Problem Chosen	2022	Team Control Number
A	MCM/ICM Summary Sheet	395

Planetary Defense Based on kinetic Energy Impact

Summary

In this article, we according to the topic given by spacecraft kinetic energy of impact asteroid planetary defense program, to carry on the reasonable guess assumptions, analyses the asteroid in the universe may have special properties, explores the possible trajectories, an asteroid hit the earth and in the presence of can take kinetic energy impact plan, through analysis and calculation, The shortest time from launch to impact asteroid is given if the Earth misses the impact.

We found that, depending on how asteroids are formed, asteroids can be divided into those made of rubble and those that can be regarded as compact balls of rock. After a brief analysis of the first case, this paper mainly explores the second case where the spacecraft and the asteroid can be regarded as a completely inelastic collision, the spacecraft needs from 58 days to 139 days to make the Earth miss the asteroid.

Keywords: asteroid;Kinetic energy of impact;spacecraft

Contents

1 Introduction

1.1 problem statement

In addition to the eight planets and other massive bodies in the solar system, there are also a large number of asteroids distributed between the orbits of Mars and Jupiter. Therefore, with the deepening of people's understanding of the potential hazards of asteroids, the research on planetary defense issues has been increasingly paid attention to, and a variety of planetary defense schemes such as nuclear detonation deviation, gravitational tug and kinetic energy impact have been proposed successively. The problem is to calculate the number of times we send a spacecraft that hits an asteroid that's going to collide with earth, and make it miss the earth. Starting from the problem, we will try and track asteroids and the earth in the solar system modeling, we mainly explored in our solar system's asteroid along the hyperbolic orbit, is planning to launch with the impact of a spacecraft, on this basis to estimate the from launch to the time needed for a collision with an asteroid.

2 Assumption and Notation

2.1 Assumptions

- The asteroid is perfectly spherical. This assumption is made due to the wide variability in the shapes of asteroid, which leads to an over-complex model but with likely insignificant changes in the final result.

- In considering the collision process between Earth and asteroid, the influence of Earth's orbit around the sun is slight within a certain Angle. For simple calculation, it can be assumed that the Earth's orbit around the sun is circular.

- To simplify the calculation, we need to make some assumptions about the range of collisions that can be taken as Earth-asteroid collisions.Since the radius of the Earth is about 6.371×10^6, we assume that if an asteroid gets within 1.5 times the radius of the Earth, which is 10^7, then we think the asteroid will collide with the Earth.

- When exploring the asteroid in this paper, it is assumed that the orbit of the asteroid in the question is completely within the ecliptic plane.

2.2 Notations

Variables	Explanations
ρ	the density of the asteroid
M_0	the mass of the earth
M_1	the mass of the asteroid
r_0	the radii of the earth
r_1	the radii of the asteroid
R	A.U.
v_0	the speed of the asteroid
m_{craft}	the speed of the spacecraft
v_R	The linear speed of the Earth's
v_a	The velocity of the asteroid relative to the sun
M_{sun}	The mass of the sun
v_{fst}	The mass of the sun
v_{2nd}	Second cosmic velocity
v_{3rd}	Third cosmic velocity

3 Physical And Analysis

3.1 Analysis of Asteroid Characteristics

According to Nebular Theory, asteroids are formed mainly from solid particles in the solar nebula that accrete through cooling and condensation, and then continuously collide and accrete.So the composition of the asteroid could be either a compact ball of rock or a ball of rubble.If the asteroid is composed of rubble, then a high velocity kinetic impact might send a large amount of rock into space, which would have a better impact effect. However, there are too many variables in the entire impact process, so this article focuses on the other scenario.Previously, we had assumed that asteroids were ideal spheres with known radii,r_1 , so we could calculate their masses simply by estimating the density of the planet ,ρ figure below, reveals that the least dense ones are mostly made of ammonia ice, while the densest ones are mostly made of iron. Therefore, within the scope of this paper, we assume that the density of the asteroid is between ammonia ice and iron, and the arithmetic square root of the product of the two gives the ρ to be about 2.53, which is close to the density of common rocks. Therefore, this result is reliable.So, we can calculate the asteroid's mass as:

$$M_1 = \frac{4}{3}\pi \cdot r_1^3 \approx 1.32 \times 10^9 kg \tag{1}$$

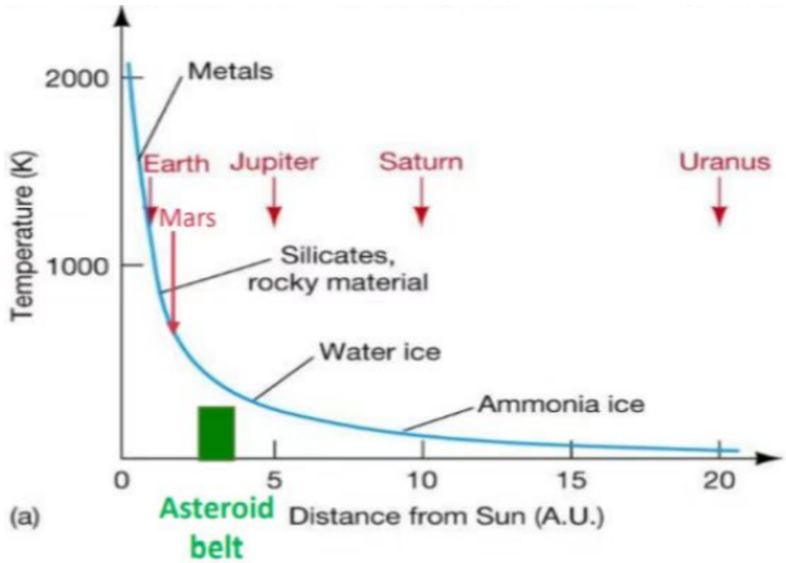


Figure 1: the composition of asteroids in the solar system

3.2 The Earth or the Sun

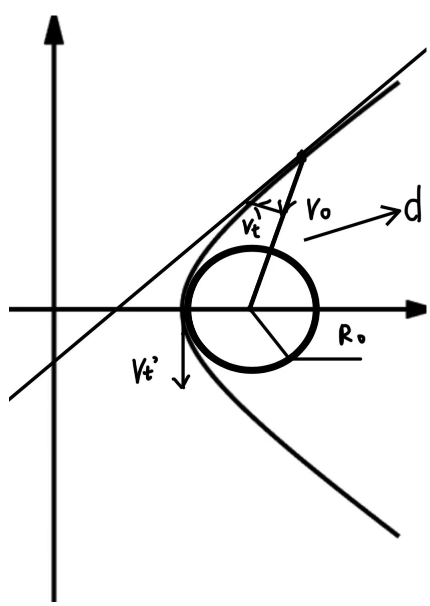
For this question, the first analysis needs to be whether the sun's gravitational pull on the asteroid or the Earth's gravitational pull on the asteroid is dominant. If the spacecraft is close to the Earth when it hits the asteroid, the earth's gravity on the asteroid is much greater than the sun's gravity on the asteroid, so the sun's gravitation can be ignored. Next, based on this assumption, we will estimate the closest distance a spacecraft will get to the Earth when it hits the asteroid so that it will not hit the Earth.Since it is only estimation, we only consider the order of magnitude of its value in this part of numerical calculation, and do not care about its exact value.From the information given in the question, we can know that when the asteroid hit the Earth, its velocity relative to the Earth was 25km/s.Now, if we take infinity as the zero of the potential energy, then when the asteroid hits the Earth, its gravitational potential energy will be

$$E_p = -\frac{GM_0M_1}{r_0} \approx -10^{16}J \tag{2}$$

and its kinetic energy is

$$E_k = \frac{1}{2}M_1v^2 \approx 10^{17}J \tag{3}$$

From this, we can see that the change in gravitational potential energy relative to kinetic energy is puny at different points during the asteroid's journey towards Earth.In addition, because the asteroid satisfies the law of conservation of energy in this process, the kinetic energy change of the asteroid is small, that is, the change of its velocity is small and can be ignored. Therefore, in this estimation process, it is approximately believe that the velocity of the asteroid remains unchanged.By observing the earth velocity of the asteroid, it can be found that the velocity of the asteroid relative to the Earth is greater than the second cosmic velocity, so its trajectory is one of the hyperbolic curve with the focus of the Earth.In order to facilitate estimation, we make the following provisions:1. When a spacecraft is not on a collision course with an asteroid, we think the asteroid's velocity is pointing towards Earth.2. We think that when the spacecraft is on a collision with the asteroid, the spacecraft's velocity with respect to the asteroid is perpendicular to the direction of the asteroid's line with Earth.3. According to the data, the maximum speed reached by the man-made satellite is 200km/s, In order to find the closest distance of the spacecraft to the Earth when it hits the asteroid, we set the velocity of the spacecraft relative to the asteroid as large as possible, take $v_{craft} = 200km/s$.4. In order to obtain the closest distance from the Earth when the spacecraft impacts the asteroid, we consider the limiting case, that is, we believe that the distance from the nearest point of the earth's center in the asteroid's trajectory after the collision between the spacecraft and the asteroid is one Earth radius.5. It is believed that the collision process between the spacecraft and the asteroid is a spacecraft crash and stay on the asteroid, that is, we believe that the collision process is a completely inelastic collision.6. To find the closest distance a spacecraft will get to the Earth when it hits an asteroid, we should make the spacecraft as massive as possible.Now let's think about the limit case, where we think the spacecraft is going to the asteroid without any loss of mass in terms of fuel or anything, and it still has its original mass,m_{craft}.(Of course, this is not possible in reality, and this is just for estimation purposes)7. Because the asteroid mass m_1 is much larger than the spacecraft mass m_{craft}, m_{craft} can be ignored compared with m_1. Therefore, it is believed that the combined mass of the two collisions is still m_1.



Below, based on the above rules, the closest distance to Earth when the spacecraft hits the asteroid is estimated.First, consider the collision process between the spacecraft and the asteroid. Since we define the collision process as a completely inelastic collision, the collision process satisfies the momentum conservation law:

$$m_{craft} \cdot v_{craft} = (m_{craft} + m_1) \cdot v_t \tag{4}$$

Where, v_t represents the velocity along the vertical direction of the line between the asteroid and the Earth after the collision between the spacecraft and the asteroid, which can be obtained$v_t \approx 4m/s$For an asteroid, it is only affected by the Earth's gravitation force, which is a force. Therefore, in the whole process of motion after the collision, the asteroid satisfies the law of conservation of angular momentum relative to the Earth, as:

$$m_1 \cdot d \cdot v_t = m_1 \cdot r_0 \cdot v_t' \tag{5}$$

$v_t'$is the velocity of the asteroid when it is on a tangent to Earth, and d is the distance from Earth when the spacecraft collides with the asteroid.At the same time, in this process, the asteroid also satisfies the law of conservation of energy, namely:

$$\frac{1}{2}m_1(v_0^2 + v_t^2) - \frac{GM_0M_1}{d} = \frac{1}{2}M_1 v_t'^2 - \frac{GM_0M_1}{r_0} \tag{6}$$

We can find both equations (5) and (6) and get$d \approx 5 \cdot 10^{10} m$At this point, we verify that the results satisfy our original hypothesis that the spacecraft was close to Earth when it hit the asteroid, and that the Earth's gravity on the asteroid is much greater than the sun's. The sun's gravitational pull on the asteroid is

$$F_{sun} = \frac{GM_{sun}M_1}{(d+R)^2} \approx 10^6 N \tag{7}$$

And the Earth's gravitational pull on the asteroid is

$$F_e = \frac{GM_0M_1}{d^2} \approx 10^2 N \tag{8}$$

It can be seen that at this time, the gravitational force of the sun on the asteroid is much larger than that of the Earth on the asteroid, which contradicts the hypothesis. Therefore, the gravitational force of the sun on the asteroid should play a dominant role in the motion process we study. Therefore, based on the above analysis, we will take the sun as the central object in the future model discussion, and appropriately ignore the effect of Earth's gravity on asteroids and spacecraft.

3.3 The velocity and mass of the spacecraft after the acceleration process are discussed

Next, we discuss the velocity and remaining mass of a spacecraft as it escapes Earth's gravitational bonds and enters orbit around the solar system.Assuming that the spaceship engine gains forward power by ejecting gas backward, the velocity formula of the spaceship after the acceleration process can be derived as

$$v_t = v_{1st} + u \ln \frac{m_c}{m_t} \tag{9}$$

Where v_t represents the final velocity of the spacecraft acceleration process, v_0 represents the initial velocity of the spacecraft acceleration process, that is, the linear velocity of the spacecraft in low-Earth orbit $v_0 = 7.9 \times 10^3 m/s$, m_t represents the remaining mass of the spacecraft after acceleration.The value of u depends on the type of engine. The current engine technology can make $u = 4 \times 10^3 m/s$ at most.The discussion in this paper will use this value. To make the most impact with the asteroid, we want the spacecraft to leave the Earth with maximum momentum, from

$$p = m_t \cdot v_t = m_t \cdot (v_0 + u \ln \frac{m_c}{m_t}) \tag{10}$$

Take the derivative of both sides of equation,we get

$$\frac{dp}{dm_t} = v_0 + ln\frac{m_c}{m_t} - u \tag{11}$$

By observing equation (13), it can be found that when $m_t < m_c$(Because the acceleration process consumes fuel, the spacecraft must end up with less mass than it started with.)The derivative value is always greater than zero, that is, the smaller the fuel mass consumed, the greater the momentum of the spacecraft after the completion of the acceleration process.In addition, in order for a spacecraft to fly to an asteroid anywhere in the solar system, its velocity relative to Earth must be at least greater than the velocity of the third universe,$v_{3nd} = 1.68 \times 10^4 m/s$So the best we can hope for is a spacecraft that uses the least amount of energy just enough to reach the third cosmic velocity$v_t = V_{3rd} = 1.68 \times 10^4 m/s$In this case, we can calculate the remaining mass of the spacecraft after it has completed the acceleration process,$m_t = 2.161 \times 10^3 kg$

3.4 To explore the original motion of the asteroid

To find where a spacecraft will strike an asteroid, it is necessary to figure out what the asteroid's path would be like without the impact of a spacecraft.In considering the path of an asteroid, we ignore the influence of the Earth's gravity.There's not a lot of information given about the asteroid's trajectory. The only certain information is that the asteroid must eventually hit the Earth vertically at a speed of 25km/s relative to the Earth.Therefore, the known position and velocity information can be used to push back the asteroid's trajectory.

As shown in the figure, we consider the Angle $\theta(0^\circ \leq \theta \leq 360^\circ)$ between the direction of the asteroid's velocity with respect to the Earth at the time of impact and the direction of the Earth's velocity with respect to the sun.According to the law of cosines, we can find that the velocity of the asteroid with respect to the sun is

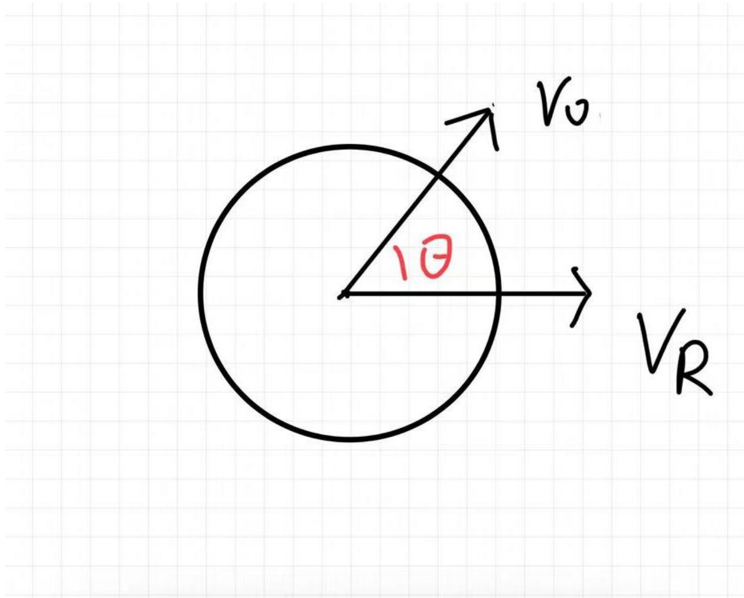
$$v_a = \sqrt{{v_0}^2 + {v_R}^2 + 2 \cdot v_0 \cdot v_R \cos\theta} \tag{12}$$

At the same time, we can get the orbital energy of the asteroid when the sun is the center of the object

$$E = \frac{1}{2} M_1 \cdot v_a^2 - \frac{G M_{sun} M_1}{R} \tag{13}$$

Put the specific value into the formula, can get

$$E = 9.834 \times 10^{17} \cdot \cos\theta - 1.695 \times 10^{17} \tag{14}$$

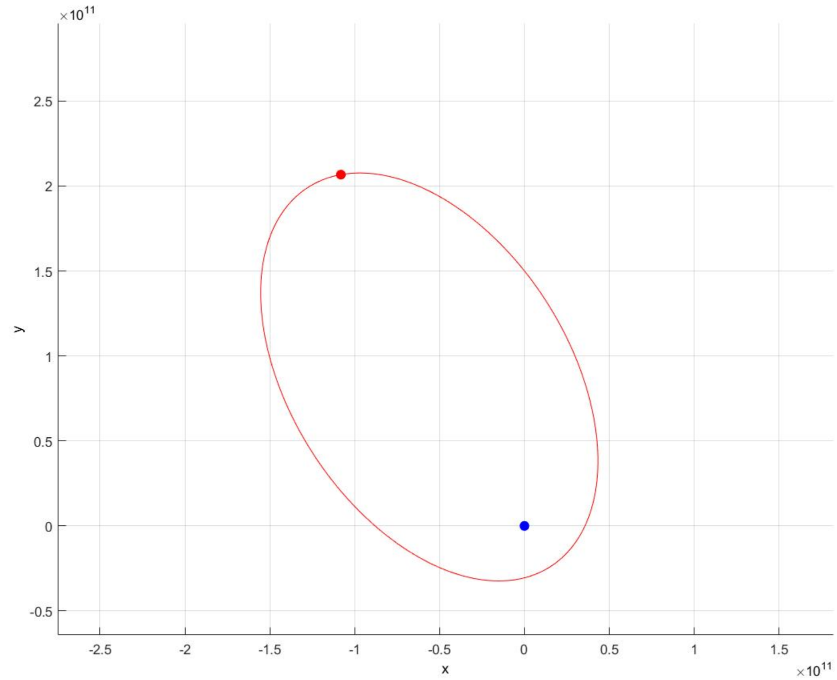


Observing this expression, we can see that,when $\theta = 80°$or $280°$,$E = 0J$.At this time, the asteroid's orbital energy is 0, and the asteroid's trajectory is a parabola with the focus of the sun.when $0° \leq \theta < 80°$ or $280° < \theta < 360°$,$E > 0J$In this case, the asteroid's orbital energy is greater than 0, and the asteroid's trajectory is one of the hyperbolic branches where one of the focal points is the sun. When $80° < \theta < 280°$,$E < 0J$.At this point, the orbital energy is less than 0, and the asteroid's trajectory is one where one focus is the sun's ellipse.Based on the above discussion, we can find that in theory, there are three main possibilities for the asteroid's motion path, namely ellipse, hyperbola and parabola.However, the value derived from the theory inevitably has more or less small errors, so in practice, it is almost impossible for us to make the orbit energy of the asteroid strictly equal to 0, as long as there is a small deviation, its trajectory will become an ellipse or hyperbola, rather than a strict parabola.Therefore, in the following model discussion, we will only discuss the two cases where the asteroid's motion path is elliptical or hyperbolic.

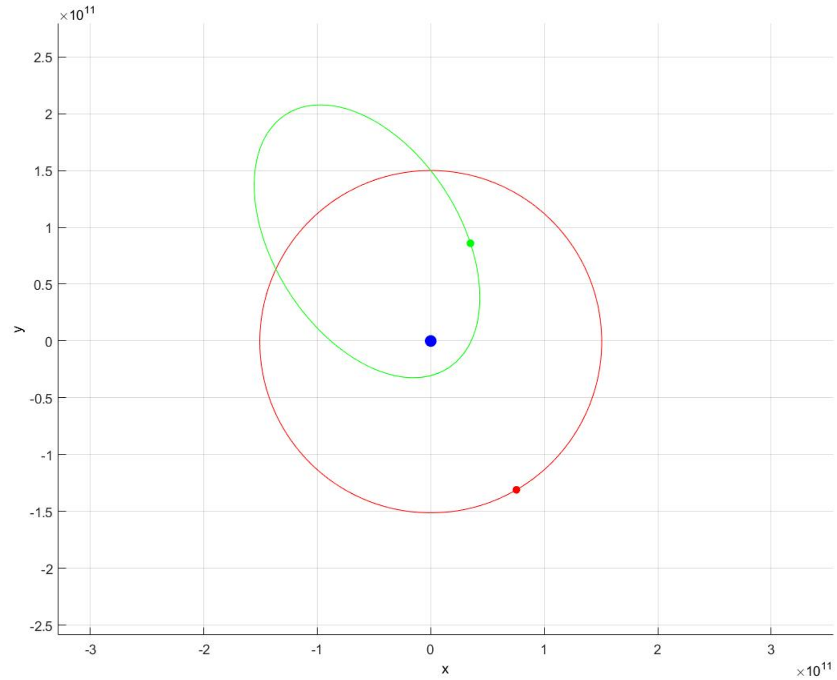
3.5 Explore collisions in two asteroid motion states

3.5.1 The original motion of the asteroid is elliptical

Next, we consider the situation that the original motion path of the asteroid is an ellipse, that is, the Angle between the asteroid's velocity direction relative to the Earth and the Earth's velocity direction relative to the sun is$80° < \theta < 280°$MATLAB software is used to simulate the original motion path of the asteroid when the Angle is θ,



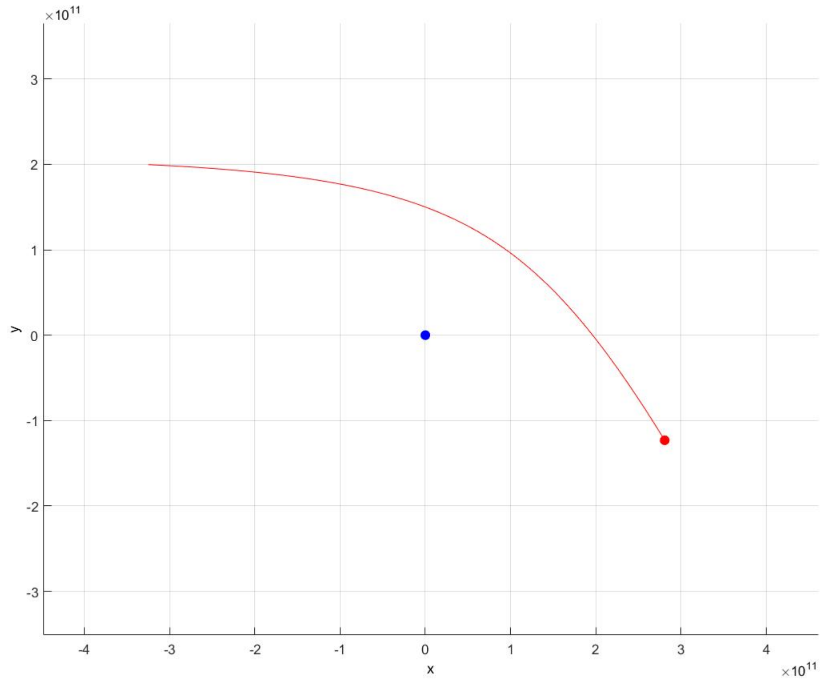
And verify that the asteroid's trajectory does not pass through the area within the radius of the sun, that is, it is actually possible for the asteroid to hit the Earth along this trajectory.Starting from the$\theta = 81°$,ncrease one degree at a single time,validation in$80° < \theta < 280°$area can each asteroid hit the Earth without being blocked by the sun.It is verified that in the area of $80° < \theta < 280°$,it is possible that an asteroid hitt the Earth. What we need to clear is that when the asteroid's orbit is an ellipse and its orbit for a hyperbolic when there is a huge difference, when one of the asteroid's orbit for the hyperbolic for asteroids orbit earth orbit in one of the intersection, the asteroid will only after that point, and then will fly to infinity, no longer come back, so, As long as the asteroid successfully avoids the collision with the earth at the intersection of the first time, then the asteroid will never hit the Earth, we can avoid the collision with the Earth by the spacecraft.However, when the asteroid's orbit is an ellipse, it will always do periodic motion around the sun, that is to say, as long as the asteroid's orbit has intersection with the earth's orbit, so in the absence of other factors, the asteroid will through its infinite time and the intersection of earth's orbit, even after the intersection point for the first time an asteroid success away from the earth, However, as long as the time span is large enough, the asteroid will always collide with the Earth. Therefore, we can believe that as long as the orbit of the asteroid still intersects with the orbit of the Earth after the spacecraft impacts the asteroid, the impact will not miss the Earth.



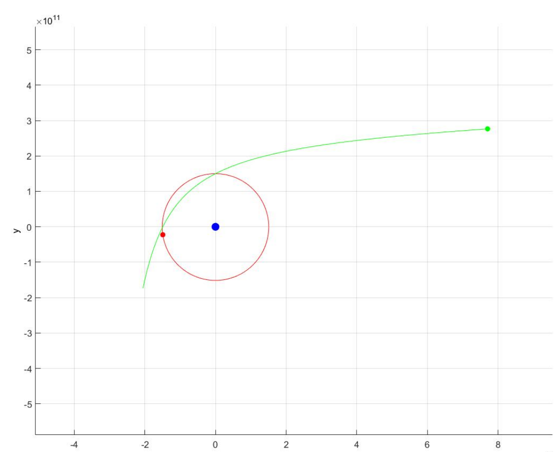
With that information in mind, let's consider the process of a spacecraft hitting an asteroid. In 3.2 we have found that the velocity change provided to the asteroid by a spacecraft impacting the asteroid is a small amount compared to its original velocity.At the same time, because asteroids are confined to a small elliptical orbit, we can't increase the displacement effect of small changes in velocity by hitting a spacecraft at a great distance to stretch the time span.Therefore, in this case, a spacecraft impact on an asteroid can cause the asteroid's orbit to be very small deviation, much less the collision after the asteroid's orbit does not intersect the Earth's orbit.
Based on the above discussion in this part, we can draw the conclusion that the Angle between the direction of the asteroid's velocity relative to the Earth and the direction of the Earth's velocity relative to the sun is$\theta(80^\circ < \theta < 280^\circ)$That is, when the original motion path of the asteroid is an ellipse, we can't make the asteroid not collide with the earth by using spacecraft to impact the asteroid.

3.5.2 The original orbits of asteroids are hyperbolic

Now, we consider the case where the asteroid's original orbit is one side of the hyperbola, that is, the Angle between the asteroid's velocity with respect to the Earth and the Earth's velocity with respect to the sun is $\theta(0^\circ < \theta < 80^\circ$or $280^\circ < \theta < 360^\circ)$.First of all, we simulate the original motion path of the asteroid when the Angle is θ through MATLAB software.



And verify that the asteroid's trajectory does not pass through the area within the radius of the sun, that is, it is actually possible for the asteroid to hit the Earth along this trajectory.Start at $\theta = 79°$and increase by one degree at a time, verifying at $-80° < \theta < 80°$.It has been verified in the area of $-80° < \theta < 80°$,The possibility of an asteroid impact in the $79°$ region is all realistic.



Now, let's consider the velocity and mass of the spacecraft when it hits the asteroid.. In part3.3, we have discussed and calculated the mass m_t of the spacecraft and its velocity relative to the earth when it escapes from the gravitational influence of the earth and its velocity relative to the earth. Since the linear velocity of the Earth relative to the sun is v_R, the maximum value of the spacecraft's velocity relative to the sun when it leaves the earth is

$$v_{craft} = v_r + v_t = 4.66 \times 10^4 \tag{15}$$

The mass of the spacecraft remained the same throughout the rest of the journey.In the process of the spacecraft from the earth to the asteroid, the spacecraft always satisfies the law of conservation of energy. Therefore, if the spacecraft and the asteroid collide at the distance r_{hit} from the sun, the velocity v_1 of the spacecraft before the collision is satisfied

$$\frac{1}{2}m_{craft} \cdot (v_1)^2 - \frac{GM_{sun}m_{craft}}{r_{hit}} = \frac{1}{2}m_{craft} \cdot {v_{craft}}^2 - \frac{GM_{sun}m_{craft}}{R} \tag{16}$$

So we have the relationship between the velocity v1 of the spacecraft before the collision and the distance from the sun

$$v_1 = \sqrt{{v_{craft}}^2 + \frac{GM_{sun}m_{craft}}{r_{hit}} - \frac{2GM_{sun}}{R}} \tag{17}$$

Next, let's consider the collision between the spacecraft and the asteroid, which we still think of as a completely inelastic collision, where the spacecraft crashes into the asteroid. In part3.2 we have found that the spacecraft asteroids, its velocity change for an asteroid is far less than the original speed of the asteroid itself, therefore, after the asteroid along the direction of original speed change quantity can be neglected, and the impact after the asteroid raw speed vertical velocity change is more important, so, here, We make the most dramatic changes in the asteroid's trajectory by directing the spacecraft to hit the asteroid perpendicular to its original direction of travel.During the collision, the system formed by the asteroid and the spacecraft satisfies the law of conservation of momentum in the vertical direction of the original velocity of the planet,so we have

$$m_{craft} \cdot v_1 = (M_1 + m_{craft})v_2 \tag{18}$$

Substitute equation (17) into Equation (18),We end up with a velocity change after the impact of the asteroid

$$v_2 = \frac{m_{craft}}{M_1 + m_{craft}} \cdot \sqrt{{v_{craft}}^2 + \frac{GM_{sun}m_{craft}}{r_{hit}} - \frac{2GM_{sun}}{R}} \tag{19}$$

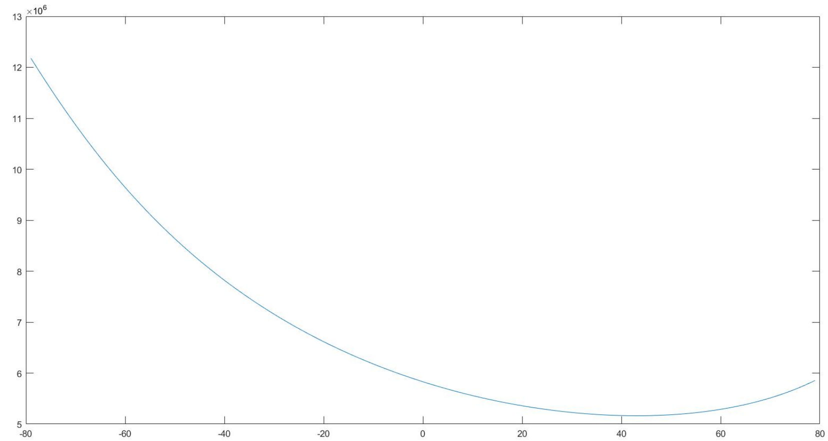
The velocity change direction is perpendicular to the original velocity of the planet, In the direct direction, by plugging in the quantity of each known quantity,we get

$$v_2 = 1.637 \times 10^-6 \cdot \sqrt{2.172 \times 10^9 + 2.655 \times 10^{20} \cdot \frac{1.5 \times 10^{11} - r_{hit}}{1.5 \times 10^{11} r_{hit}}} \tag{20}$$

For an asteroid that hits the Earth at an Angle of $\theta(-80^\circ < \theta < 80^\circ)$, we have just worked out its orbit using MATLAB software, and based on the theoretical derivation, we have worked out the amount of change in the asteroid's velocity when the spacecraft and the

asteroid collide at a certain point in the orbit.(That's because as long as the orbit is fixed, the distance from the Sun is fixed, and the change in the asteroid's velocity can be determined)Therefore, we can use MATLAB software to simulate the asteroid's motion trajectory after the asteroid's velocity increases this change amount, and judge whether the closest distance from the center of the earth is greater than 10^7m in the process of motion,whether the asteroid has successfully avoided a collision with Earth.(The evaluation criterion of whether the asteroid colliates with the Earth mentioned above is whether the distance from the center of the earth is less than 10^7m)With multiple simulations using the dichotomy method, we can zoom in to get the closest distance to the original asteroid's point of impact that would allow the asteroid to avoid collision with Earth.We take the width of this closest range as 10^7m,that is, about the length of a radius of the Earth. Since the point of collision between the spacecraft and the asteroid should be far away from the Earth, we have previously analyzed that for this distance, a range width of the order of the radius of the Earth is relatively accurate.Once we have obtained the closest distance between the spacecraft's impact point and the original asteroid's impact point, we can also use this to figure out how long it took the asteroid between the original impact point of the spacecraft and its impact with the Earth.
After obtaining the minimum time t corresponding to a certain included Angle θ,We start at $\theta = -79°$ and increase by one degree at a time to find the shortest time t for each θ in the region of $-80° < \theta < 80°$,in this way, the scatter plot is obtained. After fitting it with the smooth curve, the functional relation image of the Angle θ between the velocity direction of the earth and the velocity direction of the earth relative to the sun at the time of the shortest time t and the asteroid impact is obtained as shown in the following figure.

According to the graph information we can get,when $\theta \approx 40°$the time required is the



shortest,

$$t \approx 5 \times 10^6 s \approx 58days \tag{21}$$

when $\theta \approx -80°$, the time requred is longest,

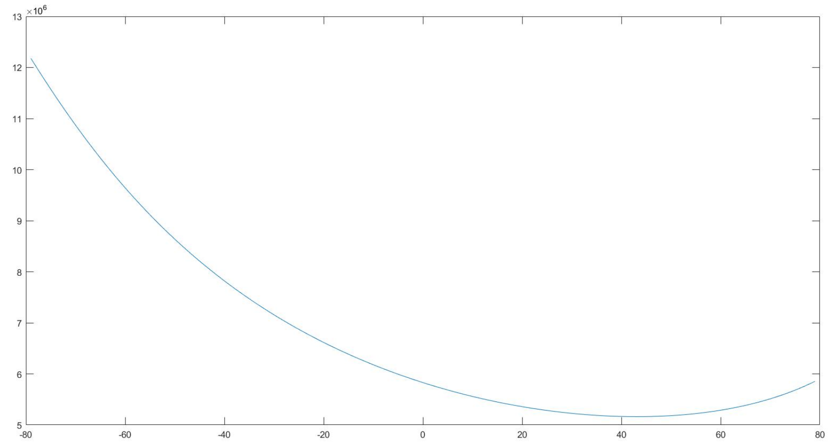
$$t \approx 1.2 \times 10^7 s \approx 139days \tag{22}$$

3.6 Consider the case of asteroids made of broken rock

Considering the formation process of the asteroid mentioned above, combined with the composition of the asteroid, it can be concluded that the asteroid is not necessarily close to a solid sphere, but may also be composed of space debris represented by broken rock.Refer to the data, when the asteroid is composed of a large number of broken rock, spacecraft and asteroid impact, a large number of broken rock in the asteroid will split and fly into space, in such a case, the force of each broken rock is extremely complex, difficult to simple modeling calculation.And the "engine" thrust generated by this process will make the asteroid's orbit deflection easier in most cases, so in this paper, we will only describe it qualitatively.

4 Conclusion

Based on the above discussion, analysis and calculation, we can conclude that when a spacecraft with a mass of 20,00kg in low Earth orbit hits an asteroid with a diameter of 100m, there are two possible scenarios.In one case, the asteroid is made of loose rubble, and a spacecraft colliding with it would disintegrate.The other scenario is that the asteroid is a tight ball of rock with which the spacecraft would collide in a completely inelastic collision. For the first type, due to its relatively complex composition, it is difficult for us to model and accurately calculate the motion of the debris, but we can find qualitatively that the general collision disturbance can easily make it deviate greatly from the original orbit and avoid the collision with the Earth.In the second case, we can first find that the asteroid's orbit may be an ellipse, a parabola, or a hyperbola, and it could hit the Earth at any Angle $\theta(0^\circ \leq \theta \leq 360^\circ)$ from the direction of the Earth's velocity with respect to the sun.When the orbit of an asteroid is parabolic, its requirements on the orbit energy of the asteroid are too strict, which is basically impossible to achieve, so we do not consider this case. Asteroids orbit is elliptical, because as long as the asteroid's orbit and the earth's orbit intersection point between the two, in a larger time scales asteroid will collide with the earth, so we think that when the asteroid's original trajectory is an ellipse, we can't through the way of using the spacecraft asteroids that an asteroid colliding with earth, not. When the asteroid's orbit is a branch of the hyperbola, we calculate the minimum time t required from the collision point of the asteroid with the spacecraft to the original collision point of the asteroid with the function of the Angle θ between the asteroid's velocity direction relative to the earth and the earth's velocity direction relative to the sun, as shown in the figure.When $\theta \approx 40$,the time required is the shortest,$t \approx 5 \times 10^6 \approx 58days$,when $\theta \approx 80$,the time required is the longest,$t \approx 1.27 \times 10^7 \approx 139days$



5 Strengths And Weaknesses

5.1 Strengths

- (1)The model is relatively simple and easy to simulate.
- (2)As MATLAB was used for modeling and drawing, The model is able to visualize the entire process and calculation results, easy for readers to understand.
- (3)Aiming at the complex asteroid collision problem, this paper is divided into the composition of the asteroid, the orbit of the asteroid and the earth, the flight of spacecraft and its impact on the asteroid and other aspects to solve the problem, thinking clearly.

5.2 Weakness

- (1) There are many complex factors in the model, which cannot be fully considered. For example:The motion path of the asteroid given in the title may not coincide with the ecliptic plane, which will greatly increase the complexity of the calculation of the possible collision between the Earth and the asteroid, but we did not consider this factor in order to simplify the calculation.
- (2) When the asteroid is close to the Earth, the earth's gravity to the asteroid becomes not negligible. However, in our calculation, we always consider only the influence of the sun on the asteroid's gravity.
- (3) When the motion path of the asteroid is elliptical, there may be some circumstances that make the asteroid and the Earth not collide for a long time during the revolution, but this paper does not discuss in detail.
- (4)In this paper, the method of classification discussion has been adopted for many times to consider the problem comprehensively.

6 References

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Appendices

Appendix A MATLAB Scripts

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asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m

```
function asteroids(Theta,m,r,t)  %Theta=1~200;M,r为小行星数据；t为模拟的时
AU=1.5e11;  %地日距离
Position_sun=[0 0 0];  %太阳的坐标位置
R=6.955e8;  %太阳半径
M=1.989e30;  %太阳质量
Position1=[0 AU 0];  %航天器起始位置
V_se=[-2.98e4 0 0];  %地日相对速度
Va=[-2.5e4*cosd(Theta) 2.5e4*sind(Theta) 0];
V=V_se+Va;  %航天器相对于太阳速度
Rc=r+R;  %相撞距离
G=6.67e-11;  %万有引力常数

j=0;  %循环开始的点
colordef white
figure
grid on
hold on
axis equal
p1=plot3(Position1(1),Position1(2),0,'r:.','markersize',25);
p2=plot3(Position_sun(1),Position_sun(2),0,'b:.','markersize',25);
h1=animatedline('color','r','MaximumNumPoints',5000);
xlabel('x');
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %实时距离
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\asteroids.m

asteroids.m earth1.m find_point.m if_collsion.m look_for_t.m loop

```
xlabel('x');
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %实时距离
    F_len=G*M*m/r12^2;  %力的大小
    F_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力的方
    a=(F_len.*F_dir)/m;  %加速度
    V=a*t+V;  %加速后的速度
    Position1=V*t+Position1;  %t时间后，航天器的位置
    j=j+1;  %绘图
    while j==10
        j=0;
        set(p1,'Xdata',Position1(1),'Ydata',Position1(2),'Zdata',0);
        set(p2,'Xdata',Position_sun(1),'Ydata',Position_sun(2),'Zdata',0);
        addpoints(h1,Position1(1),Position1(2),0);
        drawnow;
    end
    disp(V);
    disp(Position1);
    if r12<Rc  %检查相撞
        break
    end
end
string={'相撞'};
title(string);
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\earth1.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m

```
function earth1(Theta,m1,m2,t)  %1为地球，2为小行星。
AU=1.5e11;  %地日距离
Position_sun=[0 0 0];  %太阳的坐标位置
M=1.989e30;  %太阳质量
Position1=[0 AU 0];  %地球起始位置
Position2=Position1;  %小行星起始位置
V1=[-2.98e4 0 0];  %地日相对速度
Va=[-2.5e4*cosd(Theta) 2.5e4*sind(Theta) 0];
V2=V1+Va;  %小行星对日速度
G=6.67e-11;  %万有引力常数

j=0;  %循环开始的点
colordef white
figure
grid on
hold on
axis equal
p1=plot3(Position1(1),Position1(2),0,'r:.','markersize',20);
p2=plot3(Position2(1),Position2(2),0,'g:.','markersize',20);
p3=plot3(Position_sun(1),Position_sun(2),0,'b:.','markersize',30);
h1=animatedline('color','r','MaximumNumPoints',5000);
h2=animatedline('color','g','MaximumNumPoints',5000);
xlabel('x');
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\earth1.m

+1 asteroids.m earth1.m find_point.m if_collsion.m look_for_t.m loop

```matlab
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
    Position2=V2*t+Position2;  %小行星位置
    j=j+1;  %绘图
    while j==100
        j=0;
        set(p1,'Xdata',Position1(1),'Ydata',Position1(2),'Zdata',0);
        set(p2,'Xdata',Position2(1),'Ydata',Position2(2),'Zdata',0);
        set(p3,'Xdata',Position_sun(1),'Ydata',Position_sun(2),'Zdata',0);
        addpoints(h1,Position1(1),Position1(2),0);
        addpoints(h2,Position2(1),Position2(2),0);
        drawnow;
    end
end
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\asteroids.m

asteroids.m earth1.m find_point.m if_collsion.m look_for_t.m find_point

```
function asteroids(Theta,m,r,t)  %Theta=1~200;M,r为小行星数据；t为模拟的时间间隔。
AU=1.5e11;  %地日距离
Position_sun=[0 0 0];  %太阳的坐标位置
R=6.955e8;  %太阳半径
M=1.989e30;  %太阳质量
Position1=[0 AU 0];  %航天器起始位置
V_se=[-2.98e4 0 0];  %地日相对速度
Va=[-2.5e4*cosd(Theta) 2.5e4*sind(Theta) 0];
V=V_se+Va;  %航天器相对于太阳速度
Rc=r+R;  %相撞距离
G=6.67e-11;  %万有引力常数

j=0;  %循环开始的点
colordef white
figure
grid on
hold on
axis equal
p1=plot3(Position1(1),Position1(2),0,'r:.','markersize',25);
p2=plot3(Position_sun(1),Position_sun(2),0,'b:.','markersize',25);
h1=animatedline('color','r','MaximumNumPoints',5000);
xlabel('x');
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %实时距离
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\asteroids.m

+1 asteroids.m × earth1.m × find_point.m × if_collsion.m × look_for_t.m × find_point1.m × if_collsion

```
xlabel('x');
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %实时距离
    F_len=G*M*m/r12^2;  %力的大小
    F_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力的方向，从航天器指向太阳
    a=(F_len.*F_dir)/m;  %加速度
    V=a*t+V;  %加速后的速度
    Position1=V*t+Position1;  %t时间后，航天器的位置
    j=j+1;  %绘图
    while j==10
        j=0;
        set(p1,'Xdata',Position1(1),'Ydata',Position1(2),'Zdata',0);
        set(p2,'Xdata',Position_sun(1),'Ydata',Position_sun(2),'Zdata',0);
        addpoints(h1,Position1(1),Position1(2),0);
        drawnow;
    end
    disp(V);
    disp(Position1);
    if r12<Rc  %检查相撞
        break
    end
end
string={'相撞'};
title(string);
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\earth1.m

+1 | asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m | find_poi

```
function earth1(Theta,m1,m2,t)  %1为地球，2为小行星。
AU=1.5e11;  %地日距离
Position_sun=[0 0 0];  %太阳的坐标位置
M=1.989e30;  %太阳质量
Position1=[0 AU 0];  %地球起始位置
Position2=Position1;  %小行星起始位置
V1=[-2.98e4 0 0];  %地日相对速度
Va=[-2.5e4*cosd(Theta) 2.5e4*sind(Theta) 0];
V2=V1+Va;  %小行星对日速度
G=6.67e-11;  %万有引力常数

j=0;  %循环开始的点
colordef white
figure
grid on
hold on
axis equal
p1=plot3(Position1(1),Position1(2),0,'r:.','markersize',20);
p2=plot3(Position2(1),Position2(2),0,'g:.','markersize',20);
p3=plot3(Position_sun(1),Position_sun(2),0,'b:.','markersize',30);
h1=animatedline('color','r','MaximumNumPoints',5000);
h2=animatedline('color','g','MaximumNumPoints',5000);
xlabel('x');
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
```

```
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1); %地日实时距离
    r23=normest(Position_sun-Position2); %小行星和太阳距离
    F1_len=G*M*m1/r12^2; %地球引力的大小
    F2_len=G*M*m2/r23^2; %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1); %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2); %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1; %地球加速度
    a2=(F2_len*F2_dir)/m2; %小行星加速度
    V1=a1*t+V1; %地球加速时的平均速度
    V2=a2*t+V2; %小行星平均速度
    Position1=V1*t+Position1; %t时间后，地球的位置
    Position2=V2*t+Position2; %小行星位置
    j=j+1; %绘图
    while j==100
        j=0;
        set(p1,'Xdata',Position1(1),'Ydata',Position1(2),'Zdata',0);
        set(p2,'Xdata',Position2(1),'Ydata',Position2(2),'Zdata',0);
        set(p3,'Xdata',Position_sun(1),'Ydata',Position_sun(2),'Zdata',0);
        addpoints(h1,Position1(1),Position1(2),0);
        addpoints(h2,Position2(1),Position2(2),0);
        drawnow;
    end
end
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\find_point.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m | find_point1.m | if_c

```
axis equal
p1=plot3(Position1(1),Position1(2),0,'r:.','markersize',20);
p2=plot3(Position2(1),Position2(2),0,'g:.','markersize',20);
p3=plot3(Position_sun(1),Position_sun(2),0,'b:.','markersize',30);
h1=animatedline('color','r','MaximumNumPoints',3000);
h2=animatedline('color','g','MaximumNumPoints',3000);
xlabel('x');
ylabel('y');
zlabel('z');
%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
    Position2=V2*t+Position2;  %小行星位置
    j=j+1;  %绘图
    k=k+1;  %记录循环次数
    while j==100
        j=0;
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\find_point.m

asteroids.m earth1.m find_point.m if_collsion.m look_for_t.m find_point1.m if_collsi

```
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
    Position2=V2*t+Position2;  %小行星位置
    j=j+1;  %绘图
    k=k+1;  %记录循环次数
    while j==100
        j=0;
        set(p1,'Xdata',Position1(1),'Ydata',Position1(2),'Zdata',0);
        set(p2,'Xdata',Position2(1),'Ydata',Position2(2),'Zdata',0);
        set(p3,'Xdata',Position_sun(1),'Ydata',Position_sun(2),'Zdata',0);
        addpoints(h1,Position1(1),Position1(2),0);
        addpoints(h2,Position2(1),Position2(2),0);
        drawnow;
    end
    if normest(Position2-[0 AU 0])>L
        break
    end
end
T=t*k;
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\if_collsion.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m | find_point1.

```
function y=if_collsion(V1,V2,Position1,Position2,t)
%% 基础参数
AU=1.5e11;  %地日距离
Position_sun=[0 0 0];  %太阳的坐标位置
M=1.989e30;  %太阳质量
m1=5.965e24;  %地球质量
m2=1.32e9;  %小行星质量
G=6.67e-11;  %万有引力常数
Lmin=1000*AU;  %初始化小行星和太阳的最短距离
V1=-V1;  %速度反向
V2=-V2;
rc=normest(Position2-[0 0 0]);

%% 对小行星速度添加扰动
delta=1.637e-6*sqrt(2.172e9+2.655e20*(AU-rc)/(AU*rc));
cosa=V1(1)/sqrt(V1(1)^2+V1(2)^2);
sina=V1(2)/sqrt(V1(1)^2+V1(2)^2);
V1(1)=V1(1)-delta*sina;
V1(2)=V1(2)+delta*cosa;

%% 循环
j=0;  %循环开始的点
colordef white
figure
grid on
hold on
axis equal
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\if_collsion.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m | find_point1.m | if_

```matlab
%% 循环
j=0;  %循环开始的点
colordef white
figure
grid on
hold on
axis equal
p1=plot3(Position1(1),Position1(2),0,'r:.','markersize',20);
p2=plot3(Position2(1),Position2(2),0,'g:.','markersize',20);
p3=plot3(Position_sun(1),Position_sun(2),0,'b:.','markersize',30);
h1=animatedline('color','r','MaximumNumPoints',3000);
h2=animatedline('color','g','MaximumNumPoints',3000);
xlabel('x');
ylabel('y');
zlabel('z');
%% 计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\if_collsion.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m | find_point1.m | if_c

```
ylabel('y');
zlabel('z');
%% 计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
    Position2=V2*t+Position2;  %小行星位置
    %% 存储小行星与太阳的最短距离
    if r23-Lmin<0
        Lmin=r23;
    end
    %% 绘图
    j=j+1;
    while j==100
        j=0;
        set(p1,'Xdata',Position1(1),'Ydata',Position1(2),'Zdata',0);
        set(p2,'Xdata',Position2(1),'Ydata',Position2(2),'Zdata',0);
        set(p3,'Xdata',Position_sun(1),'Ydata',Position_sun(2),'Zdata',0);
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\if_collsion.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | look_for_t.m | find_point1.m

```
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
    Position2=V2*t+Position2;  %小行星位置
    %% 存储小行星与太阳的最短距离
    if r23-Lmin<0
        Lmin=r23;
    end
    %% 绘图
    j=j+1;
    while j==100
        j=0;
        set(p1,'Xdata',Position1(1),'Ydata',Position1(2),'Zdata',0);
        set(p2,'Xdata',Position2(1),'Ydata',Position2(2),'Zdata',0);
        set(p3,'Xdata',Position_sun(1),'Ydata',Position_sun(2),'Zdata',0);
        addpoints(h1,Position1(1),Position1(2),0);
        addpoints(h2,Position2(1),Position2(2),0);
        drawnow;
    end
    if normest(Position2-Position1)<1e7
        y=1;
        break
    elseif r23>2*AU
        y=0;
        break
    end
end
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\find_point1.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | find_point1.m | if_collsion1.m | reloop.m

```matlab
function [V1,V2,Position1,Position2,T]=find_point1(Theta,t,L)  %1为地球，2为小行星。
AU=1.5e11;  %地日距离
Position_sun=[0 0 0];  %太阳的坐标位置
M=1.989e30;  %太阳质量
m1=5.965e24;  %地球质量
m2=1.32e9;  %小行星质量
Position1=[0 AU 0];  %地球起始位置
Position2=Position1;  %小行星起始位置
V1=[-2.98e4 0 0];  %地日相对速度
Va=[-2.5e4*cosd(Theta) 2.5e4*sind(Theta) 0];
V2=V1+Va;  %小行星对日速度
G=6.67e-11;  %万有引力常数
k=0;  %循环次数初始化为0

%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\find_point1.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | find_point1.m | if_collsion1.m | reloop.m

```
V1=[-2.98e4 0 0];  %地日相对速度
Va=[-2.5e4*cosd(Theta) 2.5e4*sind(Theta) 0];
V2=V1+Va;  %小行星对日速度
G=6.67e-11;  %万有引力常数
k=0;  %循环次数初始化为0

%计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
    Position2=V2*t+Position2;  %小行星位置
    k=k+1;  %记录循环次数

    if normest(Position2-[0 AU 0])>L
        break
    end
end
T=t*k;
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\if_collsion1.m

asteroids.m earth1.m find_point.m if_collsion.m find_point1.m if_collsion1.m reloop.m

```
function y=if_collsion1(V1,V2,Position1,Position2,t)
%% 基础参数
AU=1.5e11;  %地日距离
Position_sun=[0 0 0];  %太阳的坐标位置
M=1.989e30;  %太阳质量
m1=5.965e24;  %地球质量
m2=1.32e9;  %小行星质量
G=6.67e-11;  %万有引力常数
Lmin=1000*AU;  %初始化小行星和太阳的最短距离
V1=-V1;  %速度反向
V2=-V2;
rc=normest(Position2-[0 0 0]);

%% 对小行星速度添加扰动
delta=1.637e-6*sqrt(2.172e9+2.655e20*(AU-rc)/(AU*rc));
cosa=V1(1)/sqrt(V1(1)^2+V1(2)^2);
sina=V1(2)/sqrt(V1(1)^2+V1(2)^2);
V1(1)=V1(1)-delta*sina;
V1(2)=V1(2)+delta*cosa;

%% 计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\if_collsion1.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | find_point1.m | if_collsion1.m | reloop.

```
%% 计算过程
for i=1:1e10
    r12=normest(Position_sun-Position1);  %地日实时距离
    r23=normest(Position_sun-Position2);  %小行星和太阳距离
    F1_len=G*M*m1/r12^2;  %地球引力的大小
    F2_len=G*M*m2/r23^2;  %小行星引力大小
    F1_dir=(Position_sun-Position1)/normest(Position_sun-Position1);  %力从地球指向太阳
    F2_dir=(Position_sun-Position2)/normest(Position_sun-Position2);  %力从小行星指向太阳
    a1=(F1_len*F1_dir)/m1;  %地球加速度
    a2=(F2_len*F2_dir)/m2;  %小行星加速度
    V1=a1*t+V1;  %地球加速时的平均速度
    V2=a2*t+V2;  %小行星平均速度
    Position1=V1*t+Position1;  %t时间后，地球的位置
    Position2=V2*t+Position2;  %小行星位置
      %% 存储小行星与太阳的最短距离
    if r23-Lmin<0
        Lmin=r23;
    end

    if normest(Position2-Position1)<1e7
        y=1;
        break
    elseif r23>2*AU
        y=0;
        break
    end
end
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\reloop.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | find_point1.m | if_collsion1.m | re

```matlab
for j=1:159
    Theta=-80+j;
    alpha(1)=0;
    beta(1)=1e12;
    t=50;
    for i=1:100
        [a,b,c,d,T]=find_point1(Theta,t,(beta(i)+alpha(i))/2);
        close;
        y(i)=if_collsion1(a,b,c,d,t);
        close;
        if y(i)==0
            alpha(i+1)=alpha(i);
            beta(i+1)=(alpha(i)+beta(i))/2;
        elseif y(i)==1
            alpha(i+1)=(alpha(i)+beta(i))/2;
            beta(i+1)=beta(i);
        end
        if abs(beta(i+1)-alpha(i+1))<1e7
            break
        end
    end
    A(j)=Theta;
    B(j)=T;
    disp(j);
end
```

编辑器 - C:\Users\TR\Desktop\美赛MATLAB\loop.m

asteroids.m | earth1.m | find_point.m | if_collsion.m | find_point1.m | if_collsion1.m

```
alpha(1)=0;
beta(1)=1e12;
for i=1:100
    [a,b,c,d,T]=find_point(-79,10000,(beta(i)+alpha(i))/2);
    close;
    y(i)=if_collsion(a,b,c,d,10000);
    close;
    if y(i)==0
        alpha(i+1)=alpha(i);
        beta(i+1)=(alpha(i)+beta(i))/2;
    elseif y(i)==1
        alpha(i+1)=(alpha(i)+beta(i))/2;
        beta(i+1)=beta(i);
    end
    if abs(beta(i+1)-alpha(i+1))<1e7
        break
    end
end
disp(T);
```