Question 1

A student traveling to Japan gets a little bored on the train journey and uses an app on their phone to measure that the Japanese bullet train "Shinkansen" accelerates from rest to a constant speed of 80 m/s in two phases. In the first phase, the acceleration is 2.0 m/s², and in the second phase, the acceleration is 1.0 m/s². The phases take the same amount of time.

How long does it take for the train to reach its constant speed?

Calculating the time for ONE of the phases:

*Ligningen løses for T vha. WordMat.*

Doubling by two:

A) 30 s

B) 37 s

C) 40 s

D) 50 s

**E) 53 s (correct answer)**

F) 62 s

G) 76 s

H) 80 s

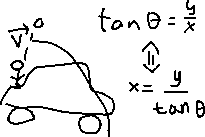
I) Ved ikke

Question 2

A car is driving at a constant speed on a horizontal road. A small child sitting in the back seat throws a small ball vertically upwards with a velocity, .

A person standing beside the road sees that when the ball is released from the child's hand, it has a velocity forming an angle, , with the horizontal.

What is the speed of the car?



It is , since that is the horizontal component of the velocity, given the vertical component…

A) 𝑣

B) 𝑣∙sin𝜃

**C**) 𝑣∙cos𝜃

D) 𝑣∙tan𝜃

E)

F)

**G) (correct answer)**

H) Don't know

Question 3

A car is driving at 100 km per hour on a flat, straight road. The static friction coefficient between the wheels and the road is 0.93. The wheels' moment of inertia, as well as air resistance on the car, can be neglected. The local acceleration due to gravity is 9.82 m/s².

What is the lower limit for the car's braking distance (to a stop) with this information, when it is solely braking via the wheels?

Velocity:

Breaking distance:

A) 37. m

**B) 42. m (correct answer)**

C) 63. m

D) 85. m

E)

F)

G) No lower limit if the braking system is properly designed.

H) Don't know

Question 4

A box with mass 𝑚 moves down a ramp with a smooth surface. The ramp forms an angle 𝜃 with the horizontal. A person pushes the box with a constant force 𝐹, whose direction forms an angle 𝜃 with the ramp.

Et billede, der indeholder linje/række, diagram, Font/skrifttype, design

Automatisk genereret beskrivelse

Which of the following equations represents Newton's second law along the ramp or perpendicular to the ramp?

Newton’s second law: .

There are two components in the -direction of the force:

Gravity:

Push:

There are three components in the -direction of the force:

Gravity:

Push:

Normal force:

A)

B)

C)

D)

E)

**F) (correct)**

G)

H)

I)

**J) (correct)**

K) Don't know

Question 5

A vintage car without anti-lock brakes is traveling on the highway at 30 m/s and needs to brake to a stop. Proper braking allows the wheels to roll throughout the deceleration. If the brakes are applied too hard, the wheels lock and skid across the road. The static and kinetic friction coefficients between the tires and the road are 1.0 and 0.7, respectively.

We need to determine the difference in braking distance between optimal braking and braking where the wheels lock throughout.

We can neglect air resistance, and assume that the braking distances are only limited by the friction between the tires and the road, not by other components in the braking system.

A) 14 m  
**B) 20 m (correct answer)**C) 28 m  
D) 39 m  
E) 45 m  
F) Don't know

Question 6.

[Continuation of the previous question]

Now, the car is assumed to be traveling up a sloping road, inclined at 5.00 degrees relative to the horizontal. Assuming the same velocity and friction coefficients as before, what is the minimum possible braking distance now with proper braking? Set the gravitational acceleration to 9.80 m/s².

Acceleration in the direction of normal force:

Tangential acceleration in the direction of down the slope:

Total deceleration:

A) 42.2 m  
**B) 42.4 m (correct answer)**  
C) 45.9 m  
D) 46.1 m  
E) 84.5 m  
F) 84.8 m  
G) Don't know

Question 7:

The human metabolism has an efficiency of about 25%, meaning around 25% of the energy in a given food consumed can theoretically be converted into mechanical energy. Mayonnaise has a caloric content of 830 kcal per 100 grams (1 kcal = 10^3 cal). In a particular fitness machine, a weight of 75 kg is lifted 45 cm vertically. The lifts occur slowly.

Approximately how many lifts are required on this machine to burn 20 grams of mayonnaise?

A) 53 lifts  
B) 88 lifts  
C) 106 lifts  
D) 125 lifts  
E) 131 lifts  
**F) 525 lifts (correct answer)**  
G) 1750 lifts  
H) 1690 lifts  
I) Don't know

Question 8:  
A student with a height of 2.00 meters and a mass of 90.0 kg is on vacation in the south and spends their time bungee jumping from a bridge, which is located 30.0 meters above a river. The elastic rope is 10.0 meters long in the unstretched state and has a spring constant, . The student's center of mass is located in the middle of the body, and the acceleration due to gravity can be set to . A y-axis is included in the figure below.

Et billede, der indeholder tekst, skærmbillede, diagram, linje/række

Automatisk genereret beskrivelse

What is the velocity in B, right before the elastic begins to stretch?

*Ligningen løses for t vha. WordMat.*

A) v = 11.1 m/s  
B) v = -14.0 m/s  
C) v = 14.0 m/s  
**D) v = -15.4 m/s (correct answer)**  
E) v = -10.2 m/s  
F) v = 10.2 m/s  
G) v = -11.1 m/s  
H) v = 15.4 m/s  
I) Don't know

Question 9

[Continuation of the previous question]

At figure C, the student's head has just reached the water, and luckily her velocity here is zero. What is the spring constant?

A) k = 112 N/m  
B) k = 81.4 N/m  
C) k = 77.4 N/m  
D) k = 56.2 N/m  
**E) k = 164 N/m**  
F) k = 1470 N/m  
G) Don't know

Question 10

Two balls collide as shown in the figure below. Before the collision, the light ball moves with horizontal velocity, and the dark ball is stationary. After the collision, the dark ball moves up to the right. The magnitudes of the velocities and the masses of the balls are unknown.

Et billede, der indeholder diagram, cirkel, Font/skrifttype, design

Automatisk genereret beskrivelse

Which of the following general directions for the velocity of the light ball after the collision are possible? The directions of the arrows are purely horizontal, purely vertical, or diagonal (the diagonal arrows have no specific angle).

No matter what, the momentum remains constant:

Thus, the vertical velocity component must be negative. The horizontal can be whatever (positive, zero or negative) depending on the magnitudes of and .

A)   
B)   
C)   
**D) (correct answer)**  
E)   
F)   
**G) (correct answer)  
H) (correct answer)**  
I) Don't know

Question 11

Three train cars, A, B, and C, are on the same track with B between A and C. They all have the same mass, , and B is connected to C. The connection can be described as a massless spring with spring constant . B and C are stationary on the track, while A moves towards B with a constant velocity ​.

A collides with B and undergoes a perfectly elastic collision. What are the velocities of A (​), B (​), and C () immediately after the collision?

Perfect elastic collision means:

Conservation of kinetic energy:

Conservation of momentum:

Substituting:

*Ligningssystemet løses for v\_a,v\_bc vha. WordMat's 'Løs Ligninger' funktion,*

Buuut that is way after the collision, also counting C. At the point just immediately after, the collision is only between A and B:

*Ligningssystemet løses for v\_a,v\_b vha. WordMat's 'Løs Ligninger' funktion,*

A) , ,   
B) , ,   
C) , ,   
**D) ,,**   
E) , ,   
F) , ,   
G) Don't know

Question 12

[Continuation of the previous question]

Three train cars, A, B, and C, are on the same track with B between A and C. They all have the same mass, , and B is connected to C. The connection can be described as a massless spring with spring constant . B and C are stationary on the track, while A moves towards B with a constant velocity ​.

A collides with B and undergoes a perfectly elastic collision. What is the maximum compression of the spring in the coupling?

Only half of the kinetic energy is to be transferred from B to C:

*Ligningen løses for x vha. WordMat.*

A)   
B)   
C)   
D)   
**E)**   
F) Don't know

Question 13

The system shown in the figure consists of two homogeneous disks that are connected. They can rotate around a fixed, horizontal axis through their center of mass. The small disk has a radius and a mass . The large disk has a radius and a mass . A black box with a mass hangs from the small disk. A white box with a mass hangs from the large disk. Both boxes start at a height of above the ground. The system is released from rest.

Et billede, der indeholder tekst, diagram, skærmbillede, ur

Automatisk genereret beskrivelse

Which of the following statements are correct?

For solid cylinders:

For black box and small disk:

For white box and big disk:

Thus:

For both boxes, the angular velocity is the same because they are connected to the same rotating system.

A) The white box will move downwards and the black box will move upwards.

**B) The white box will move upwards and the black box will move downwards.**

**C) Just before the first box hits the ground, the white box will have a greater speed than the black box.**

D) Just before the first box hits the ground, the white box will have a smaller speed than the black box.

E) Just before the first box hits the ground, the white box will have the same speed as the black box.

F) The boxes will not move.

G) Do not know.

Question 14

An IC4 train with a total mass of 500 tons is moving at 50.0 m/s. The train rolls without slipping on four sets of wheels, each set having two wheels. Each wheel can be considered a homogeneous disk with a mass of 400 kg and a diameter of 1.00 meter. What percentage of the train's total kinetic energy is tied up in the rotational energy of the wheels?

For a solid cylinder:

Condition for rolling without slipping:

Kinetic rotational energy for the wheels:

Kinetic translational energy for whole of train:

Kinetic total energy (rotational + translational) for whole of train:

Energy fraction:

A) 0.0399 %

B) 0.0740 %

C) 0.159 %

D) 0.215 %

E) 0.217 %

F) 0.280 %

**G) 0.319 %**

H) 0.320 %

I) 0.473 %

J) Don’t know

Question 15

A figure skater with arms extended rotates about their longitudinal axis with an angular velocity of 7,50 and has a moment of inertia of . The skater then very quickly pulls their arms close to their body, thereby reducing their moment of inertia to . During the subsequent rotation, the skater is subjected to a constant torque of due to the finite extension of the skate blade and friction with the ice. The torque acts to slow down the skater's rotation.

What is the skater's angular velocity after completing 10 full rotations with their arms pulled in?

First, we calculate the angular momentum for when the skater has stretched arms:

Then, using conservation of that angular momentum, the new angular velocity for when the skater’s arms are pulled in is now calculated, by plugging in the new inertia:

*Ligningen løses for ω vha. WordMat.*

Then, we calculate the angular deceleration caused by the torque:

And the time required to fulfill 10 rotations:

*Ligningen løses for t vha. WordMat.*

At last, the final angular velocity can be computed:

A) 2.84 𝑠−1

B) 6.97 𝑠−1

C) 8.64 𝑠−1

**D) 10.4 𝑠−1**

E) 12.5 𝑠−1

F) 14.3 𝑠−1

G) 16.9 𝑠−1

H) Ved ikke

Question 16

A hollow cylinder has an inner radius of and an outer radius of *R*. The cylinder has a mass of . The cylinder rolls down an inclined plane inclined at an angle 𝜃 with respect to the horizontal.

Et billede, der indeholder cirkel, skærmbillede, linje/række, diagram

Automatisk genereret beskrivelse

What is the acceleration of the cylinder's center of mass, ?

For a hollow cylinder:

Gravitational force:

Calculation of frictional force by , and :

Parallel gravitational force minus friction force is mass x acceleration :

*Ligningen løses for a vha. WordMat.*

A)   
B) ​  
C) ​  
D) ​  
E) ​  
**F) ​**  
G) ​  
H) Don't know

Question 17

[Continuation of the previous question]

The torque that gives the cylinder its angular acceleration with respect to the center of mass is due to:

Without static friction force, there would be no force making it turn.

A) Gravity  
B) Normal force  
C) Kinematic friction force  
**D) Static friction force**E) Don't know

Question 18

[Continuation of the previous question]

The hollow cylinder is now rolling up the incline, not down.

Et billede, der indeholder diagram, cirkel, linje/række, skærmbillede

Automatisk genereret beskrivelse

Which of the vectors shown in the figure should be included in a force diagram for the cylinder rolling up the incline?

Only the three original forces that alone describe the system:

Force of gravity vector D, Normal (reactant) force vector B and Pushing force uphill F

A) A  
**B) B (correct)**  
C) C  
**D) D (correct)**  
E) E  
**F) F (correct)**  
G) Don't know