1.— [from lecture 2011-10-06] I swung a coffee cup over my head and the coffee did not spill out. If, at the top of the swing, the cup was moving at speed $v$ on a circular path of radius $R$, what needed to be true for the coffee to stay securely in the cup?

A: $\frac{v^2}{R} = 0$  
B: $\frac{v^2}{R} < g$  
C: $\frac{v^2}{R} = g$  
D: $\frac{v^2}{R} > g$  
E: None of these

2.— [from lecture 2011-10-13] We considered a block sliding down a frictionless hill and off a frictionless jump. The block flew up into the air, but it did not return to the height from which it started. Why not?

A: Energy was not conserved.  
B: The block lost energy to heat during its slide.  
C: Not all of the potential energy was converted into kinetic energy.  
D: After the jump, the horizontal component of velocity is constant.  
E: There are energies other than kinetic and potential to consider.

3.— [from lecture 2011-10-18] A small bullet of mass $m$ moving at velocity $\vec{v}$ lodged in a big block of mass $M$. Immediately before the collision, the bullet had momentum $\vec{p}_i = m \vec{v}$ and kinetic energy $K_i = \frac{1}{2} m |\vec{v}|^2$. Immediately after the collision, the momentum $\vec{p}_f$ and kinetic energy $K_f$ of the bullet+block system were

A: $|\vec{p}_f| = |\vec{p}_i|$ and $K_f = K_i$  
B: $|\vec{p}_f| = |\vec{p}_i|$ and $K_f < K_i$  
C: $|\vec{p}_f| = |\vec{p}_i|$ and $K_f > K_i$  
D: $|\vec{p}_f| < |\vec{p}_i|$ and $K_f = K_i$  
E: $|\vec{p}_f| > |\vec{p}_i|$ and $K_f = K_i$

4.— [from lecture 2011-10-18] A block of mass $[M + m]$ attached to the ceiling by a string of length $L$ is moving at speed $v_f$ when the string is vertical, that is, when the block is at the minimum of potential energy. It will then swing up to some maximum height $h_{\text{max}}$ given by

A: $h_{\text{max}} = \frac{v_f^2}{2g}$  
B: $h_{\text{max}} = \frac{v_f^2}{g}$  
C: $h_{\text{max}} = \frac{v_f}{g}$  
D: $h_{\text{max}} = \frac{v_f^2}{2g}$  
E: none of these
5.— [from lecture 2011-10-20] A block of mass 5.0 kg moves at 2.0 m s\(^{-1}\) in the positive \(x\) direction and a block of mass 3.0 kg moves at 3.0 m s\(^{-1}\) in the negative \(x\) direction. What is the \(x\)-direction velocity of the center of mass (or the velocity of the center-of-mass frame)?
\[ A: 0.125 \text{ m s}^{-1}\quad B: 0.5 \text{ m s}^{-1}\quad \text{C: 1.0 m s}^{-1}\quad \text{D: 2.375 m s}^{-1}\quad \text{E: 19.0 m s}^{-1}\]

6.— [from lecture 2011-10-25] We found the forces on a light table holding a very heavy block of mass \(M\). The table was supported by two supports (support 1 and support 2) separated by a distance \(L\). The block was a distance \(x\) from support 1. The ratio of the normal force \(N_2\) at support 2 to the normal force \(N_1\) at support 1 was
\[ A: \frac{N_2}{N_1} = |x|\quad B: \frac{N_2}{N_1} = |x - L|\quad \text{C: }\frac{N_2}{N_1} = \left|\frac{x}{x - L}\right|\quad \text{D: }\frac{N_2}{N_1} = \left|\frac{x - L}{x}\right|\quad \text{E: none of these}\]

7.— [from lecture 2011-10-27] The hanging sign problem we did had a cable that made an angle \(\theta\) with respect to the horizontal direction. Imagine making \(\theta\) very small, so the cable is nearly horizontal. What happens to the tension \(T\) in the cable as \(\theta\) gets small?
\[ A: \text{T gets very small}\quad B: \text{T approaches } M g + m g/2\quad \text{C: T gets very large}\quad \text{D: T doesn’t depend on } \theta\quad \text{E: none of these}\]

8.— [from lecture 2011-11-01] Stress is proportional to strain. What formula is most related to this fact?
\[ A: \vec{F} = m \vec{a}\quad B: \vec{F} = -k \vec{x}\quad \text{C: } E = \frac{1}{2} m v^2\quad \text{D: } E = \frac{|\vec{p}|^2}{2 m}\quad \text{E: } \vec{p} = m \vec{v}\]

9.— [from problem set 5, problem 1] The driver of a car traveling east slams on the brakes, so that the car goes through a period of rapid deceleration. The total force on the ground from the car must
\[ \text{A: have a downwards component and an eastwards component}\quad \text{B: have a downwards component and a westward component}\quad \text{C: have an upwards component and an eastwards component}\quad \text{D: have an upwards component and a westward component}\]
10. — [from problem set 5, problem 1] You are sitting in the passenger seat of a car moving forwards at high speed but also rapidly decelerating, with your seatbelt securely fastened. The deceleration has been going on for some time, and you are tightly held in your seat by your seatbelt. What is the direction of the net force acting on you?
A: There is (almost) no net force acting on you.
B: The net force points towards the front of the car.
C: The net force points towards the back of the car.
D: The net force points downwards.

11. — [from problem set 5, problem 2] Why do the astronauts in the Space Station feel weightless?
A: There is no gravity in space.
B: The Space Station is accelerating downwards at \( \vec{g} \).
C: The Space Station is going on a circular trajectory.
D: The Space Station is very far from Earth.

12. — [from problem set 5, problem 3] You may have learned something like \( P V = nRT \), where \( P \) is pressure (force per area) and \( V \) is volume. Whether or not you ever have heard that, what are the units of this equation? Note: You don’t need to know what \( n \), \( R \), or \( T \) are to solve this problem.
A: force  B: energy  C: mass  D: length  E: momentum

13. — [from problem set 6, problem 1] You computed the energy expended by a college-age human by considering the potential energy gain over time of climbing 9 flights of stairs at a reasonable pace. The human also has kinetic energy during this climb. Compare the kinetic energy \( K \) of the human during the climb to her or his total change in potential energy \( \Delta U \) during the climb.
A: \( K \) is much less than \( \Delta U \).  B: \( K \) is about equal to \( \Delta U \).
C: \( K \) is much greater than \( \Delta U \).
D: It is impossible to answer this question.

14. — [from problem set 6, problem 1] A good athlete can climb stairs at a mechanical energy output of 1 hp (horsepower). Roughly how long would it take such an athlete to climb nine flights of stairs?
A: 0.03 s  B: 0.3 s  C: 3 s  D: 30 s  E: 300 s
15. — [from problem set 6, problem 2] If you compare the energy content of gasoline and olive oil, you find that
A: olive oil has more than 10 times higher energy density
B: they are about the same
C: gasoline has more than 10 times higher energy density

16. — [from problem set 6, problem 3] A ball bounces on a hard surface. In the period between bounces, when the ball is in free-fall, a graph of the kinetic energy as a function of time will look like
A: a straight line
B: two straight lines connected at a point
C: a parabola going from high to low to high
D: a parabola going from low to high to low
E: none of these

17. — [from problem set 7, problem 1] Which of these figures—cut from a sheet of constant-thickness aluminum—has its center of mass precisely at the point (0, 0)?

E: none of these

18. — [from problem set 7, problem 2] Just before jumping out of the way, a (daring) student throws a ball at 10 mi h$^{-1}$ straight at a bus moving towards the student at 35 mi h$^{-1}$. Assume that these are the speeds just before the collision, that the collision is head-on, that the collision is elastic, and that the front of the bus is a flat, vertical plane. Right after the collision (after the ball leaves contact with the bus), what will be the speed of the ball? Give your answer for the original reference frame.
A: 60 mi h$^{-1}$
B: 70 mi h$^{-1}$
C: 80 mi h$^{-1}$
D: 90 mi h$^{-1}$
19. — [from problem set 7, problem 3] A student of mass $m_{\text{student}} = 80 \text{ kg}$ stands at rest next to a block of ice of mass $m_{\text{ice}} = 160 \text{ kg}$, also at rest, on a frictionless frozen lake. The student pushes on the block until both the student and the block are moving (in opposite directions). What is the ratio of their speeds?

A: $\frac{|\vec{v}_{\text{student}}|}{|\vec{v}_{\text{ice}}|} = 4$
B: $\frac{|\vec{v}_{\text{student}}|}{|\vec{v}_{\text{ice}}|} = 2$
C: $\frac{|\vec{v}_{\text{student}}|}{|\vec{v}_{\text{ice}}|} = \sqrt{2}$
D: $\frac{|\vec{v}_{\text{student}}|}{|\vec{v}_{\text{ice}}|} = 1$
E: $\frac{|\vec{v}_{\text{student}}|}{|\vec{v}_{\text{ice}}|} = \frac{1}{2}$

20. — [from problem set 8, problem 1] In this bridge, is the very top strut (across the top) in compression or tension?

A: compression  B: tension  C: neither  D: depends

21. — [from problem set 8, problem 2] When you are holding a heavy bag of weight $N$ (heavier than your arm) in your arm, and you have your arm angled so the upper arm is vertical and the forearm is horizontal, there is a tension force $T$ in your bicep muscle and a compression force $F_h$ in your humerus bone (the vertical bone in your upper arm). In addition to gravity, these three forces ($N$, $T$, and $F_h$) are all acting on the lower part of the arm.

A: $|F_h| > |N| > |T|$
B: $|N| > |F_h| > |T|$
C: $|F_h| > |T| > |N|$
D: $|T| > |N| > |F_h|$
E: $|T| > |F_h| > |N|$

22. — [from problem set 8, problem 3] A ladder leans in static equilibrium against a frictionless wall, making an angle $\theta$ with the vertical. How does the normal force $N$ between the floor and the ladder vary as we increase $\theta$ (make the ladder less vertical)?

A: $N$ increases  B: $N$ decreases  C: $N$ stays the same
23. — [from *Newton’s Second Law* lab] In one of the experiments, a glider mass is attached to a hanging mass by a string going over a pulley. In the theory for this experiment, you assumed that the “smart pulley” was massless. This assumption was made to
A: ensure that Newton’s law holds
B: make sure the smart pulley reads out correct information
C: reduce the friction in the system
D: make the tension in the string single-valued

24. — [from *Centripetal Force* lab] What is the relationship between the angular frequency \( \omega \) and the period \( T \)?
A: \( \omega = \frac{2\pi}{T} \)
B: \( \omega = \frac{T}{2\pi} \)
C: \( \omega = 2\pi T \)
D: \( \omega = \frac{1}{2\pi T} \)
E: you need more information to answer this

25. — [from *Conservation of Energy* lab] The spring used in this lab had a spring constant \( k \) with units of \( Nm^{-1} \), and a mass \( m \) attached to it. If you compress the spring by a distance \( x \), you store potential energy \( U \), where
A: \( U = mkx \)
B: \( U = \frac{1}{2} mkx^2 \)
C: \( U = \frac{1}{2} kx^2 \)
D: \( U = \frac{1}{3} kx^3 \)
E: \( U = \sqrt{k/m} \)