Problems from 2008 F=Ma exam

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by riben

1 A bird flying in a straight line, initially at 10 m/s, uniformly increases its speed to 18 m/s while covering a distance of 40 m. What is the magnitude of the acceleration of the bird?

(a) 0.1 m/s^2
(b) 0.2 m/s^2
(c) 2.0 m/s^2
(d) 2.8 m/s^2
(e) 5.6 m/s^2

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2 A cockroach is crawling along the walls inside a cubical room that has an edge length of 3 m. If the cockroach starts from the back lower left hand corner of the cube and finishes at the front upper right hand corner, what is the magnitude of the displacement of the cockroach?

(a) 3$\sqrt{2}$ m
(b) 3$\sqrt[3]{2}$ m
(c) 3$\sqrt{3}$ m
(d) 3 m
(e) 9 m

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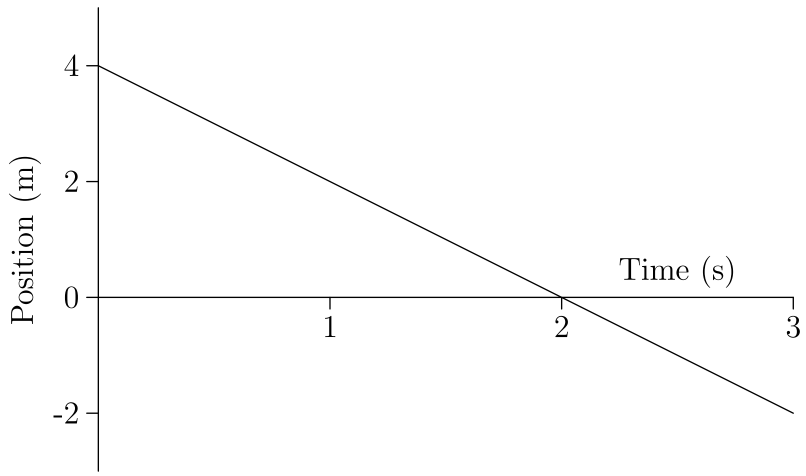
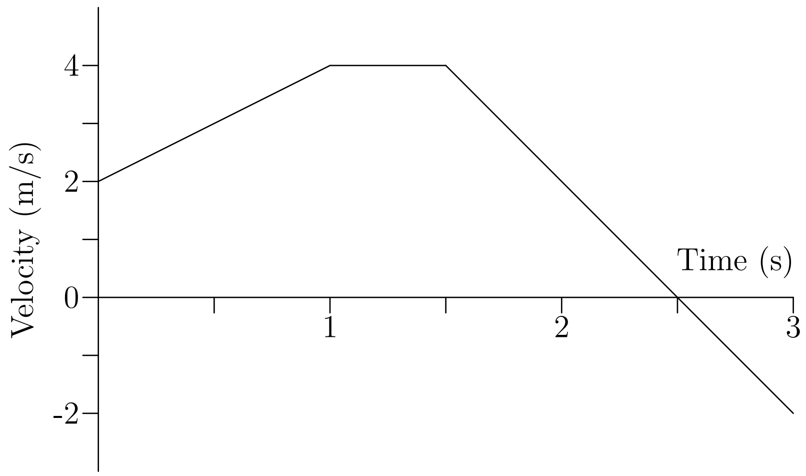
3 The position *vs.* time graph for an object moving in a straight line is shown below. What is the instantaneous velocity at t = 2 s?



(a) -2 m/s
(b) $-\frac{1}{2}$ m/s
(c) 0 m/s
(d) 2 m/s
(e) 4 m/s

– **The information below is for the next two problems**
Shown below is the velocity *vs.* time graph for a toy car moving along a straight line.



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4 What is the maximum displacement from start for the toy car?

(a) 3 m
(b) 5 m
(c) 6.5 m
(d) 7 m
(e) 7.5 m

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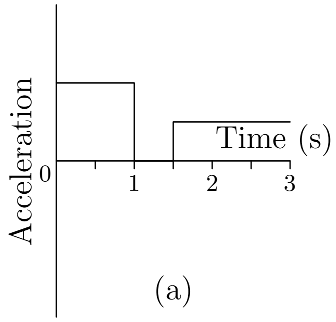
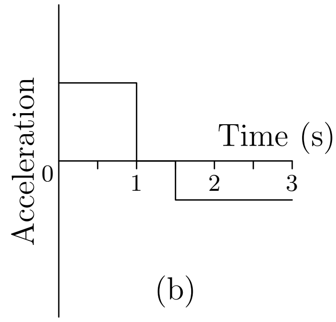
5 Which of the following acceleration *vs.* time graphs most closely represents the acceleration of the toy car?



(a)



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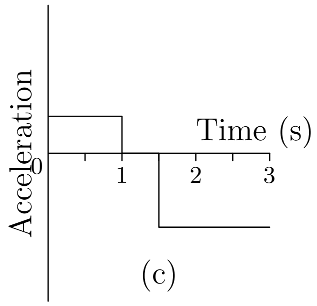
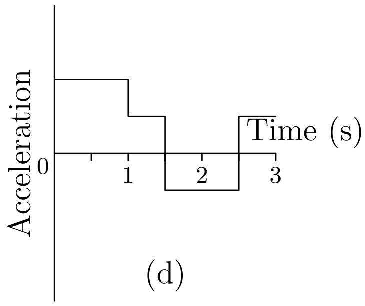
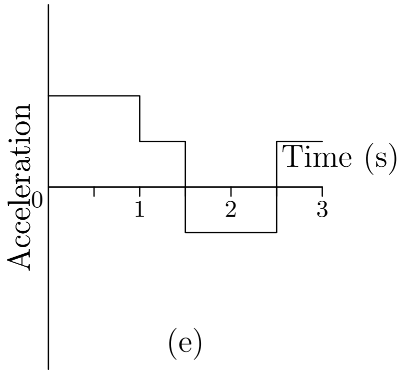


(c)



(d)



(e)

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6 A cannon fires projectiles on a flat range at a fixed speed but with variable angle. The maximum range of the cannon is L. What is the range of the cannon when it fires at an angle $\frac{\pi}{6}$ above the horizontal? Ignore air resistance.

(a) $\frac{\sqrt{3}}{2}L$

(b) $\frac{1}{\sqrt{2}}L$

(c) $\frac{1}{\sqrt{3}}L$

(d) $\frac{1}{2}L$

(e) $\frac{1}{3}L$

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7 A toboggan sled is traveling at 2.0 m/s across the snow. The sled and its riders have a combined mass of 120 kg. Another child ($m_{\text{child}} = 40$ kg) headed in the opposite direction jumps on the sled from the front. She has a speed of 5.0 m/s immediately before she lands on the sled. What is the new speed of the sled? Neglect any effects of friction.

(a) 0.25 m/s
(b) 0.33 m/s
(c) 2.75 m/s
(d) 3.04 m/s
(e) 3.67 m/s

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8 Riders in a carnival ride stand with their backs against the wall of a circular room of diameter 8.0 m. The room is spinning horizontally about an axis through its center at a rate of 45 rev/min when the floor drops so that it no longer provides any support for the riders. What is the minimum coefficient of static friction between the wall and the rider required so that the rider does not slide down the wall?

(a) 0.0012
(b) 0.056
(c) 0.11
(d) 0.53
(e) 8.9

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9 A ball of mass m_1 travels along the x-axis in the positive direction with an initial speed of v_0. It collides with a ball of mass m_2 that is originally at rest. After the collision, the ball of mass m_1 has velocity $v_{1x}\hat{x} + v_{1y}\hat{y}$ and the ball of mass m_2 has velocity $v_{2x}\hat{x} + v_{2y}\hat{y}$.

Consider the following five statements: I) $0 = m_1 v_{1x} + m_1 v_{2x}$ II) $m_1 v_0 = m_1 v_{1y} + m_2 v_{2y}$ III) $0 = m_1 v_{1y} + m_2 v_{2y}$ IV) $m_1 v_0 = m_1 v_{1x} + m_1 v_{1y}$ V) $m_1 v_0 = m_1 v_{1x} + m_2 v_{2x}$

Of these five statements, the system must satisfy

(a) I and II
(b) III and V
(c) II and V
(d) III and IV
(e) I and III

– **The following information applies to the next two problems**
An experiment consists of pulling a heavy wooden block across a level surface with a spring force meter. The constant force for each try is recorded, as is the acceleration of the block.

The data are shown below.

Force F in Newtons	3.05	3.45	4.05	4.45	5.05
acceleration a in meters/second^2	0.095	0.205	0.295	0.405	0.495

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10 Which is the best value for the mass of the block?

(a) 3 kg
(b) 5 kg
(c) 10 kg
(d) 20 kg
(e) 30 kg

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11 Which is the best value for the coefficient of friction between the block and the surface?

(a) 0.05
(b) 0.07
(c) 0.09
(d) 0.5
(e) 0.6

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12 A uniform disk rotates at a fixed angular velocity on an axis through its center normal to the plane of the disk, and has kinetic energy E. If the same disk rotates at the same angular velocity about an axis on the edge of the disk (still normal to the plane of the disk), what is its kinetic energy?

(a) $\frac{1}{2}E$

(b) $\frac{3}{2}E$

(c) $2E$

(d) $3E$

(e) $4E$

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13 A mass is attached to the wall by a spring of constant k. When the spring is at its natural length, the mass is given a certain initial velocity, resulting in oscillations of amplitude A. If the spring is replaced by a spring of constant $2k$, and the mass is given the same initial velocity, what is the amplitude of the resulting oscillation?

(a) $\frac{1}{2}A$

(b) $\frac{1}{\sqrt{2}}A$

(c) $\sqrt{2}A$

(d) $2A$

(e) $4A$

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14 A spaceborne energy storage device consists of two equal masses connected by a tether and rotating about their center of mass. Additional energy is stored by reeling in the tether; no external forces are applied. Initially the device has kinetic energy E and rotates at angular velocity ω. Energy is added until the device rotates at angular velocity 2ω. What is the new kinetic energy of the device?

(a) $\sqrt{2}E$
(b) $2E$
(c) $2\sqrt{2}E$
(d) $4E$
(e) $8E$

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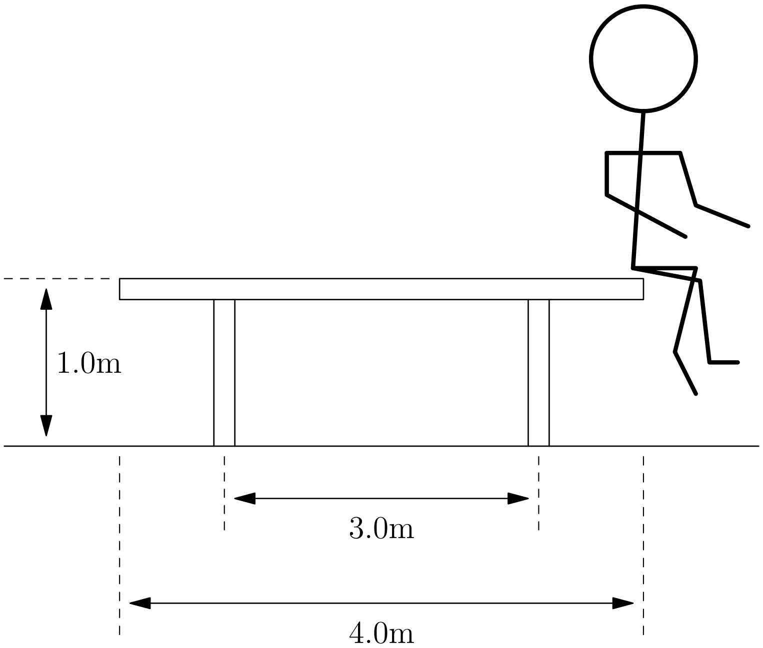
15 A uniform round tabletop of diameter 4.0 m and mass 50.0 kg rests on massless, evenly spaced legs of length 1.0 m and spacing 3.0 m. A carpenter sits on the edge of the table. What is the maximum mass of the carpenter such that the table remains upright? Assume that the force exerted by the carpenter on the table is vertical and at the edge of the table.



(a) 67 kg
(b) 75 kg
(c) 81 kg
(d) 150 kg
(e) 350 kg

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16 A *massless* spring with spring constant k is vertically mounted so that bottom end is firmly attached to the ground, and the top end free. A ball with mass m falls vertically down on the top end of the spring, becoming attached, so that the ball oscillates vertically on the spring. What equation describes the acceleration a of the ball when it is at a height y above the *original* position of the top end of the spring? Let down be negative, and neglect air resistance; g is the magnitude of the acceleration of free fall.

(a) $a = mv^2/y + g$
(b) $a = mv^2/k - g$
(c) $a = (k/m)y - g$
(d) $a = -(k/m)y + g$
(e) $a = -(k/m)y - g$

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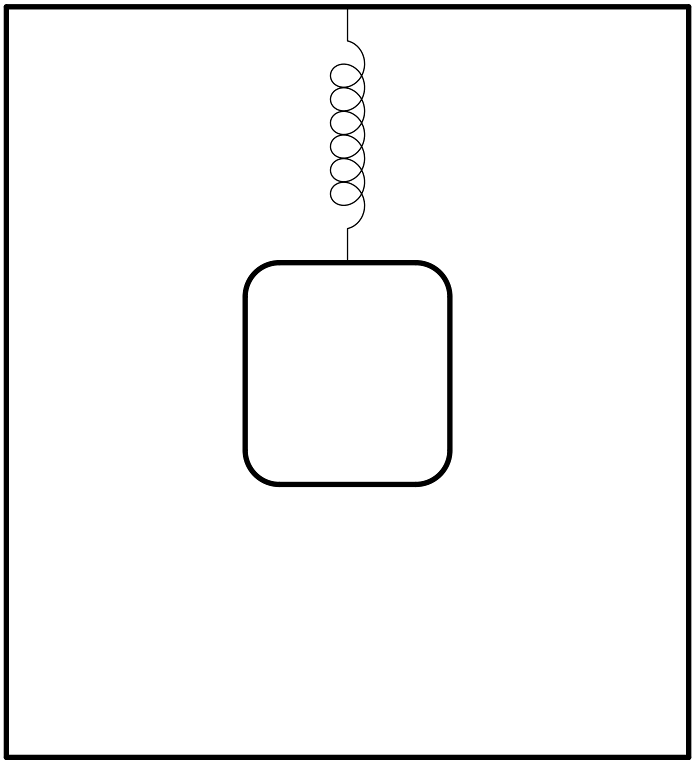
17 A mass m is resting at equilibrium suspended from a vertical spring of natural length L and spring constant k inside a box as shown:



The box begins accelerating upward with acceleration a. How much closer does the equilibrium position of the mass move to the bottom of the box?

(a) $(a/g)L$
(b) $(g/a)L$
(c) $m(g+a)/k$
(d) $m(g-a)/k$
(e) ma/k

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18 A uniform circular ring of radius R is fixed in place. A particle is placed on the axis of the ring at a distance much greater than R and allowed to fall towards the ring under the influence of the rings gravity. The particle achieves a maximum speed v. The ring is replaced with one of the same (linear) mass density but radius $2R$, and the experiment is repeated. What is the new maximum speed of the particle?

(a) $\frac{1}{2}v$

(b) $\frac{1}{\sqrt{2}}v$

(c) v

(d) $\sqrt{2}v$

(e) $2v$

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19 A car has an engine which delivers a constant power. It accelerates from rest at time $t = 0$, and at $t = t_0$ its acceleration is a_0. What is its acceleration at $t = 2t_0$? Ignore energy loss due to friction.

(a) $\frac{1}{2}a_0$

(b) $\frac{1}{\sqrt{2}}a_0$

(c) a_0

(d) $\sqrt{2}a_0$

(e) $2a_0$

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20 The Youngs modulus, E, of a material measures how stiff it is; the larger the value of E, the more stiff the material. Consider a solid, rectangular steel beam which is anchored horizontally to the wall at one end and allowed to deflect under its own weight. The beam has length L, vertical thickness h, width w, mass density ρ, and Youngs modulus E; the acceleration due to gravity is g. What is the distance through which the other end moves? (*Hint: you are expected to solve this problem by eliminating implausible answers. All of the choices are dimensionally correct.*)

(a) $h \exp\left(\frac{\rho g L}{E}\right)$

(b) $2\frac{\rho g h^2}{E}$

(c) $\sqrt{2Lh}$

(d) $\frac{3}{2}\frac{\rho g L^4}{E h^2}$

(e) $\sqrt{3}\frac{EL}{\rho g h}$

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21 Consider a particle at rest which may decay into two (daughter) particles or into three (daughter) particles. Which of the following is true in the two-body case but false in the three-body case? (There are no external forces.)

(a) The velocity vectors of the daughter particles must lie in a single plane.
(b) Given the total kinetic energy of the system and the mass of each daughter particle, it is possible to determine the speed of each daughter particle.
(c) Given the speed(s) of all but one daughter particle, it is possible to determine the speed of the remaining particle.
(d) The total momentum of the daughter particles is zero.
(e) None of the above.

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22 A bullet of mass m_1 strikes a pendulum of mass m_2 suspended from a pivot by a string of length L with a horizontal velocity v_0. The collision is perfectly inelastic and the bullet sticks to the bob. Find the minimum velocity v_0 such that the bob (with the bullet inside) completes a circular vertical loop.

(a) $2\sqrt{Lg}$
(b) $\sqrt{5Lg}$
(c) $(m_1 + m_2)2\sqrt{Lg}/m_1$
(d) $(m_1 - m_2)\sqrt{Lg}/m_2$
(e) $(m_1 + m_2)\sqrt{5Lg}/m_1$

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23 Consider two uniform spherical planets of equal density but unequal radius. Which of the following quantities is the same for both planets?

(a) The escape velocity from the planets surface.
(b) The acceleration due to gravity at the planets surface.
(c) The orbital period of a satellite in a circular orbit just above the planets surface.
(d) The orbital period of a satellite in a circular orbit at a given distance from the planets center.
(e) None of the above.

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24 A ball is launched upward from the ground at an initial vertical speed of v_0 and begins bouncing vertically. Every time it rebounds, it loses a proportion of the magnitude of its velocity due to the inelastic nature of the collision, such that if the speed just before hitting the ground on a bounce is v, then the speed just after the bounce is rv, where $r < 1$ is a constant. Calculate the total length of time that the ball remains bouncing, assuming that any time associated with the actual contact of the ball with the ground is negligible.

(a) $\frac{2v_0}{g}\frac{1}{1-r}$

(b) $\frac{v_0}{g}\frac{r}{1-r}$

(c) $\frac{2v_0}{g}\frac{1-r}{r}$

(d) $\frac{2v_0}{g}\frac{1}{1-r^2}$

(e) $\frac{2v_0}{g}\frac{1}{1+(1-r)^2}$

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25 Two satellites are launched at a distance R from a planet of negligible radius. Both satellites are launched in the tangential direction. The first satellite launches correctly at a speed v_0 and enters a circular orbit. The second satellite, however, is launched at a speed $\frac{1}{2}v_0$. What is the minimum distance between the second satellite and the planet over the course of its orbit?

(a) $\frac{1}{\sqrt{2}}R$

(b) $\frac{1}{2}R$

(c) $\frac{1}{3}R$

(d) $\frac{1}{4}R$

(e) $\frac{1}{7}R$
