Nagy,

Tibor

Keep this exam **CLOSED** until advised by the instructor.

50 minute long closed book exam.

Fill out the bubble sheet: last name, first initial, **student number**. Leave the section, code and form areas empty.

A two-sided handwritten 8.5 by 11 help sheet is allowed.

When done, hand in your **test** and your **bubble sheet**.

Thank you and good luck!

Posssibly useful constant:

- g = 9.81 m/s^2

nagytibo@msu

Please, sit in row C.

1 pt Are you sitting in the seat assigned?

1.A ◯ Yes, I am.

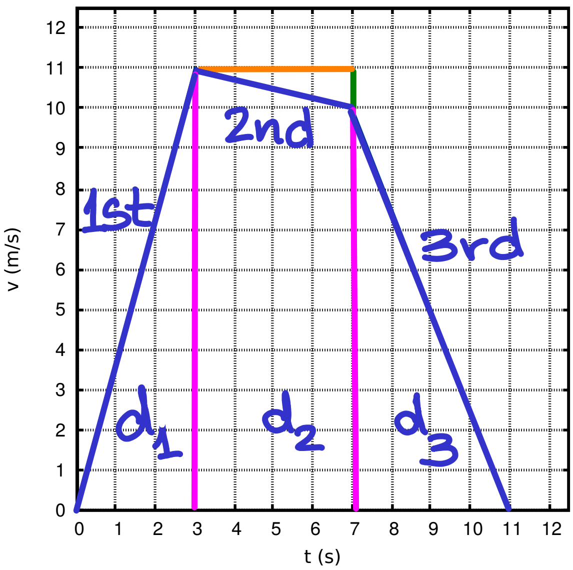
$\boxed{4\ pt}$ An apple, a brick and a hammer are all dropped from the second floor of a building at the same time. Which object(s) will hit the ground first?

2.A◯ Without knowing the masses of the objects, we cannot tell which one hits the ground first.
B◯ The hammer and the apple will hit the ground first in a tie.
C◯ The hammer will hit first.
D◯ They will all hit the ground at the same time.
E◯ The apple and the brick will hit the ground first in a tie.
F◯ The brick and the hammer will hit the ground first in a tie.
G◯ The brick will hit first.
H◯ The apple will hit first.

All compact and dense objects fall together, when they are released from the same height at the same time.

Galileo Galilei

A car is waiting at an intersection. When the traffic light turns green, the car starts moving. After some time the car comes to rest at another traffic light. The figure below shows the velocity of the car as a function of time.



acceleration:

$$a = \frac{\Delta v}{\Delta t} = \frac{\text{rise}}{\text{run}} = \text{slope}$$

One can clearly identify three different stages of this motion.

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3 pt What is the acceleration of the car during the second stage of the motion? *(in* m/s^2*)*

3. **A** ◯ -0.500 **B** ◯ -0.333 **C** ◯ -0.250 **D** ◯ -0.200
E ◯ 0.167 **F** ◯ 0.200 **G** ◯ 0.250 **H** ◯ 0.500

$$a = \frac{-1\,m/s}{4\,s} = -0.25\,\frac{m}{s^2}$$

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3 pt What is the total distance travelled by the car between the two traffic lights? *(in* m*)*

4. **A** ◯ 44.4 **B** ◯ 59.0 **C** ◯ 78.5 **D** ◯ 104 **E** ◯ 139 **F** ◯ 185 **G** ◯ 246 **H** ◯ 327

The area under the velocity vs. time function is the distance travelled.

$$D = d_1 + d_2 + d_3 = \frac{0+11}{2}\cdot 3 + \frac{11+10}{2}\cdot 4 + \frac{10+0}{2}\cdot 4 =$$

$$= 16.5 + 42 + 20 = 78.5\,m$$

$\boxed{4\ pt}$ On a car trip you drive for 2 hours and 34 minutes on a highway at a speed of 125.0 km/h. Then you stop at a gas station to fill up your tank. You also eat a quick lunch. The whole break lasts 31 minutes. After the break you start your engine up and you switch to a state road. You drive for another 3 hours and 30 minutes at a speed of 72.0 km/h before you arrive to your destination. What was your average speed for the whole trip with the lunchbreak included?
(in km/h*)*

5. **A**◯ 2.85×10^1 **B**◯ 3.56×10^1 **C**◯ 4.46×10^1 **D**◯ 5.57×10^1
E◯ 6.96×10^1 **F**◯ 8.70×10^1 **G**◯ 1.09×10^2 **H**◯ 1.36×10^2

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

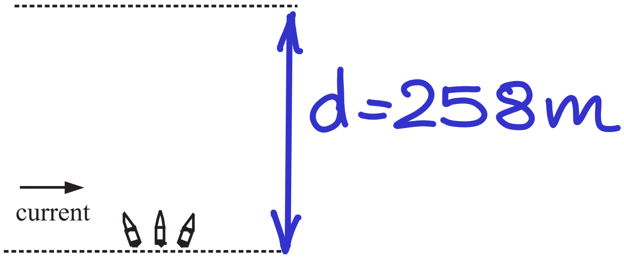
$$\bar{v} = \frac{v_1 \cdot t_1 + v_2 \cdot t_2 + v_3 \cdot t_3}{t_1 + t_2 + t_3}$$

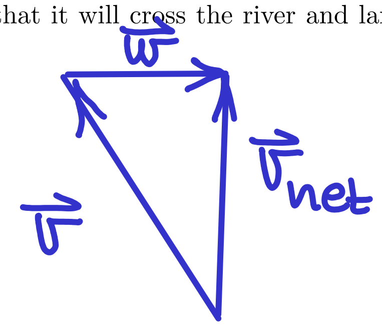
Convert the times to minutes, keep the speeds in km/h units.

$$\bar{v} = \frac{125 \cdot 154 + 0 \cdot 31 + 72 \cdot 210}{154 + 31 + 210} = \frac{34{,}370}{395}$$

$$\bar{v} = 87.0 \text{ km/h}$$

4 pt A boat crossing a 258.0 m wide river is directed so that it will cross the river and land on the opposite shore directly across from the starting point.





The boat has a speed of 5.00 m/s in still water and the river flows uniformly at 2.70 m/s. Calculate the time required for the boat to reach the opposite shore.
(in s*)*

6. **A**◯ 2.04×10^1 **B**◯ 2.39×10^1 **C**◯ 2.80×10^1 **D**◯ 3.27×10^1
E◯ 3.83×10^1 **F**◯ 4.48×10^1 **G**◯ 5.24×10^1 **H**◯ 6.13×10^1

Galilean velocity addition:

$$\vec{v}_{net} = \vec{v} + \vec{w}$$

Pythagorean theorem:

$$v^2 = w^2 + v_{net}^2 \Rightarrow \sqrt{v^2 - w^2} = v_{net}$$

Time to cross:

$$t = \frac{d}{v_{net}} = \frac{d}{\sqrt{v^2 - w^2}} = \frac{258}{\sqrt{5^2 - 2.7^2}}$$

$$t = \frac{258}{4.21} = 61.3\ \text{s}$$

3 pt An artillery shell is launched on a flat, horizontal field at an angle of $\alpha = 31.8°$ with respect to the horizontal and with an initial speed of $v_0 = 280$ m/s. What is the horizontal velocity of the shell after 20.35 s of flight? (Neglect air friction. Use the coordinate system where the x-axis is horizontal and points to the right; and the y-axis is vertical and points up.)
(in m/s*)*

7. **A**◯ 1.65×10^2 **B**◯ 1.86×10^2 **C**◯ 2.11×10^2 **D**◯ 2.38×10^2
E◯ 2.69×10^2 **F**◯ 3.04×10^2 **G**◯ 3.43×10^2 **H**◯ 3.88×10^2

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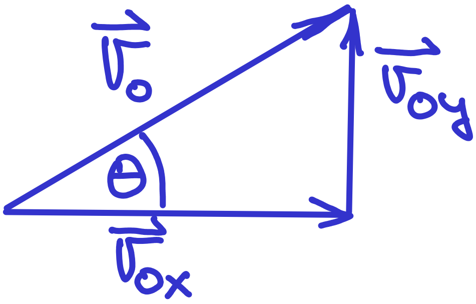
3 pt What is the vertical velocity of the shell at this moment?
(in m/s*)*

8. **A**◯ -1.30×10^2 **B**◯ -1.04×10^2 **C**◯ -5.21×10^1 **D**◯ -2.61×10^1
E◯ 2.61×10^1 **F**◯ 5.21×10^1 **G**◯ 1.04×10^2 **H**◯ 1.30×10^2



Trigonometry:

$$v_{0x} = v_0 \cdot \cos\theta$$
$$v_{0y} = v_0 \cdot \sin\theta$$

Horizontal velocity:

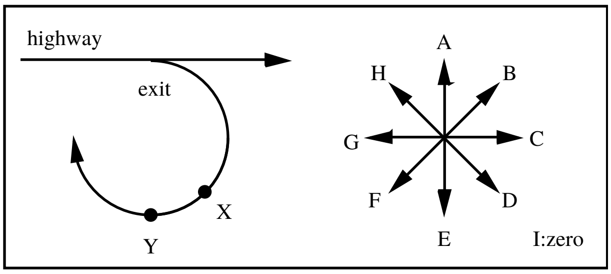
$$v_x(t) = v_{0x} = v_0 \cdot \cos\theta = 280 \cdot \cos(31.8°)$$
$$v_x(t) = 238 \text{ m/s}$$

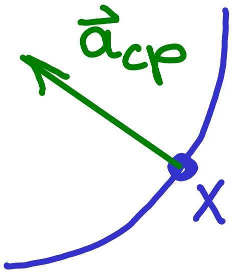
Vertical velocity:

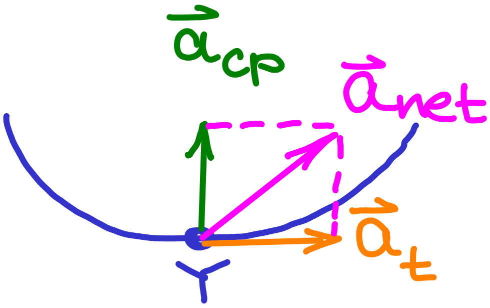
$$v_y(t) = v_{0y} - gt = v_0 \cdot \sin\theta - gt$$
$$v_y(t) = 280 \cdot \sin(31.8°) - 9.81 \cdot 20.35$$
$$v_y(t = 20.35\text{s}) = -52.1 \text{ m/s}$$

Negative velocity means downward.

A car is exiting the highway on a circular exit ramp. (See figure.)







3 pt The driver slows the car down to the posted speed limit, enters the exit ramp and then maintains a constant speed. When the car is at point **X** on the ramp, which vector best represents the direction of the car's acceleration?

9.A◯ A.
B◯ B.
C◯ C.
D◯ D.
E◯ E.
F◯ F.
G◯ G.
H◯ H.
I◯ I: the acceleration is zero.

At X the car accelerates toward the center : a_{cp} only, because the speed is constant.

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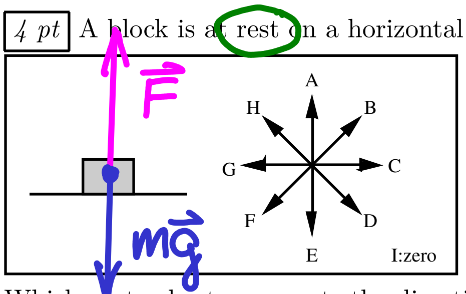
3 pt After passing point **X** but before reaching point **Y** the driver starts to push the brake pedal and applies the brakes for the rest of the exit ramp. Which vector best represents the direction of the car's acceleration when the car is at point **Y**?

10.A◯ A.
B◯ B.
C◯ C.
D◯ D.
E◯ E.
F◯ F.
G◯ G.
H◯ H.
I◯ I: the acceleration is zero.

At Y the car accelerates toward the center and backward at the same time : a_{cp} : A, a_t : C , a_{net} : B.

$\boxed{4\ pt}$ A block is at rest on a horizontal surface. (See figure.)



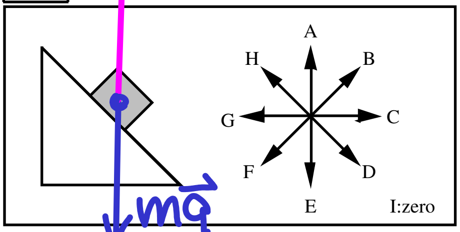
Which vector best represents the direction of the force exerted by the surface on the block?

11.A◯ A
B◯ B
C◯ C
D◯ D
E◯ E
F◯ F
G◯ G
H◯ H
I◯ I: the force is zero.

The object is at rest. Therefore the force $\vec{F}$ by the surface on the block must exactly balance out the weight $m\vec{g}$.
Since the surface is horizontal, and the force $\vec{F}$ is vertical, therefore $\vec{F}$ is the normal force "supplied" by the surface.
This surface can be frictionless.

$\vec{F}$

$\boxed{4\ pt}$ A block is at rest on a frictional incline. (See figure.)

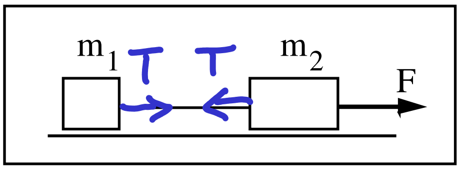


Which vector best represents the direction of the force exerted by the surface on the block?

12.A◯ A
B◯ B
C◯ C
D◯ D
E◯ E
F◯ F
G◯ G
H◯ H
I◯ I: the force is zero.

The object is at rest. Therefore the force $\vec{F}$ by the surface on the block must exactly balance out the weight $m\vec{g}$.
The normal component of this force $\vec{F}$ is the normal force of the surface. The parallel component of this force is the static friction.
Only a frictional incline can hold this block. A frictionless incline cannot do this job.

Two masses, $m_1 = 2.15$ kg and $m_2 = 6.67$ kg are on a horizontal frictionless surface and they are connected together with a rope as shown in the figure.



$\mu = 0$

At the breaking point the rope provides the maximum tension T_{max}, but it doesn't break yet.

3 pt The rope will snap if the tension in it exceeds 50.0 N. What is the maximum value of the force **F** which can be applied?
(in N)

13. **A**○ 8.72×10^1 **B**○ 9.85×10^1 **C**○ 1.11×10^2 **D**○ 1.26×10^2
E○ 1.42×10^2 **F**○ 1.61×10^2 **G**○ 1.82×10^2 **H**○ 2.05×10^2

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3 pt What is the acceleration of the whole system, when this maximum force is applied?
(in m/s^2)

14. **A**○ 2.06×10^1 **B**○ 2.33×10^1 **C**○ 2.63×10^1 **D**○ 2.97×10^1
E○ 3.36×10^1 **F**○ 3.79×10^1 **G**○ 4.28×10^1 **H**○ 4.84×10^1

Newton's 2nd law for #1:

$$T_{max} = m_1 \cdot a_{max} \Rightarrow a_{max} = \frac{T_{max}}{m_1}$$

$$a_{max} = \frac{50\,N}{2.15\,kg} = 23.3\,m/s^2$$

Newton's 2nd law for #2:

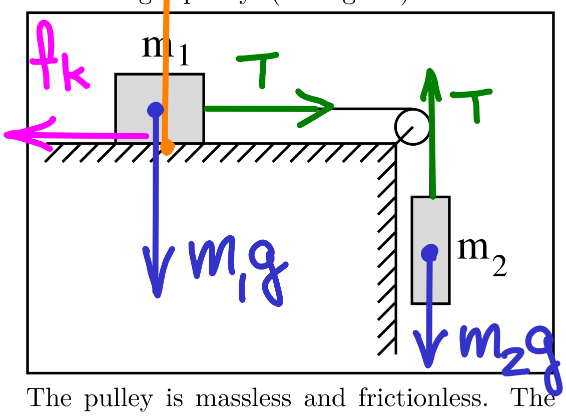
$$F - T_{max} = m_2 a_{max}$$

$$F = m_2 a_{max} + T_{max}$$

$$F = 6.67\,kg \cdot 23.3\,\frac{m}{s^2} + 50\,N$$

$$F = 205.4\,N$$

5 pt Mass m_1 = 13.3 kg is on a horizontal table. Mass m_2 = 5.19 kg hangs on a rope which is attached to the first mass using a pulley. (See figure.)



constant speed ⇒ no acceleration: $a = 0$ ⇒ the weight of m_2 is exactly balanced out by the kinetic friction f_k.

The pulley is massless and frictionless. The system is observed to move with constant speed. Determine μ_k, the coefficient of kinetic friction between mass m_1 and the surface of the table.

15. **A** ◯ 0.239 **B** ◯ 0.270 **C** ◯ 0.306 **D** ◯ 0.345
E ◯ 0.390 **F** ◯ 0.441 **G** ◯ 0.498 **H** ◯ 0.563

Newton's 2nd law for #2 in y dir:

$$N - m_2 g = m_2 \cdot 0 \Rightarrow N = m_2 g$$

Newton's 2nd law for #2 in x dir:

$$T - f_k = m_2 \cdot 0 \Rightarrow T = f_k$$

Newton's 2nd law for #1 in y dir:

$$T - m_1 g = m_1 \cdot 0 \Rightarrow T = m_1 g$$

All combined:

$$m_2 g = T = f_k = \mu_k \cdot N = \mu_k \cdot m_1 g$$

$$\frac{m_2}{m_1} = \mu_k \qquad \mu_k = \frac{5.19\,\text{kg}}{13.3\,\text{kg}} = 0.390$$