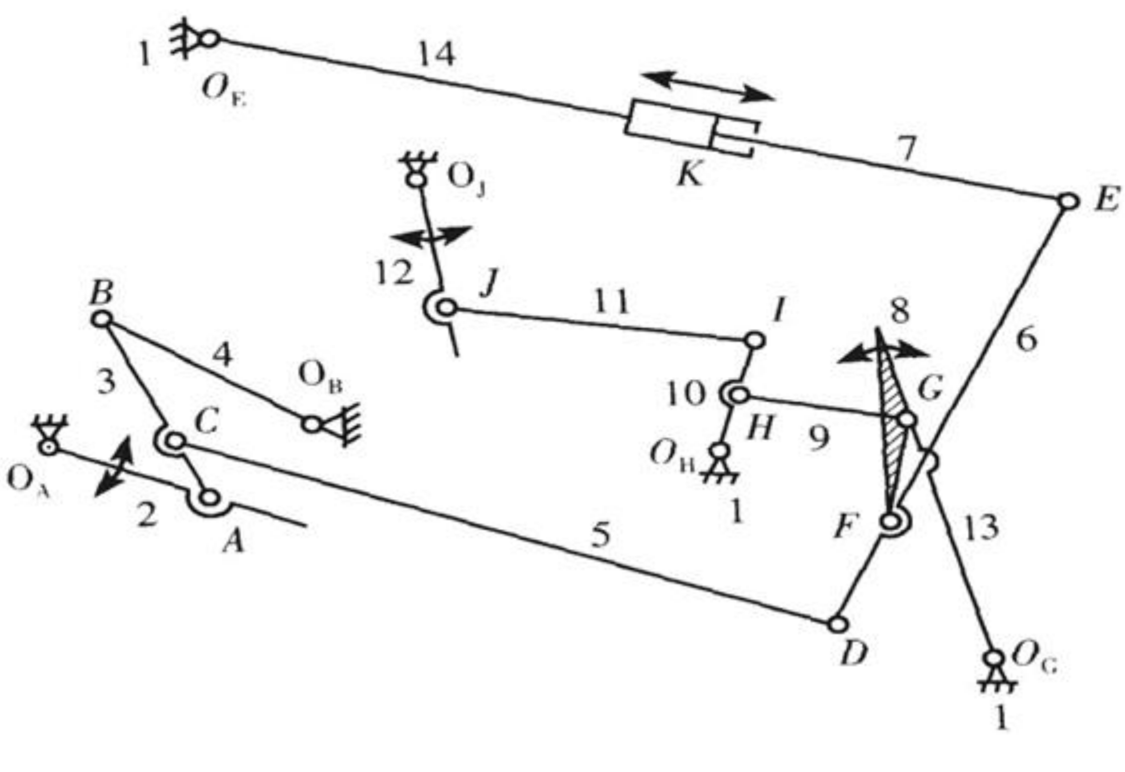
ME311 Quiz 1/3

本试卷共（3）大题，满分（100）分，请用中文或英文作答，将答案单独写在答题纸上，在答题纸右上角标注姓名学号，仅提交答题纸，注意字迹清晰。

There are 3 problems in total for 100 points. Write answers in a separate sheet in Chinese or English. Identify your name and student number on the top right corner of your answer sheets. Submit answer sheet only. Write clearly.

1. （30 分）图示为一飞机水平尾翼操纵机构的简图。其中构件 1 为机架，操纵杆 2 为原动件，有时还可以从襟翼输入（即构件 12 摆动）或从稳定增效器输入（即构件 7 相对构件 14 移动），构件 8 为输出杆。
   The figure is a simplified diagram of the horizontal tail control mechanism of an aircraft. Component 1 is the frame, control rod 2 is the prime mover, and sometimes it can also be input from the flap (i.e. component 12 swings) or from the stability amplifier (i.e. component 7 moves relative to component 14), and component 8 is the output rod.



（1）（3 分）请解释机构自由度，并给出 K 个构件组成的平面机构对应的自由度 F 计算公式，说明公式参数含义；

Please explain the degrees of freedom of the mechanism and give the calculation formula for the degrees of freedom F corresponding to a planar mechanism composed of K components;

（2） （3 分）请说明机构具有确定运动的条件；

Please explain the conditions under which the mechanism has a certain motion;

（3） （12 分）仅由操纵杆 2 输入时，试求机构自由度，说明机构运动是否确定；

Calculate the degree of freedom of the mechanism when only the joystick 2 is used for input.

（4） （12 分）由操纵杆 2、襟翼 12、稳定增效器 7 同时输入，试求机构自由度，说明机构运动是否确定。

Given the simultaneous inputs from the joystick 2, flaps 12, and stabilizer amplifier 7, determine the degrees of freedom of the mechanism.

答案：

（1） （3 分）机构的自由度是指机构中各活动构件相对于机架所具有的独立运动的数目。

$$F = 3(K-1) - 2P_L - P_H$$

其中 F 为自由度，K 为构建数量，P_L为低副数量，P_H为高副数量。

The degree of freedom of a mechanism refers to the number of independent movements of each active component in the mechanism relative to the frame.

$$F = 3(K-1) - 2P_L - P_H$$

Where F is the degree of freedom, K is the number of constructions, P_L is the number of low pairs, and P_H is the number of high pairs.

（2） （3 分）机构具有确定运动的条件是：

a) 机构自由度必须大于零
b) 机构原动件的数目必须等于机构自由度数目

The conditions for a mechanism to have a definite motion are:

a) The degree of freedom of the mechanism must be greater than zero
b) The number of the mechanism's prime movers must be equal to the number of the mechanism's degrees of freedom

（3） （12 分）当襟翼不输入运动时，杆 9、10、11、12 和 13 均不运动，铰链 G 为固定铰链；当稳定增效器不输入运动时，杆 7 与杆 14 为一定长杆，可视为 1 个构件。此时机构只有 7 个活动构件，以 10 个转动副相连接。机构自由度为：

$$F = 3n - 2p_l - p_h = 3 \times 7 - 2 \times 10 - 0 = 1$$

自由度数等于原动件数，有确定运动。

When the flap does not input motion, rods 9, 10, 11, 12 and 13 do not move, and the hinge G is a fixed hinge; when the stabilizer does not input motion, rods 7 and 14 are rods of a certain length and can be regarded as one component. At this time, the mechanism has only

7 active components, connected by 10 revolute pairs. The degree of freedom of the mechanism is:

$$F = 3n - 2p_l - p_h = 3 \times 7 - 2 \times 10 - 0 = 1$$

The number of degrees of freedom is equal to the number of prime movers, and there is a definite motion.

（4）（12 分）由操纵杆 2、襟翼 12、稳定增效器 7 同时输入

同理分析，此时，杆 7 和杆 14 为两个活动构件，机构有 13 个活动构件，G 处为复合铰链,K 处有一个移动副，共以 18 个低副相连接。机构自由度为：

$$F = 3n - 2p_l - p_h = 3 \times 13 - 2 \times 18 - 0 = 3$$

自由度数等于原动件数，有确定运动。

Inputted by joystick 2, flap 12, and stabilizer 7 at the same time

Similarly, at this time, rod 7 and rod 14 are two active components, the mechanism has 13 active components, G is a compound hinge, K has a moving pair, and a total of 18 low pairs are connected. The degree of freedom of the mechanism is:

$$F = 3n - 2p_l - p_h = 3 \times 13 - 2 \times 18 - 0 = 3$$

The number of degrees of freedom is equal to the number of prime movers, and there is a definite motion.

2、（40 分）已知某钢制零件受弯曲变应力作用，其中最大工作应力σ_{max}=200MPa，最小工作应力σ_{min}=-50MPa，危险截面上的应力集中系数k_σ=1.2，尺寸系数ε_σ =0.85，表面状态系数β=1。材料的σ_s=750MPa，σ_0=580MPa，σ_{-1}=450MPa。试求：

An alloy steel part suffers bending stress:

$$\sigma_s\text{=750MPa，}\sigma_0\text{=580MPa，}\sigma_{-1}\text{=450MPa}$$

Working stress: σ_{max}=200MPa， σ_{min}=-50MPa，k_σ=1.2， ε_σ =0.85， β=1

（1）（10 分）绘制材料的简化极限应力图，并在图中标出工作应力点的位置；

Make the stress endurance figure, and find the working point.

（2）（15 分）求材料在该应力状态下的疲劳极限应力σ_r；

Find the fatigue stress limitation σ_r;

（3）（15 分）按疲劳极限应力和安全系数分别校核此零件是否安全（取 S_{min}=1.5）。

Check if this part is safe, using the fatiguc stress limitation and the safety factor (if S_{min}=1.5)

答案

解：（1）计算应力振幅、平均应力：

$$\sigma_a = \frac{1}{2}(\sigma_{max} - \sigma_{min}) = \frac{1}{2}(200 + 50) = 125MPa$$

$$\sigma_m = \frac{1}{2}(\sigma_{max} + \sigma_{min}) = \frac{1}{2}(200 - 50) = 75MPa$$

有效应力集中系数：

$$(K_\sigma)_D = \frac{k_\sigma}{\varepsilon_\sigma \beta} = \frac{1.2}{0.85 \times 1} = 1.4118$$

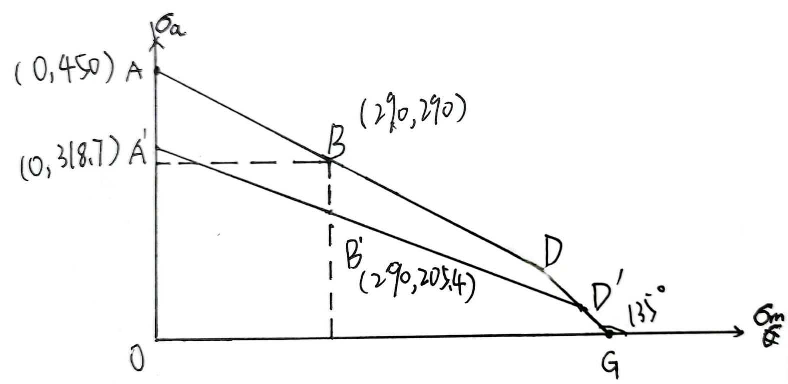
A’点位置为：

$$\frac{\sigma_{-1}}{(K_\sigma)_D} = \frac{450}{1.4118} = 318.7MPa$$

B’点位置为：

$$\frac{\sigma_0}{[2(K_\sigma)_D]} = \frac{580}{2 \times 1.4118} = 205.4MPa$$

做出零件的极限图，如下：



工作应力点 M 位置如上图所示，在 OA’D’内。

（2）计算疲劳极限应力σ_r

$$\psi_\sigma = \frac{2\sigma_{-1} - \sigma_0}{\sigma_0} = \frac{2 \times 450 - 580}{580} = 0.5517$$

$$\sigma'_{\mathrm{a}} = \frac{\sigma_{-1}\sigma_{\mathrm{a}}}{\sigma_{\mathrm{a}} + \psi_\sigma \sigma_{\mathrm{m}}} \quad \sigma'_{\mathrm{m}} = \frac{\sigma_{-1}\sigma_{\mathrm{m}}}{\sigma_{\mathrm{a}} + \psi_\sigma \sigma_{\mathrm{m}}}$$

$$\sigma_{\mathrm{r}}=\sigma_{\max}^{'}=\sigma_{\mathrm{m}}^{'}+\sigma_{\mathrm{a}}^{'}=\frac{\sigma_{-1}(\sigma_{\mathrm{a}}+\sigma_{\mathrm{m}})}{\sigma_{\mathrm{a}}+\psi_{\sigma}\sigma_{\mathrm{m}}}=\frac{450\times(75+125)}{125+0.5517\times 75}=540.93MPa$$

（3）检查强度

允许应力：

$$[\sigma]=\frac{\sigma_{\mathrm{r}}}{[S]}=\frac{413.79}{1.5}=275.86\mathrm{MPa}$$

$$\because \sigma_{\max}=200\mathrm{MPa}$$
$$\therefore \sigma_{\max}<[\sigma]$$

是安全的

安全系数：

$$S=\frac{\sigma_r}{\sigma_{\max}}=\frac{413.79}{200}=2.07>[S]=1.5$$

$$S=\frac{\sigma_{-1}}{[(K_\sigma)_D\sigma_a+\psi_\sigma\sigma_m]}=\frac{450}{(1.4118\times 125+0.5517\times 75)}=2.07>[S]=1.5$$

是安全的

3、（30 分）图中为一曲柄滑块机构，偏距 e=10mm，曲柄 AB 长度为 20mm，连杆 BC 长度 60mm。

The figure shows a crank slider mechanism, offset e=10mm, the length of the crank AB is 20mm, and the length of the connecting rod BC is 60mm.

(1) （10 分）求机构的最小传动角γ_{min}；

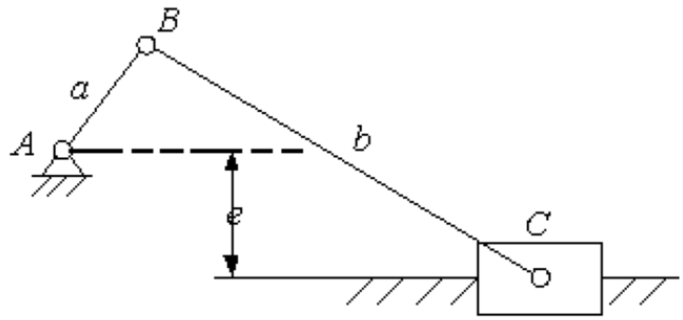
Find the minimum transmission Angle γ_{min} of the mechanism;

(2) （10 分）求滑块的行程 H；

Find the stroke H of the slider;

(3) （10 分）若曲柄 AB 和连杆 BC 的长度分别为 a 和 b，偏距为 e，写出该机构的极位夹角θ的表达式。

If the length of the crank AB and the connecting rod BC are a and b respectively, and the offset is e, write the expression of the crank angle θ between extreme positions .

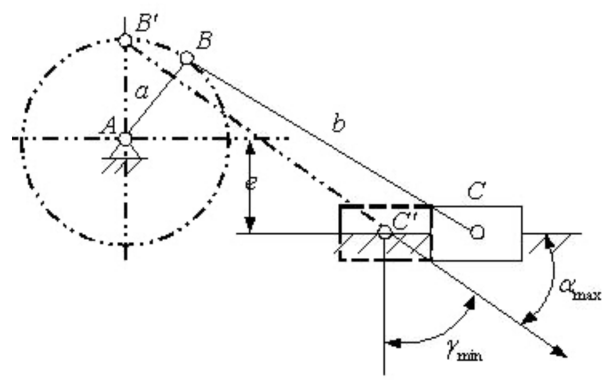


答案：

第一问（10 分）：

最小传动角出现在如右图所示位置

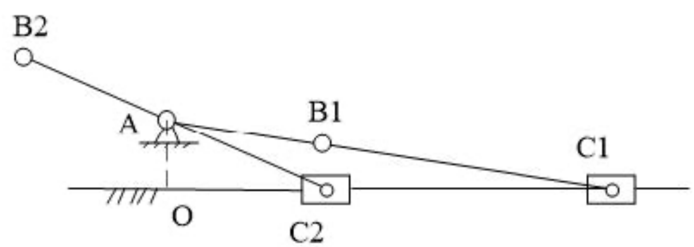
The minimum transmission Angle appears in the position shown on the right.



$\alpha_{max} = \sin^{-1}(\frac{AB+e}{BC}) = \sin^{-1}(\frac{20+10}{60}) = 30°$ （3 分）

$\gamma_{min} = 90° - \alpha_{max} = 60°$ （2 分）

第二问（10 分）：



$OC_1 = \sqrt{(\mathrm{AB}+\mathrm{BC})^2 - \mathrm{OA}^2} = \sqrt{(60+20)^2 - 10^2}$

$= 30\sqrt{7} \approx 79.37$mm (4 分)

$OC_2 = \sqrt{(\mathrm{BC}-\mathrm{AB})^2 - \mathrm{OA}^2} = \sqrt{(60-20)^2 - 10^2}$

$= 10\sqrt{15} \approx 38.73$mm（4 分）

H=$C_1C_2 = OC_1 - OC_2 = 30\sqrt{7} - 10\sqrt{15} \approx 40.64$mm（2 分）

第三问（10 分）：

$\angle OAC_1 = \cos^{-1}(\frac{OA}{AB+BC}) = \cos^{-1}(\frac{e}{a+b})$（4 分）

$\angle OAC_2 = \cos^{-1}(\frac{OA}{BC-AB}) = \cos^{-1}(\frac{e}{b-a})$ （4 分）

$\theta = \angle OAC_1 - \angle OAC_2 = \cos^{-1}(\frac{e}{a+b}) - \cos^{-1}(\frac{e}{b-a})$ （2 分）