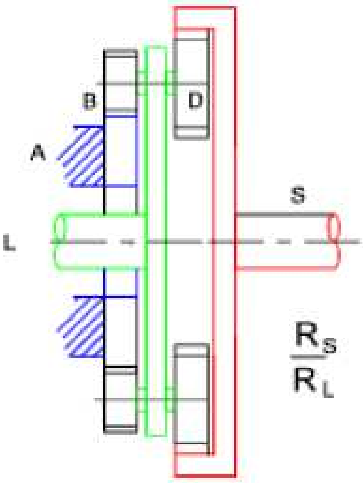
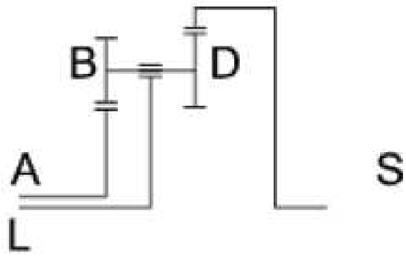
e. *None of the above* **2**



$$\frac{R_S}{R_L} = 1 + \frac{N_A N_D}{N_B N_S}$$



A= Fixed

Action	Rotation (CW= +ve) from action.....................N_X = number of teeth			
	L	A	B-D	S
Turn whole gear through 1 rev CW	1	1	1	1
Fix L and rotate A back CCW 1 rev	0	-1	$+ N_A / N_B$	$+ (N_A / N_B).(N_D / N_S)$
Add the two motions above	1	0	$1 + (N_A / N_B)$	$1 + (N_A . N_D)/(N_B . N_S)$

NA=30, NB=12, ND=18, NS=60. We obtain: 1.75