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

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Please, sit in row L.

1 pt Are you sitting in the seat assigned?

1.A◯ Yes, I am.

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?

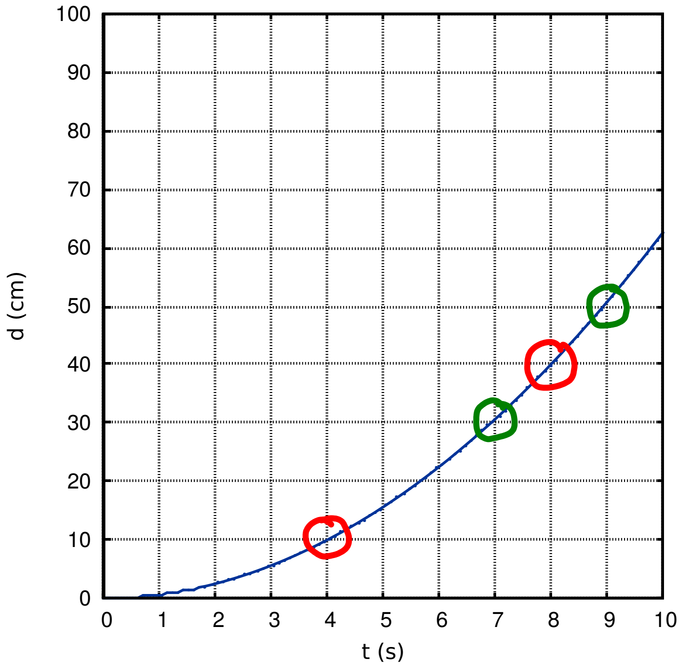
2.A◯ The hammer will hit first.
B◯ The brick and the hammer will hit the ground first in a tie.
C◯ The apple will hit first.
D◯ The hammer and the apple will hit the ground first in a tie.
E◯ They all hit the ground at the same time.
F◯ Without knowing the masses of the objects, we cannot tell which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

All compact, dense objects (no wings or balloons attached) fall together with the same acceleration when released at the same time from the same place, no matter what their masses are. (Galileo Galilei)

$$F = m \cdot a \Rightarrow a = \frac{F}{m} = \frac{mg}{m} = g$$

But this cancellation is the biggest mystery in the Universe. The mass in the numerator is the gravitational mass, the mass in the denominator is the inertial mass. We don't know why, but they are equal according to the experiments. Physics is an experimental science. 375 years after Galileo we are still doing the equivalence measurements. The relative diffence between the two types of masses is measured to be about 1 in 10^{11} in the latest experiments. Einstein declared the equivalence of the two types of masses as the postulate (the only one postulate) of General Relativity, the theory of gravity.

A small marble is rolling down on an incline. The distance travelled by the marble as the function of time is shown in the figure.



Locate the grid intersection(s): red

$d = \frac{1}{2}at^2 \Rightarrow \frac{2d}{t^2} = a$

$a = \frac{2 \cdot 40}{8^2} = \frac{80}{64} = 1.25 \frac{cm}{s^2}$

Try the other intersection circled in red.

$\boxed{4\ pt}$ What is the acceleration of the marble? Please, note that the curve goes through at least one grid intersection point.
(in `cm/s^2`*)*

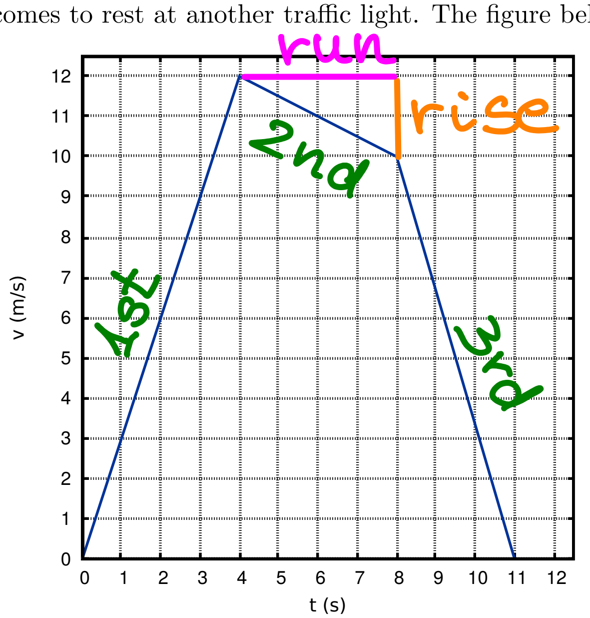
3. **A**◯ 0.283 **B**◯ 0.410 **C**◯ 0.595 **D**◯ 0.862
E◯ 1.25 **F**◯ 1.81 **G**◯ 2.63 **H**◯ 3.81

Any (t, d) pair should give you the acceleration, if you read out the values well: green circles:

$\frac{2 \cdot 31}{7^2} = 1.265\ cm/s^2$

$\frac{2 \cdot 51}{9^2} = 1.259\ cm/s^2$

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.



rise : −2 m/s (negative!)
run : 4 s
acceleration:

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

$$= \frac{-2\,m/s}{4\,s} = -0.5\ m/s^2$$

(It is a deceleration.)

One can clearly identify three different stages of this motion.

$\boxed{\textit{3 pt}}$ What is the acceleration of the car during the second stage of the motion?
(in m/s^2*)*

4. **A**◯ -0.667 **B**◯ -0.500 **C**◯ -0.400 **D**◯ -0.333
E◯ 0 **F**◯ 0.333 **G**◯ 0.500 **H**◯ 0.667

$\boxed{\textit{3 pt}}$ What is the total distance travelled by the car between the two traffic lights?
(in m*)*

5. **A**◯ 66.4 **B**◯ 83.0 **C**◯ 104 **D**◯ 130. **E**◯ 162 **F**◯ 203 **G**◯ 253 **H**◯ 317

Distance travelled is the area under the v-vs-t plot:

$$d = \frac{12}{2}\cdot 4 + \frac{12+10}{2}\cdot 4 + \frac{10}{2}\cdot 3 =$$

$$= 24 + 44 + 15 = 83\,m$$

3 pt An artillery shell is launched on a flat, horizontal field at an angle of $\alpha = 41.4°$ with respect to the horizontal and with an initial speed of $v_0 = 261$ m/s. What is the horizontal velocity of the shell after 20.95 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*)*

6. **A**◯ 2.66×10^1 **B**◯ 3.54×10^1 **C**◯ 4.70×10^1 **D**◯ 6.26×10^1
E◯ 8.32×10^1 **F**◯ 1.11×10^2 **G**◯ 1.47×10^2 **H**◯ 1.96×10^2

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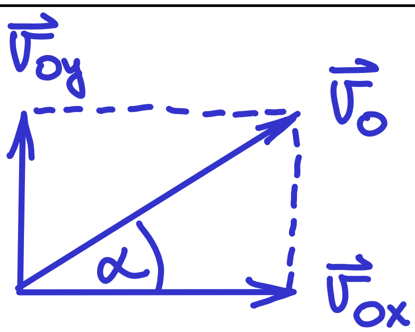
3 pt What is the vertical velocity of the shell at this moment?
(in m/s*)*

7. **A**◯ -6.59×10^1 **B**◯ -4.94×10^1 **C**◯ -3.30×10^1 **D**◯ -1.65×10^1
E◯ 1.65×10^1 **F**◯ 6.59×10^1 **G**◯ 8.24×10^1 **H**◯ 9.89×10^1



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

$$v_{0x} = 261 \cdot \cos 41.4° = \underline{196 \text{ m/s}}$$

The horizontal component of the velocity doesn't change throughout the motion, because the gravitational acceleration g is vertical, it cannot change a horizontal velocity. But it can change the vertical velocity component:

$$v_y(t) = v_{0y} - gt = v_0 \cdot \sin\alpha - gt =$$
$$= 261 \cdot \sin 41.4° - 9.81 \cdot 20.95 = \underline{-32.9 \text{ m/s}}$$

It is negative, the shell already passed the turning point, it is coming down.

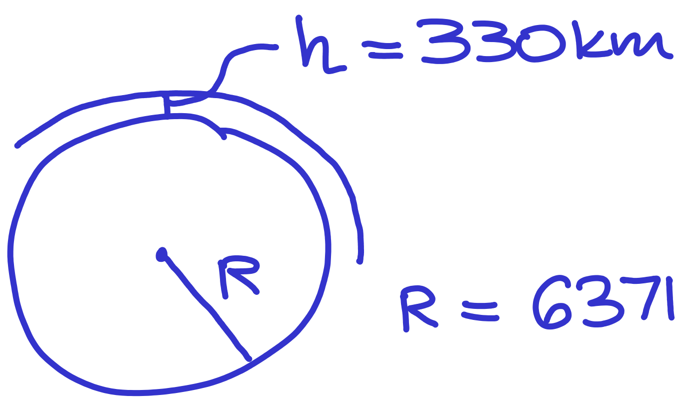
$\boxed{4\ pt}$ The International Space Station (ISS) flies on a circular orbit with a speed of 7.71 km/s at a height of 330.0 km above the surface of the Earth. What is the centripetal acceleration of the station? (The radius of the Earth is 6371 km.)
(in m/s^2*)*

8. **A** ◯ 2.33 **B** ◯ 2.91 **C** ◯ 3.63 **D** ◯ 4.54
E ◯ 5.68 **F** ◯ 7.10 **G** ◯ 8.87 **H** ◯ 1.11×10^{1}

centripetal acceleration:

$$a_{cp} = \frac{v^2}{r}\ ;\ v = 7.71\ km/s = 7710\ m/s$$

But what is the radius of the orbit?



R = 6371 km

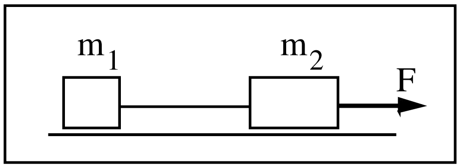
$$r = R + h = 6371 + 330 = 6701\ km$$

$$r = 6.701 \cdot 10^6\ m$$

$$a_{cp} = \frac{v^2}{r} = \frac{7710^2}{6.701 \cdot 10^6} = \underline{8.87\ m/s^2}$$

Notice that this acceleration is only about $1\ m/s^2$ less than g on the surface of the Earth. The gravitational field is weaker at 330 km, but it is not zero! But what is weightlessness then?

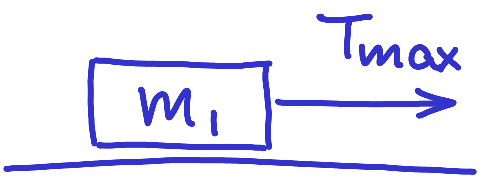
Two masses, $m_1 = 2.20$ kg and $m_2 = 6.80$ kg are on a horizontal frictionless surface and they are connected together with a rope as shown in the figure.



$\boxed{4\ pt}$ The rope connecting the two masses will snap, if the tension in it exceeds 55.0 N. What is the maximum value of the force **F** which can be applied on the right hand side?
(in N*)*

9. **A**◯ 4.07×10^1 **B**◯ 5.41×10^1 **C**◯ 7.19×10^1 **D**◯ 9.56×10^1
E◯ 1.27×10^2 **F**◯ 1.69×10^2 **G**◯ 2.25×10^2 **H**◯ 2.99×10^2

The connecting rope is maxed out:



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

$a_{max} = \frac{T_{max}}{m_1}$ } this is the largest acceleration we can have

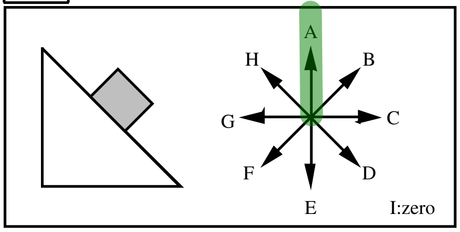
Newton's second law for the whole system:

$F_{max} = (m_1 + m_2) \cdot a_{max} = (m_1 + m_2) \cdot \frac{T_{max}}{m_1}$

$F_{max} = \frac{m_1 + m_2}{m_1} \cdot T_{max}$

$F_{max} = \frac{2.2 + 6.8}{2.2} \cdot 55 = \underline{225\,N}$

3 pt A block is at rest on a frictional incline. (See figure.)



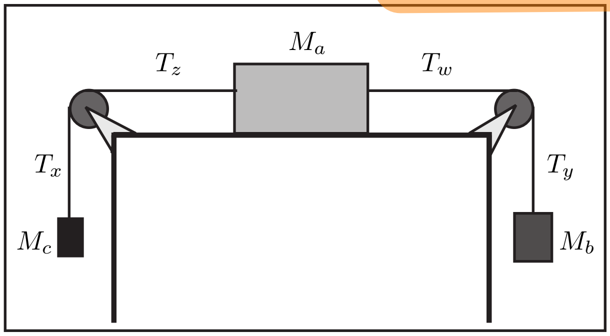
vertically up

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

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

The block is at rest, therefore the force exerted by the surface must balance the weight of the block out. The weight of the object points vertically down, therefore the force by the surface points vertically up. The normal component of this force is the normal force. The parallel component of this force is the static friction. The force by the incline on the object is one single force, we just break it up to two components: normal (N) and parallel (f_s). A frictionless incline cannot hold an object at rest, unless the incline is exactly horizontal.

In the figure below, assume that the pulleys are massless and frictionless. → $T_x = T_z$; $T_w = T_y$



$\boxed{12\ pt}$ The masses of the blocks are M_a=5.50 kg, M_b=3.00 kg, M_c=1.50 kg, and there is friction between the horizontal plane and M_a, ($\mu_k \neq 0$). M_a is observed to travel at a constant velocity. → $a = 0$

▷ T_w is .... T_y.
11. **A**◯ True **B**◯ False **C**◯ Greater than **D**◯ Less than **E**◯ Equal to   b/c ideal pulley

▷ T_w is .... T_x.
12. **A**◯ True **B**◯ False **C**◯ Greater than **D**◯ Less than **E**◯ Equal to $T_w = T_z + f_k$

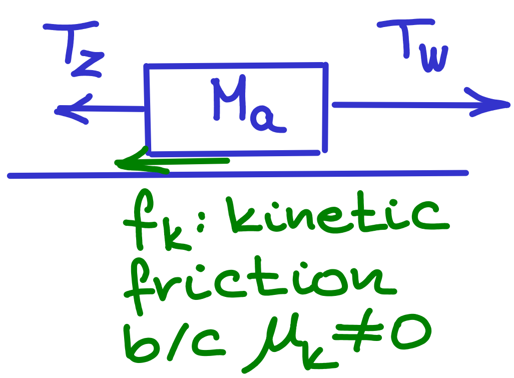
▷ M_a is moving to the left.
13. **A**◯ True **B**◯ False **C**◯ Greater than **D**◯ Less than **E**◯ Equal to $M_b > M_c$ to the right

▷ The magnitude of the total force on M_a is .... 0.
14. **A**◯ True **B**◯ False **C**◯ Greater than **D**◯ Less than **E**◯ Equal to   b/c $a = 0$

▷ M_c accelerates upward.
15. **A**◯ True **B**◯ False **C**◯ Greater than **D**◯ Less than **E**◯ Equal to $a = 0$!

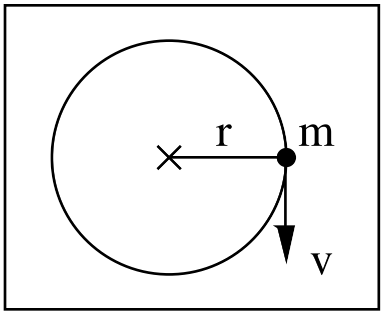
▷ T_x is .... M_c*g.
16. **A**◯ True **B**◯ False **C**◯ Greater than **D**◯ Less than **E**◯ Equal to   b/c $a = 0$

The system will move to the right, because M_b on the right is greater than M_c on the left.



$T_w = T_z + f_k \Rightarrow F_{net}$ on M_a is zero, the system is observed to be moving at a constant velocity.

A small object with a mass of m = 961 g is whirled at the end of a rope in a vertical circle with a radius of r = 151 cm.



3 pt When it is at the location shown, (mid-height), its speed is v = 5.82 m/s. Determine the tension in the rope. *(in N)*

17. **A**◯ 3.36 **B**◯ 4.88 **C**◯ 7.07 **D**◯ 1.03×10^1
E◯ 1.49×10^1 **F**◯ 2.16×10^1 **G**◯ 3.13×10^1 **H**◯ 4.53×10^1

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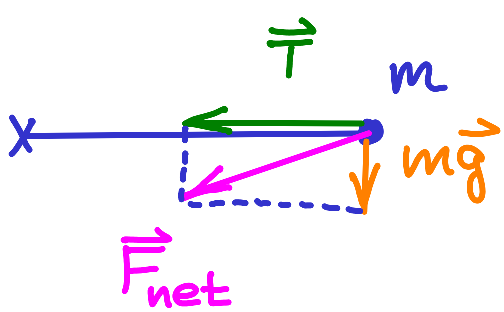
3 pt Calculate the magnitude of the total force acting on the mass at that location. *(in N)*

18. **A**◯ 3.67 **B**◯ 5.32 **C**◯ 7.72 **D**◯ 1.12×10^1
E◯ 1.62×10^1 **F**◯ 2.35×10^1 **G**◯ 3.41×10^1 **H**◯ 4.95×10^1

Newton's second law in the radial direction: $T = ma$ and $a = a_{cp} = \frac{v^2}{r}$

$\Rightarrow T = m\frac{v^2}{r} = 0.961 \cdot \frac{5.82^2}{1.51} = \underline{21.6\,N}$

Total or net force at that location:



Πυθαγορας said:

$$F_{net}^2 = T^2 + (mg)^2$$

$$F_{net} = \sqrt{T^2 + (mg)^2} =$$

$$= \sqrt{21.6^2 + (0.961 \cdot 9.81)^2} = \underline{23.6\,N}$$