Physical Constants:

Earth's free-fall acceleration $= g = 9.80$ m/s^2

Circle the letter of the single best answer. Each question is worth 1 point

1. Receptive Rupert works late into the night on a physics problem that involves an inclined plane (with inclination $\theta \in [0°, 90°]$), a spring (spring constant k), a string (tension T), various masses (m_1, etc.), kinetic friction (given by μ_k), a disk of radius R, and gravity. The problem asks him to calculate the acceleration a, but he just can't figure it out. At 3 A.M. he gives up and goes to sleep. At 5 A.M. he wakes up from a dream in which Einstein tells him the solution to the problem. He struggles to find some paper on which to write down the answer. It takes him a few minutes, but he finally writes down:

$$a = \frac{\sin\theta + \mu_k}{\frac{m_1}{T} + \frac{m_2}{kR} + \frac{1}{g}}$$

   Rupert's dream answer has:

   A. unit problems

   B. infinite acceleration for possible parameters

   C. zero acceleration for possible parameters

   D. none of the above

2. A 100 kg biker + bicycle combination must pedal at a constant 90 rpm in order to maintain a speed of 5 m/s going straight into a 10 m/s headwind. He has to push harder on the pedal in the up-hills and wind gusts, but he maintains the 90 rpm grind. ($\rho_{\text{air}} = 1.2$ kg/m^3, drag coefficient × cross sectional area $= C_D A = .5$ m^2.) The net force on the biker is greatest:

   A. riding up a long straight 5° slope.

   B. when the wind gusts to 15 m/s.

   C. when he hits the end of the straight road and makes the 90° turn putting the wind at his side.

   D. not enough information to determine.

3. A refreshed Rupert jumps out of a high flying airplane and falls towards the Earth. The reaction force to the force of gravity on Rupert is:

   A. the downward acceleration at g.

   B. a combination of the downward acceleration and air drag.

   C. Rupert's pull on the Earth.

   D. the normal force.

4. True or False: In football, many things contribute to success, but fundamentally to move through the line you must push your opponent harder than he pushes you.

   A. True

   B. False

5. A crate rests in the middle of the floor in an otherwise empty van stopped at a red light. The light turns green, so the driver (roadhog Rupert) hits the gas and the van accelerates down the road. Through out this process the crate sits at the same spot on the van's floor. We can conclude:

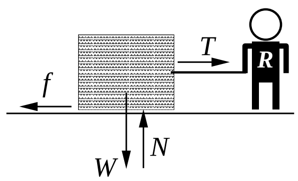
   A. since the crate didn't move, the forces on the crate must balance.

   B. the net force on the crate points towards the front of the truck.

   C. the net force on the crate points towards the back of the truck.

   D. the force of the engine on the road moves the van and its contents down the road.

6. A resolute Rupert pulls a box across a horizontal surface at a constant velocity v, by pulling on a rope with tension T. Other forces (W: gravity, N: normal force, f: friction) also act in the directions indicated. Which of the following relations among the force magnitudes must be true?



A. $T = f$ and $N = W$

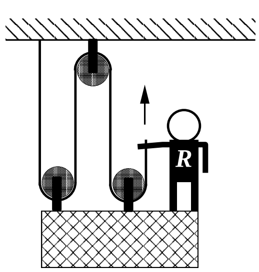
B. $T > f$ and $N = W$

C. $T > f$ and $N > W$

D. $T > f$ and $N < W$

7. The *mechanical advantage* of a simple machine is the ratio of the actual load raised to the force applied to the machine to raise the load. For example, you might apply a force of 3 N to one end of a lever to raise a weight of 12 N at the other. The mechanical advantage is then 12/3=4.

Rotund Rupert is in an elevator supported by a single rope that threads through three pulleys as shown below. By pulling on the rope (as shown by the arrow) Rupert can pull the elevator up. What is the mechanical advantage of this machine, i.e., what is the ratio of the weight of the system to Rupert's pull?



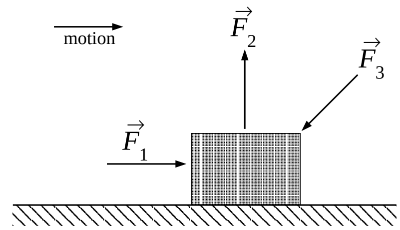
A. 2

B. 3

C. $3\frac{1}{2}$

D. 4

8. Three forces of equal magnitude but different direction act on a block as shown below. The block moves 3 m to the *right*. Rank the work done by each force. (The work done by force $\vec{F}_1$ is W_1, etc.)



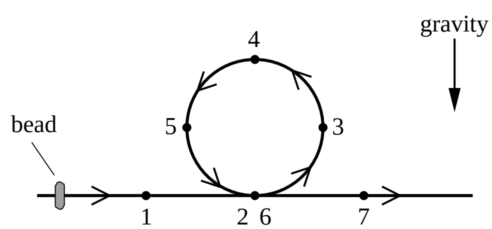
A. $W_1 > W_2 > W_3$

B. $W_2 > W_3 > W_1$

C. $W_3 > W_1 > W_2$

D. $W_3 > W_2 > W_1$

9. A bead is slides frictionlessly on a wire that includes a vertical circular loop. The bead passes through points 1, 2, 3, 4, 5, 6, and 7 in order around the loop. At point 4:



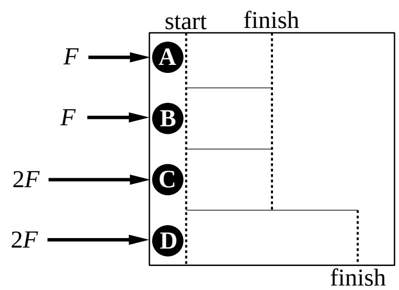
A. gravity has done negative work on the bead.

B. gravitational potential energy is at a maximum.

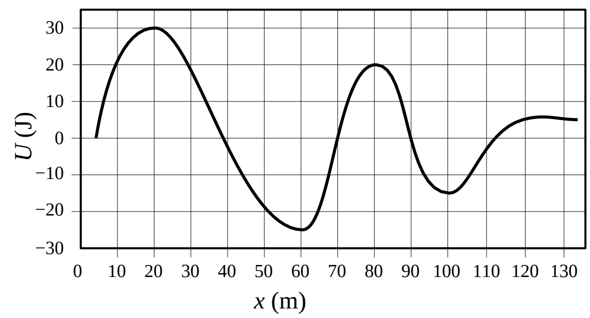
C. the kinetic energy of the bead is at a minimum.

D. all of the above.

10. Four pucks race on a frictionless surface. The pucks have masses: $M_A = 1$ kg, $M_B = 2$ kg, $M_C = 3$ kg, and $M_D = 4$ kg. As shown below, they are subjected to different forces and race lengths. Circle the puck with the largest kinetic energy when it crosses its finish line.



11. While parked in deep space the crew of the Enterprise notice a blip on the screen: a copy of our physics text is just 130 m from the ship (i.e., $x = 130$ m on the below graph), drifting directly toward them with a kinetic energy of 10 J. Frightened by the incredible wealth of knowledge contained in the book, a crew member (reincarnated Rupert) turns on the tractor beam which subjects the book to the below potential energy field. The largest repulsive force occurs at:



A. $x = 20$ m

B. $x = 70$ m

C. $x = 80$ m

D. $x = 90$ m

12. The book's speed reaches its maximum value at:

A. $x = 20$ m

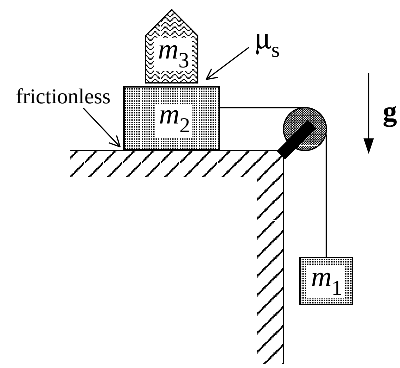
B. $x = 60$ m

C. $x = 90$ m

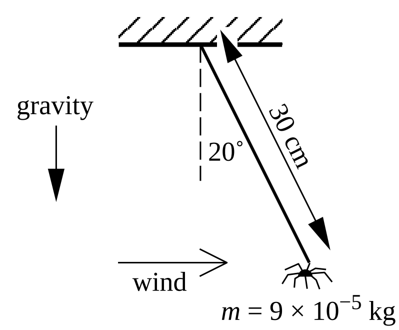
D. $x = 100$ m

The following questions are worth 5 pts each

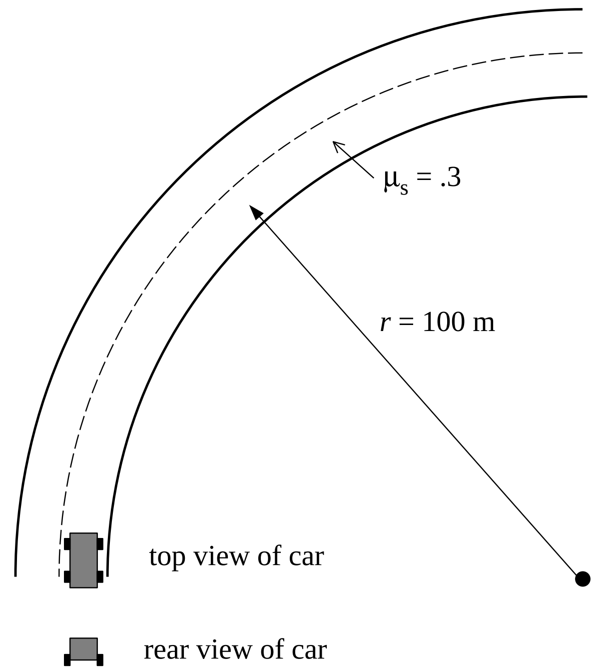
13. A frictionless surface allows the mass $m_2 = 3$ kg to be accelerated by any horizontal force, such as that supplied by the string connected to the falling mass m_1. A mass $m_3 = 1$ kg sits atop m_2, held in place only by static friction ($\mu_s = .2$). What is the largest falling mass m_1 for which m_2 and m_3 stay together? Please draw a free body diagram for each of the three masses showing and naming all forces acting.



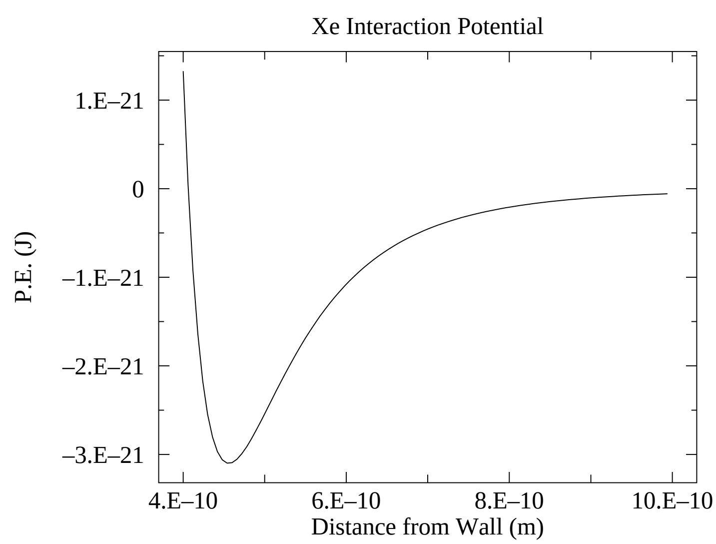
14. A spider of mass $m = 9 \times 10^{-5}$ kg hangs straight down on a 30 cm long thread she has just created. What is the tension in the thread? A steady breeze from the south pushes the hanging spider towards the north so that the thread makes an angle of 20° with the vertical. What is the tension in the thread now? Please draw a free body diagram for each situation!



15. What is the maximum speed a car can complete an unbanked highway curve of radius 100 m without slipping if the road/tires have a coefficient of friction of 0.3? On the below diagram of the car show and name all forces acting on the car.



16. All atoms feel a "small" force (van der Waals) when near a wall. Below is a plot of the corresponding potential energy for an atom of xenon (an inert gas) interacting with its container's wall. No surprise: the distances and energies are small: "`1.E-10`" m $= 1 \times 10^{-10}$ m often denoted 1 Å, "`1.E-21`" J $= 1 \times 10^{-21}$ J. (Small energies are often expressed in "eV": 10^{-21} J $= 6.24 \times 10^{-3}$ eV= 6.24 meV.) The mass of a xenon atom is also "small": $M_{Xe} = 2.2 \times 10^{-25}$ kg. A xenon atom is released from rest 10 Å from the wall. What is its speed when it is 5 Å from the wall? How close does it get to the wall? (Note: accurate reading the plot's data is part of this problem.)



17. Restrained Rupert (mass = 80 kg) decides to bungie jump out of a tall building. The bungie has a spring constant of 60 N/m and a length such that it will start taking effect after Rupert has fallen 5 m.

   A. What is the maximum extension of the bungie cord?

   B. After bouncing up and down Rupert ends up at a spot where the spring force of the bungie matches the force of gravity. Where is that location?