WRITTEN EXAM GAME PHYSICS

MAY 27, 2013

Student name:	Student number:

- This exam is 3 hours long and consists of 15 exercises.
- Calculators and official formulas sheet are allowed. Phones, books, personal notes and computers are not allowed.
- All the answers have to be written in the corresponding boxes. If needed, put your name and student number on each additional paper you hand in. Please answer in English.
- An explanation must be part of every answer. Simple or direct answers (such as “42” and “no”) will not be given any credit.
- Indicate the unit of every quantitative answer.

EXERCISE 1

Explain what the main advantage is, in games, of using physics over kinematics in order to animate objects.

EXERCISE 2

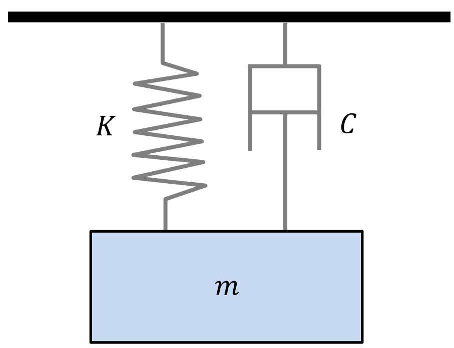
In a soccer game, the player is attempting a penalty kick at a distance of 11 meters from the goal. The ball reaches the goal in a straight line after 1 second. What was the average acceleration of the ball?

EXERCISE 3

We usually define the gravitation acceleration on Earth as $g = 9.81\ m/s^2$. Calculate at what altitudes the gravitation acceleration is respectively equal to 9.80 and 9.82 m/s^2.
Note: $m_{Earth} = 5.98 \times 10^{24}$ kg and $r_{Earth} = 6.377 \times 10^6$ m.

EXERCISE 4

In mechanics it is common to associate a damper with a spring to create a mass-spring-damper system and reduce the amplitude of oscillations. Imagine the following system, where $m = 1$ kg, $K = 12$ N/m, $C = 2.5$ kg/s and the rest length of the spring is 10 cm.



At a certain moment in time, due to gravity, the mass has a velocity of 0.9 m/s directed downwards and the length of the spring is 22 cm. What is the acceleration of the mass at that time?

EXERCISE 5

Suppose that the Earth is orbiting around the Sun at a constant distance $d = 1.5 \times 10^{11}$ m. The tangential linear velocity of the Earth on its orbit is $v = 29.89$ km/s and its mass is $m = 5.98 \times 10^{24}$ kg.

(a) Calculate the angular momentum L of the Earth around the Sun.
(b) Calculate its angular velocity ω.
(c) Convert ω into degree/day and confirm your answer using your general knowledge about the rotation of the Earth around the Sun.

(a) Angular momentum

(b) Angular velocity

(c) Angular velocity in degree/day

EXERCISE 6

Give a textual definition of the center of mass of an object.

EXERCISE 7

Knowing that the moment of inertia of a solid cylinder is given by $I = 2\pi\rho h\frac{r^4}{4}$, give the moment of inertia of a cylinder shell of radius r_1 and cylindrical cavity of radius r_2 (where $r_2 < r_1$). Conclude from it the moment of inertia of a hollow cylinder (*i.e.* surface cylinder).

Hints: $a^n - b^n = (a-b)(a^{n-1} + a^{n-2}b + \cdots + ab^{n-2} + b^{n-1})$
A shell can be constructed by subtraction of the two cylinders.

Exercise 8

Give two examples of constraints between rigid bodies that you can observe in a game. Indicate the type and number of degrees of freedom of each constraint.

Exercise 9

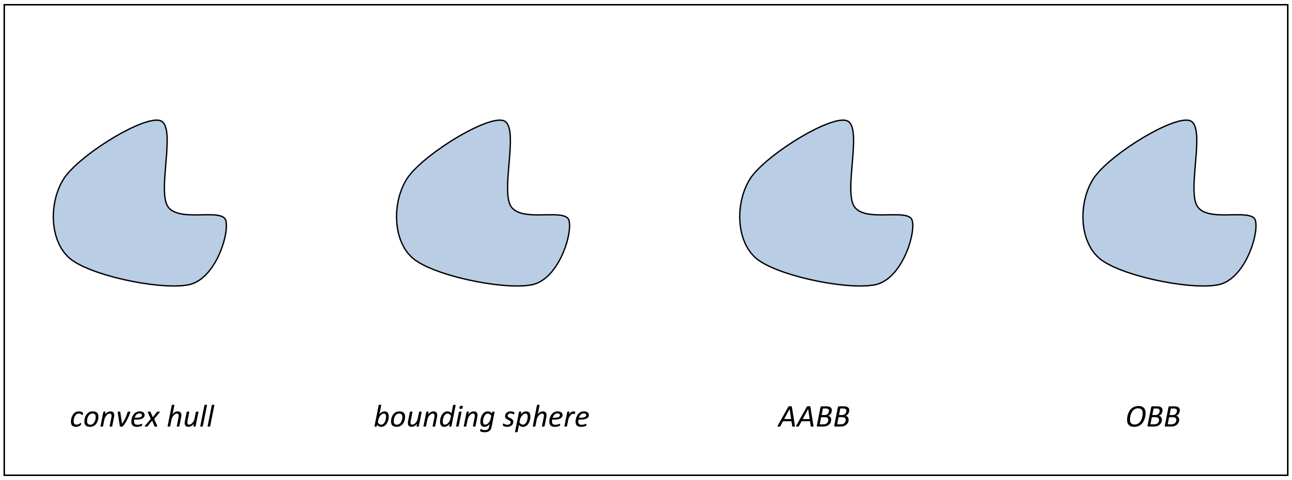
Assuming an immobile object located at $(2, 3)$. Starting at $t = 0$ second, we apply a force resulting in an acceleration $a(t, v) = (t, t^2)$. Calculate the position of the object after 1 and 2 seconds using the Verlet integration method and the semi-implicit integration method.

Verlet integration method

Semi-implicit integration method

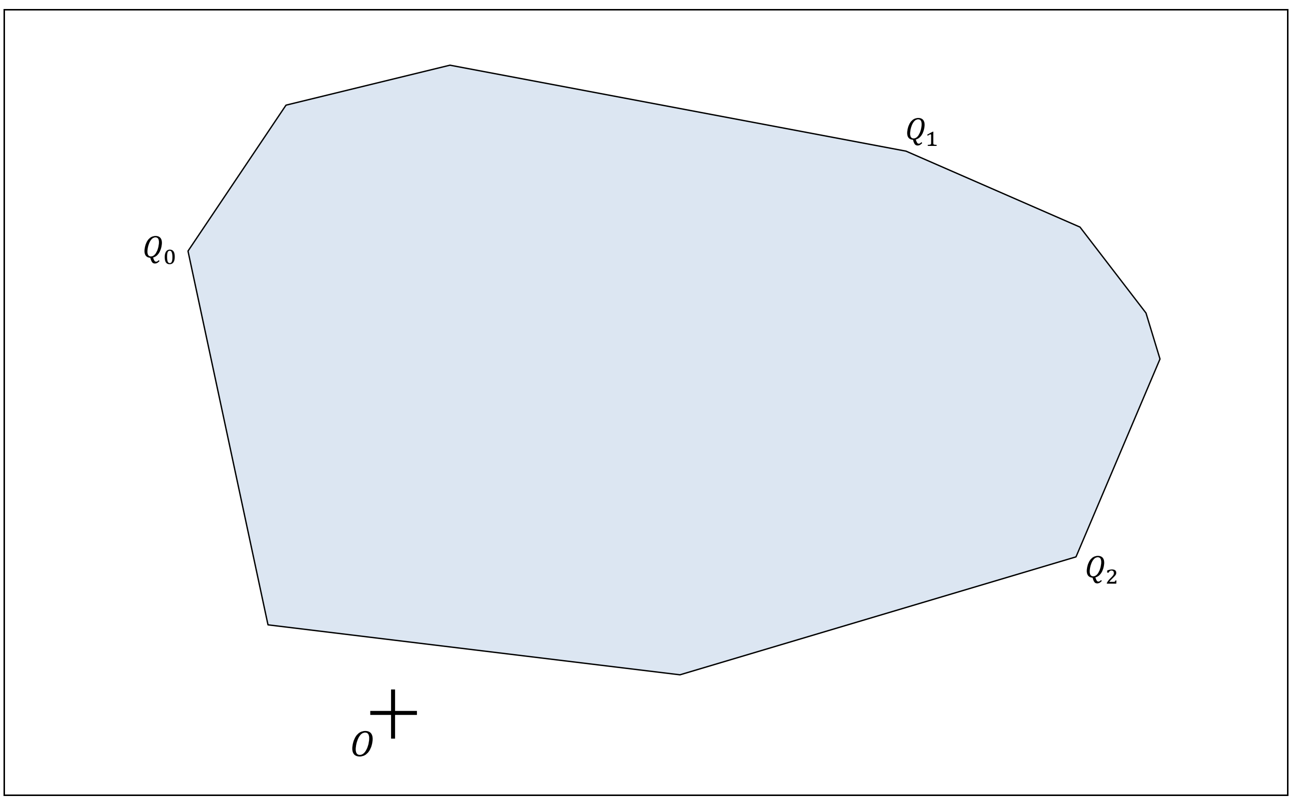
EXERCISE 10

Draw the respective bounding surfaces on the following 2D object.



EXERCISE 11

Execute two iterations of the GJK algorithm on the following object where $Q = \{Q_0, Q_1, Q_2\}$. Indicate where are P_1, V_1, P_2, V_2 and give the value of Q after the two iterations.



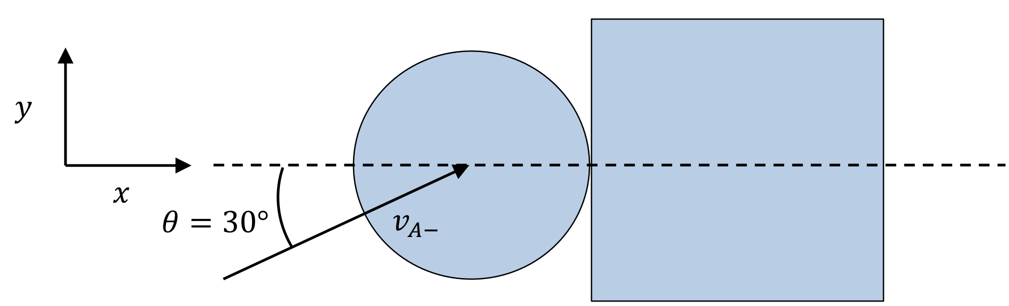
EXERCISE 12

Two objects A and B collide (without rotation) with incoming velocities v_{A-} and v_{B-} and velocities after collision v_{A+} and v_{B+}. Imagine that the same collision occurs again between the two objects but v_{A-} is now twice as large as during the previous collision. What can you say about the velocities after collision between the two collisions?

EXERCISE 13

Assuming the following objects, what are the velocities after collision of the ball A and the cube B?

The ball incoming speed is $v_{A-} = 5$ m/s, the coefficients of restitutions are both 0.6, the mass of the ball is 2 kg and the mass of the box is 1 kg.



EXERCISE 14

Imagine a player shooting a 2 cm wide cylindrical bullet straight into a flat target with a linear acceleration $a = 5\ m/s^2$. What is the stress produced by the bullet on the target if the mass of the bullet is $m = 50\ g$?

EXERCISE 15

Indicate the main difference between Lagrangian methods and Eulerian methods in their way of simulating soft bodies.