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Nagy,

Tibor

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

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120 minute long closed book exam.

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

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Four two-sided handwritten 8.5 by 11 help sheets are allowed.

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

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Thank you and good luck!

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Possibly useful constants:

- $g = 9.81 \text{ m/s}^2$
- $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$
- $\rho_{\text{water}} = 1000 \text{ kg/m}^3 = 1 \text{ kg/l} = 1 \text{ g/cm}^3$
- $1 \text{ atm} = 101.3 \text{ kPa} = 760 \text{ mmHg}$
- $N_A = 6.02 \times 10^{23} \text{ 1/mol}$
- $R = 8.31 \text{ J/(molK)}$
- $k_B = 1.38 \times 10^{-23} \text{ J/K}$
- $c_{\text{water}} = 4.1868 \text{ kJ/(kg}^\circ\text{C)} = 1 \text{ kcal/(kg}^\circ\text{C)}$
- $1 \text{ cal} = 4.1868 \text{ J}$
- $\sigma = 5.67 \times 10^{-8} \text{ W/(m}^2\text{K}^4)$
- $b = 2.90 \times 10^{-3} \text{ m}\cdot\text{K}$

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Possibly useful Moments of Inertia:

- Solid homogeneous cylinder:  $I_{\text{CM}} = (1/2)MR^2$
  - Solid homogeneous sphere:  $I_{\text{CM}} = (2/5)MR^2$
  - Thin spherical shell:  $I_{\text{CM}} = (2/3)MR^2$
  - Straight thin rod with axis through center:  $I_{\text{CM}} = (1/12)ML^2$
  - Straight thin rod with axis through end:  $I = (1/3)ML^2$
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Please, sit in seat:

Thank you!

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1 pt Are you sitting in the seat assigned?

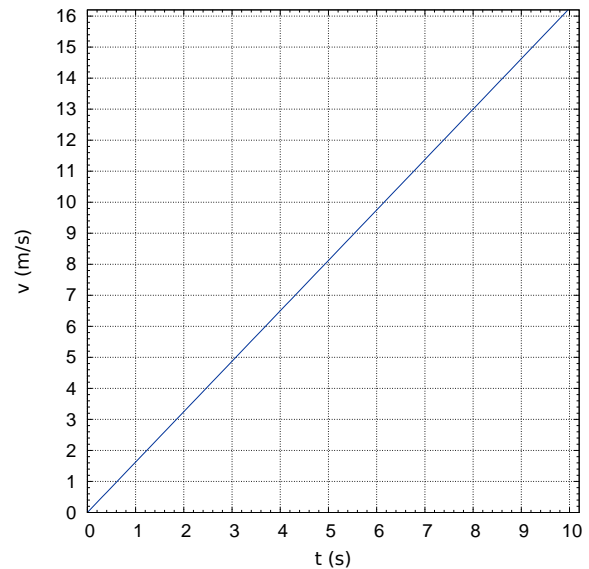
1.A  Yes, I am.

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

The graph shows the speed of a car as a function of time.



**3 pt** Initially the car is at rest. What is the acceleration of the car? Please, note that the graph goes through at least one grid intersection point.

(in  $\text{m/s}^2$ )

3. **A**  0.7805    **B**  0.8820    **C**  0.9966  
**D**  1.126    **E**  1.273    **F**  1.438  
**G**  1.625    **H**  1.836

**3 pt** How much distance does the car cover between  $t_1 = 2.05$  s and  $t_2 = 4.99$  s?

(in m)

4. **A**  4.041    **B**  5.374    **C**  7.148    **D**  9.507  
**E**  12.64    **F**  16.82    **G**  22.37    **H**  29.75

**4 pt** A baseball is projected horizontally with an initial speed of 8.49 m/s from a height of 1.64 m. What is the speed of the baseball when it hits the ground? (Neglect air friction.)

(in m/s)

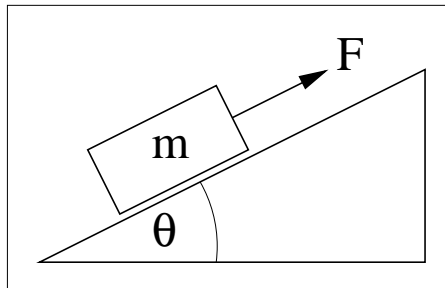
5.    **A**  6.26            **B**  7.08            **C**  8.00  
       **D**  9.04            **E**   $1.02 \times 10^1$     **F**   $1.15 \times 10^1$   
       **G**   $1.30 \times 10^1$     **H**   $1.47 \times 10^1$

**4 pt** Two forces  $\mathbf{F}_1 = -9.90\mathbf{i} + 3.10\mathbf{j}$  and  $\mathbf{F}_2 = 7.50\mathbf{i} + 6.40\mathbf{j}$  are acting on an object with a mass of  $m = 6.10$  kg. The forces are measured in newtons,  $\mathbf{i}$  and  $\mathbf{j}$  are the unit vectors. What is the magnitude of the object's acceleration?

(in  $\text{m/s}^2$ )

6.    **A**   $8.57 \times 10^{-1}$     **B**  1.00            **C**  1.17  
       **D**  1.37            **E**  1.61            **F**  1.88  
       **G**  2.20            **H**  2.57

**4 pt** A force  $\mathbf{F}$ , with a magnitude of 20.10 N, acts on an object with a mass of  $m = 1.34$  kg parallel to the plane of the incline as shown in the figure.



The angle of the incline is  $\theta = 42.2^\circ$ . The object is observed to move at a constant velocity of 4.15 m/s up on the incline. Calculate the magnitude of the frictional force acting on the object.

(in N)

7.    **A**  9.97            **B**   $1.13 \times 10^1$     **C**   $1.27 \times 10^1$   
       **D**   $1.44 \times 10^1$     **E**   $1.63 \times 10^1$     **F**   $1.84 \times 10^1$   
       **G**   $2.08 \times 10^1$     **H**   $2.35 \times 10^1$

**3 pt** A crane at a construction site lifts a concrete block with a mass of  $m = 486$  kg from the ground to the top of a building with a height of  $h = 17.6$  m. How much work did the motor of the crane do? (Assume zero energy loss in the lifting mechanism due to friction.)

(in J)

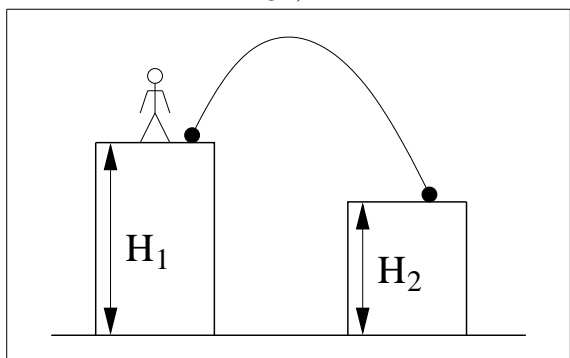
8.    **A**   $3.99 \times 10^4$     **B**   $5.79 \times 10^4$     **C**   $8.39 \times 10^4$   
       **D**   $1.22 \times 10^5$     **E**   $1.76 \times 10^5$     **F**   $2.56 \times 10^5$   
       **G**   $3.71 \times 10^5$     **H**   $5.38 \times 10^5$

**3 pt** If the duration of the lift was 1.55 minutes, then what was the average power performed by the crane?

(in W)

9.    **A**   $1.23 \times 10^2$     **B**   $1.63 \times 10^2$     **C**   $2.17 \times 10^2$   
       **D**   $2.88 \times 10^2$     **E**   $3.84 \times 10^2$     **F**   $5.10 \times 10^2$   
       **G**   $6.78 \times 10^2$     **H**   $9.02 \times 10^2$

**4 pt** A soccer ball is kicked from the top of one building with a height of  $H_1 = 32.7$  m to another building with a height of  $H_2 = 13.0$  m. (It is not a very smart idea to play soccer on the roof of tall buildings.)



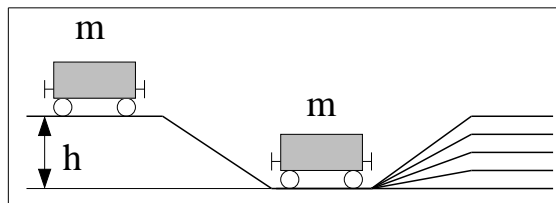
The ball is kicked with a speed of  $v_0 = 16.3$  m/s at an angle of  $\theta = 76.9^\circ$  with respect to the horizontal. The mass of a size 5 soccer ball is  $m = 450$  g. What is the speed of the soccer ball, when it lands on the roof of the second building? The soccer ball is kicked without a spin. Neglect air resistance.  
(in m/s)

10. **A**   $1.16 \times 10^1$     **B**   $1.36 \times 10^1$     **C**   $1.59 \times 10^1$   
**D**   $1.87 \times 10^1$     **E**   $2.18 \times 10^1$     **F**   $2.55 \times 10^1$   
**G**   $2.99 \times 10^1$     **H**   $3.50 \times 10^1$

**4 pt** A 75.3 kg wood board is resting on very smooth ice in the middle of a frozen lake. A 36.9 kg boy stands at one end of the board. He walks from one end of the board to the other end with a velocity of 1.47 m/s relative to the ice in the positive direction. What is the velocity of the board relative to the ice?  
(in m/s)

11. **A**  -1.13    **B**  -0.994    **C**  -0.857    **D**  -0.720  
**E**  0.720    **F**  0.857    **G**  0.994    **H**  1.13

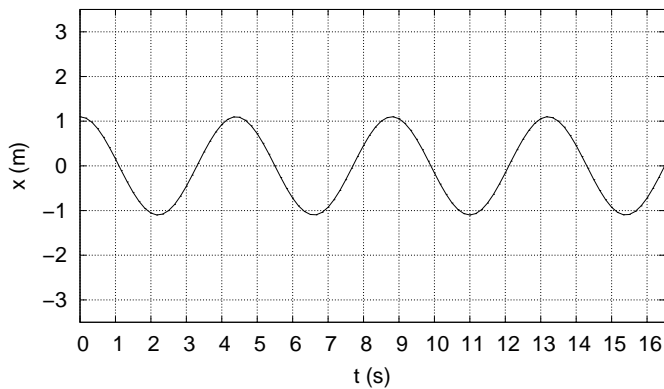
**4 pt** A railroad cart with mass  $m$  is at rest on the top of a hill with height  $h$ . (See figure.)



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.)

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

The graph shows the x-displacement as a function of time for a particular object undergoing simple harmonic motion.



This function can be described by the following formula:  
 $x(t) = A\cos(\omega t)$ , where  $x$  and  $A$  are measured in meters,  $t$  is measured in seconds,  $\omega$  is measured in rad/s.

**3 pt** Using the graph determine the amplitude  $A$  of the oscillation.

(in m)

13. A   $2.00 \times 10^{-1}$     B   $5.00 \times 10^{-1}$     C  1.10  
 D  2.00    E  2.60    F  3.20  
 G  3.50    H  4.40

**3 pt** Determine the period  $T$  of the oscillation.

(in s)

14. A  2.80    B  4.00    C  4.40    D  4.80  
 E  5.20    F  6.40    G  7.20    H  7.60

**3 pt** An object is performing simple harmonic oscillation whose amplitude is 30.0 cm, and period is 3.35 s. Determine the maximum speed of the object.

(in m/s)

15. A   $3.45 \times 10^{-1}$     B   $3.90 \times 10^{-1}$     C   $4.41 \times 10^{-1}$   
 D   $4.98 \times 10^{-1}$     E   $5.63 \times 10^{-1}$     F   $6.36 \times 10^{-1}$   
 G   $7.18 \times 10^{-1}$     H   $8.12 \times 10^{-1}$

**3 pt** Determine the maximum acceleration of the object.

(in  $\text{m/s}^2$ )

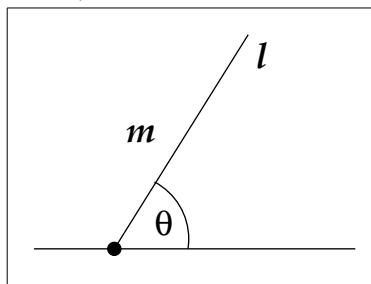
16. A   $6.75 \times 10^{-1}$     B   $8.44 \times 10^{-1}$     C  1.06  
 D  1.32    E  1.65    F  2.06  
 G  2.58    H  3.22

**4 pt** Planet-X has a mass of  $5.30 \times 10^{24}$  kg and a radius of 3760 km. What is the Escape Speed *i.e.* the minimum speed required for a satellite in order to break free permanently from the planet?

(in km/s)

17. A  1.02      B  1.48      C  2.14  
D  3.10      E  4.50      F  6.52  
G  9.46      H   $1.37 \times 10^1$

**4 pt** A uniform rod with a mass of  $m = 1.72$  kg and a length of  $l = 2.39$  m is attached to a horizontal surface with a hinge. The rod can rotate around the hinge without friction. (See figure.)



The rod is held at rest at an angle of  $\theta = 65.7^\circ$  with respect to the horizontal surface. What is the angular acceleration of the rod, when it is released?

(in  $\text{rad/s}^2$ )

18. A  1.55      B  1.76      C  1.98      D  2.24  
E  2.53      F  2.86      G  3.24      H  3.66

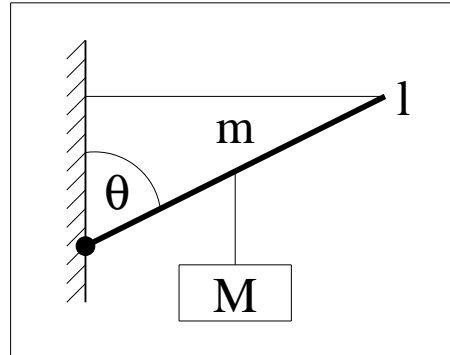
**2 pt** You are going to back out of a driveway. You put your car in reverse and you start driving backwards. The driveway is straight and horizontal. What is the direction of the velocity vector of your car?

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

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

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

A crate with a mass of  $M = 67.5$  kg is suspended by a rope from the midpoint of a uniform boom. The boom has a mass of  $m = 122$  kg and a length of  $l = 9.25$  m. The end of the boom is supported by another rope which is horizontal and is attached to the wall as shown in the figure.



**3 pt** The boom makes an angle of  $\theta = 57.4^\circ$  with the vertical wall. Calculate the tension in the vertical rope.  
(in N)

21. **A**   $5.30 \times 10^2$     **B**   $6.62 \times 10^2$     **C**   $8.28 \times 10^2$   
**D**   $1.03 \times 10^3$     **E**   $1.29 \times 10^3$     **F**   $1.62 \times 10^3$   
**G**   $2.02 \times 10^3$     **H**   $2.53 \times 10^3$

**3 pt** What is the tension in the horizontal rope?  
(in N)

22. **A**   $6.98 \times 10^2$     **B**   $7.89 \times 10^2$     **C**   $8.91 \times 10^2$   
**D**   $1.01 \times 10^3$     **E**   $1.14 \times 10^3$     **F**   $1.29 \times 10^3$   
**G**   $1.45 \times 10^3$     **H**   $1.64 \times 10^3$

**6 pt** A solid, homogeneous sphere with a mass of  $m_0$ , a radius of  $r_0$  and a density of  $\rho_0$  is placed in a container of water. Initially the sphere floats and the water level is marked on the side of the container. What happens to the water level, when the original sphere is replaced with a new sphere which has different physical parameters? Notation: r means the water level rises in the container, f means falls, s means stays the same.

▷ The new sphere has a density of  $\rho = \rho_0$  and a radius of  $r < r_0$ .  
**23.** A  r    B  f    C  s

▷ The new sphere has a radius of  $r > r_0$  and a mass of  $m = m_0$ .  
**24.** A  r    B  f    C  s

▷ The new sphere has a mass of  $m > m_0$  and a density of  $\rho = \rho_0$ .  
**25.** A  r    B  f    C  s

**4 pt** A rock band uses a wall built out of 39 identical speakers. If one single speaker can produce a sound level of 93.5 dB in the front row area, then what is the sound level produced by the whole wall?  
(in dB)

- 26.** A  70.0    B  87.5    C  109.4    D  136.8  
E  171.0    F  213.7    G  267.1    H  333.9

**4 pt** An organ pipe is 1.70 m long and it is open at one end and closed at the other end. What are the frequencies of the lowest three harmonics produced by this pipe? The speed of sound is 340 m/s. Only one answer is correct.

- 27.** A  50 Hz, 100 Hz, 150 Hz  
B  100 Hz, 200 Hz, 300 Hz  
C  200 Hz, 300 Hz, 400 Hz  
D  50 Hz, 100 Hz, 200 Hz  
E  100 Hz, 300 Hz, 500 Hz  
F  50 Hz, 150 Hz, 250 Hz  
G  200 Hz, 400 Hz, 600 Hz  
H  200 Hz, 600 Hz, 1000 Hz

**4 pt** An aluminium object with a mass of 2.79 kg and at a temperature of 22.8 °C comes to thermal contact with a 7.26 kg copper object which is initially at a temperature of 87.1 °C. What is going to be the equilibrium temperature of the two objects? Neglect heat transfer between the objects and the environment. The specific heats are:  $c_{Al} = 900 \text{ J/kg}^\circ\text{C}$  and  $c_{Cu} = 387 \text{ J/kg}^\circ\text{C}$ .  
(in degC)

- 28.** A  36.3    B  45.4    C  56.8    D  70.9  
E  88.7    F  110.8    G  138.6    H  173.2



**4 pt** 5.10 liters of Nitrogen gas at 23.0°C temperature and 1.60 atm pressure contains how many moles?

29. **A**  0.143    **B**  0.161    **C**  0.182    **D**  0.206  
**E**  0.233    **F**  0.263    **G**  0.297    **H**  0.336
- 

**5 pt** Constant amount of ideal gas is kept inside a cylinder by a piston. Then the piston compresses the gas **adiabatically**. Compare the initial (i) and the final (f) physical quantities of the gas to each other.

▷ The volume  $V_f$  is ...  $V_i$ .

30. **A**  equal to    **B**  less than  
**C**  greater than

▷ The pressure  $p_f$  is ...  $p_i$ .

31. **A**  equal to    **B**  less than  
**C**  greater than

▷ The internal energy  $U_f$  is ...  $U_i$ .

32. **A**  equal to    **B**  less than  
**C**  greater than

▷ The entropy  $S_f$  is ...  $S_i$ .

33. **A**  equal to    **B**  less than  
**C**  greater than

▷ The temperature  $T_f$  is ...  $T_i$ .

34. **A**  equal to    **B**  less than  
**C**  greater than
- 

**3 pt** An ideal heat engine has an efficiency of 15.2 percent. It operates between two heat reservoirs differing in temperature by 66.7 C°. What is the temperature of the hot reservoir? (in K)

35. **A**   $2.00 \times 10^2$     **B**   $2.34 \times 10^2$     **C**   $2.74 \times 10^2$   
**D**   $3.21 \times 10^2$     **E**   $3.75 \times 10^2$     **F**   $4.39 \times 10^2$   
**G**   $5.13 \times 10^2$     **H**   $6.01 \times 10^2$
-