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 (PID)**. Leave the section, code, form and signature areas empty.

Two two-sided handwritten 8.5 by 11 help sheets are 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

Posssibly useful Moments of Inertia:

- Solid homogeneous cylinder: $I_{CM} = (1/2)MR^2$
- Solid homogeneous sphere: $I_{CM} = (2/5)MR^2$
- Thin spherical shell: $I_{CM} = (2/3)MR^2$
- Thin uniform rod, axis perpendicular to length: $I_{CM} = (1/12)ML^2$

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Please, sit in row H.

1 pt Are you sitting in the seat assigned?

1.A◯ Yes, I am.

3 pt There are 135 steps between the ground floor and the sixth floor in a building. Each step is 16.6 cm tall. It takes 3 minutes and 46 seconds for a person with a mass of 61.2 kg to walk all the way up. How much work did the person do?
(in J)

2. **A**◯ 1.35×10^4 **B**◯ 1.52×10^4 **C**◯ 1.72×10^4 **D**◯ 1.94×10^4
E◯ 2.19×10^4 **F**◯ 2.48×10^4 **G**◯ 2.80×10^4 **H**◯ 3.17×10^4

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3 pt What was the average power performed by the person during the walk?
(in W)

3. **A**◯ 2.83×10^1 **B**◯ 4.11×10^1 **C**◯ 5.95×10^1 **D**◯ 8.63×10^1
E◯ 1.25×10^2 **F**◯ 1.81×10^2 **G**◯ 2.63×10^2 **H**◯ 3.82×10^2

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number of steps: $n = 135$

height of one step: $h = 16.6\,cm = 0.166\,m$

total height: $H = n \cdot h$

mass of the person: $m = 61.2\,kg$

duration: $\Delta t = 3\,min\,46\,s = 226\,s$

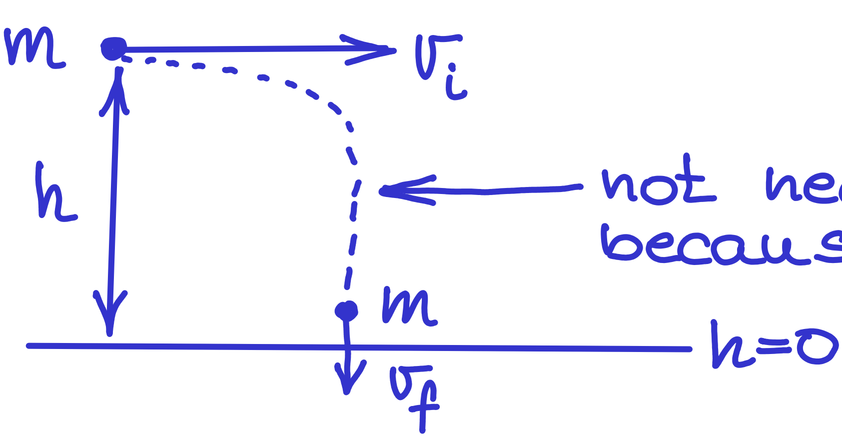
work: $W = F \cdot H = mgH = mgnh$

$W = 1.35 \times 10^4\,J$

power: $P = \frac{W}{\Delta t} = \frac{1.35 \times 10^4}{226} = 59.5\,W$

5 pt An airplane is flying with a speed of 335 km/h at a height of 2570 m above the ground. A parachutist whose mass is 79.2 kg, jumps out of the airplane, opens the parachute and then lands on the ground with a speed of 4.00 m/s. How much energy was dissipated on the parachute by the air friction?
(in MJ*)*

4. **A**◯ 1.46 **B**◯ 1.71 **C**◯ 2.00 **D**◯ 2.34 **E**◯ 2.74 **F**◯ 3.20 **G**◯ 3.75 **H**◯ 4.38



$3.6\,\frac{km}{h} = 1\,\frac{m}{s}$

not necessarily a parabola because it is not a fall, it is a parachute ride

Energy balance:

$$PE_i + KE_i = \underbrace{PE_f}_{=0} + KE_f + \Delta E_{th}$$

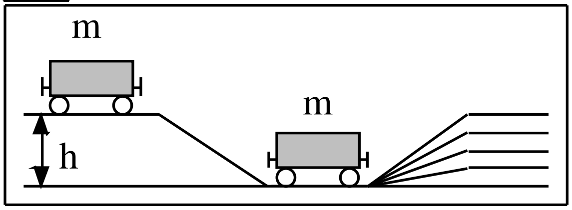
$$mgh + \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 + \Delta E_{th}$$

$$\Delta E_{th} = mgh + \frac{1}{2}mv_i^2 - \frac{1}{2}mv_f^2$$

$$\Delta E_{th} = 79.2 \cdot 9.81 \cdot 2570 + \frac{1}{2} \cdot 79.2 \cdot \left(\frac{335}{3.6}\right)^2 - \frac{1}{2} \cdot 79.2 \cdot 4^2 =$$

$$= 2.00\,MJ + 0.34\,MJ - 634\,J = 2.34\,MJ$$

4 pt A railroad cart with mass **m** is at rest on the top of a hill with height **h**. (See figure.)



Then it starts to roll down. At the bottom it collides with an identical cart. The two carts lock together. How high can they reach together? (Neglect any losses due to friction.)

5.A◯ Zero, they cannot climb any height.
B◯ (1/2)**h**, half of the original height.
C◯ (3/4)**h**, three quarter of the original height.
D◯ (1/4)**h**, one quarter of the original height.
E◯ **h**, the original height.

$h \downarrow v$: Potential energy → kinetic energy

$$mgh = \frac{1}{2}mv^2$$

$$2gh = v^2$$

$v \downarrow v/2$: Perfectly inelastic collision: linear momentum conservation:

$$mv_i + m \cdot 0 = 2m \cdot v_f$$

$$\frac{v_i}{2} = v_f$$

$v/2 \downarrow h/4$: Kinetic energy → potential energy

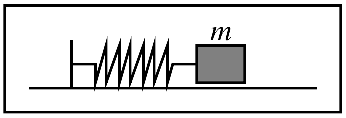
$$\frac{1}{2}(2m) \cdot \left(\frac{v}{2}\right)^2 = (2m)\, g h_f$$

$$\left(\frac{v}{2}\right)^2 = 2gh_f$$

From 1st phase: $v^2 = 2gh_i$

$$h_f = \frac{h_i}{4}$$

2 pt A mass of $m = 1.49$ kg connected to a spring oscillates on a horizontal frictionless surface as shown in the figure.



The equation of motion of the mass is given by
$x = 0.203 \cos(2.55t)$
where the position x is measured in meters, the time t in seconds. Determine the period of the motion.
(in s*)*

6. **A** ◯ 1.85 **B** ◯ 2.46 **C** ◯ 3.28 **D** ◯ 4.36
E ◯ 5.80 **F** ◯ 7.71 **G** ◯ 1.03×10^{1} **H** ◯ 1.36×10^{1}

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2 pt What is the maximum speed reached by the mass?
(in m/s*)*

7. **A** ◯ 3.59×10^{-1} **B** ◯ 4.05×10^{-1} **C** ◯ 4.58×10^{-1} **D** ◯ 5.18×10^{-1}
E ◯ 5.85×10^{-1} **F** ◯ 6.61×10^{-1} **G** ◯ 7.47×10^{-1} **H** ◯ 8.44×10^{-1}

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2 pt Determine the spring constant.
(in N/m*)*

8. **A** ◯ 6.68 **B** ◯ 9.69 **C** ◯ 1.40×10^{1} **D** ◯ 2.04×10^{1}
E ◯ 2.95×10^{1} **F** ◯ 4.28×10^{1} **G** ◯ 6.21×10^{1} **H** ◯ 9.00×10^{1}

$$x = A \cdot \cos(\omega t)$$

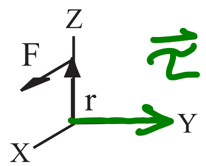
$$\omega = \frac{2\pi}{T} \rightarrow T = \frac{2\pi}{\omega} = \frac{2\pi \text{ rad}}{2.55 \text{ rad/s}} = 2.46 \text{ s}$$

$$v_{max} = A\omega = 0.203 \text{ m} \cdot 2.55 \tfrac{1}{s} = 0.518 \tfrac{m}{s}$$

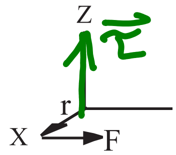
$$\omega^2 = \frac{k}{m} \Rightarrow k = m\omega^2 = 1.49 \text{ kg} \cdot \left(2.55 \tfrac{1}{s}\right)^2 = 9.69 \tfrac{N}{m}$$

| *6 pt* | A body (not shown) has its center of mass (CM) at the origin. In each case below give the direction for the torque τ with respect to the CM on the body due to force **F** acting on the body at a location indicated by the vector **r**.

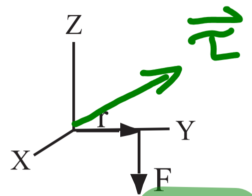
$\vec{\tau} = \vec{r} \times \vec{F}$



▷ **9.** **A**◯ X **B**◯ -X **C**◯ Y **D**◯ -Y **E**◯ Z **F**◯ -Z

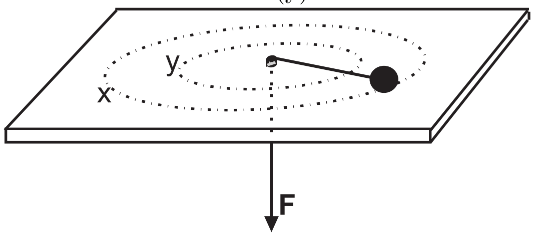


▷ **10.** **A**◯ X **B**◯ -X **C**◯ Y **D**◯ -Y **E**◯ Z **F**◯ -Z



▷ **11.** **A**◯ X **B**◯ -X **C**◯ Y **D**◯ -Y **E**◯ Z **F**◯ -Z

10 pt A small mass M attached to a string slides in a circle (x) on a frictionless horizontal table, with the force **F** providing the necessary tension (see figure). The force is then increased slowly and then maintained constant when M travels around in circle (y). The radius of circle (x) is twice the radius of circle (y).



▷ While going from x to y, there is no torque on M.
12. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

$\tau = 0$

▷ M's angular velocity at x is one quarter that at y.
13. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

$\omega_x = \omega_y / 4$

▷ As M moves from x to y, the work done by **F** is .... 0.
14. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

$W > 0$

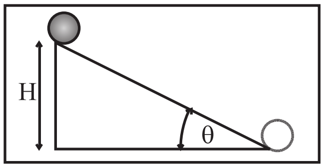
▷ M's angular momentum at y is .... that at x.
15. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

$L_y = L_x$

▷ M's kinetic energy at y is twice that at x.
16. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

$KE_y = 4KE_x$

A solid homogeneous cylinder of mass M = 3.50 kg is released from rest at the top of an incline of height H = 5.23 m and rolls without slipping to the bottom. The ramp is at an angle of $\theta = 24.1°$ to the horizontal.



4 pt Calculate the speed of the cylinder's Center of Mass at the bottom of the incline.
(in m/s)

17. **A**◯ 8.27 **B**◯ 1.03×10^1 **C**◯ 1.29×10^1 **D**◯ 1.62×10^1
E◯ 2.02×10^1 **F**◯ 2.52×10^1 **G**◯ 3.16×10^1 **H**◯ 3.94×10^1

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solid cylinder: $I = \frac{1}{2}MR^2$; $k = \frac{1}{2}$

Energy balance:

$$PE_i = KE_{f,t} + KE_{f,r}$$

$$MgH = \frac{1}{2}Mv_f^2 + \frac{1}{2}I\omega_f^2$$

$$MgH = \frac{1}{2}Mv_f^2 + \frac{1}{2}kM\underbrace{R^2\omega_f^2}_{v_f^2}$$

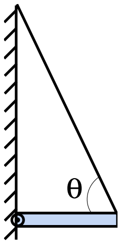
v_f^2 b/c $v_f = R\omega_f$ (no slip condition)

$$MgH = \frac{1}{2}Mv_f^2 + \frac{1}{2}kMv_f^2$$

$$2gH = v_f^2(1+k)$$

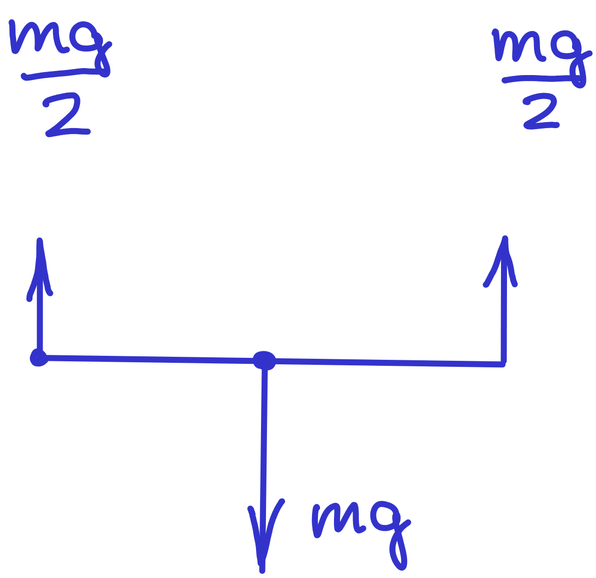
$$v_f = \sqrt{\frac{2gH}{1+k}} = \sqrt{\frac{2 \cdot 9.81 \cdot 5.23}{1+\frac{1}{2}}} = 8.27\,m/s$$

4 pt A 38.0 kg beam is attached to a wall with a hinge while its far end is supported by a cable such that the beam is horizontal.



If the angle between the beam and the cable is $\theta = 60.0°$ what is the vertical component of the force exerted by the hinge on the beam?
(in N*)*

18. **A**◯ 1.86×10^2 **B**◯ 2.18×10^2 **C**◯ 2.55×10^2 **D**◯ 2.99×10^2
E◯ 3.49×10^2 **F**◯ 4.09×10^2 **G**◯ 4.78×10^2 **H**◯ 5.59×10^2



The endpoints of a uniform rod need to be held with a force of $\frac{mg}{2}$ each in the vertical direction no matter what the forces are in the horizontal direction.

2 pt You ride your bicycle in the forward direction on a straight horizontal road. What is the direction of the velocity vector of your bicycle?

19.A ◯ down to the ground
B ◯ to your left
C ◯ to your right
D ◯ The velocity is zero.
E ◯ backward
F ◯ up to the sky
G ◯ forward

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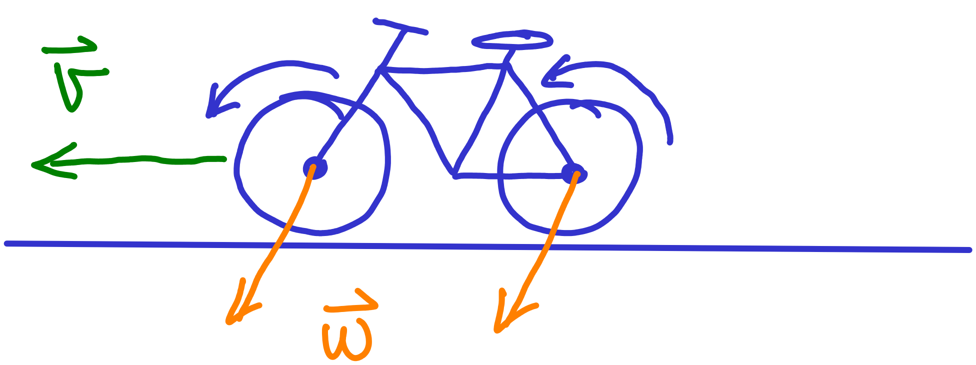
2 pt What is the direction of the angular velocity vector of your wheels?

20.A ◯ backward
B ◯ up to the sky
C ◯ The angular velocity is zero.
D ◯ forward
E ◯ down to the ground
F ◯ to your right
G ◯ to your left



If you move in the forward direction, your velocity vector $\vec{v}$ points forward. The angular velocity vector $\vec{\omega}$ of your wheels point to your left according to the right hand rule.