1. A boy is standing at the stern (back) of a boat that is 8.0 m long. There is no friction between the boat and the water. The boy has a mass of 63 kg and the boat has a mass of 780 kg. The bow (front) of the boat is touching a dock and the fore-and-aft axis of the boat is perpendicular to the dock. The boy walks from the stern of the boat to the bow. When he reaches the bow, his distance from the dock is:

   a) 7.7 m
   b) 0.3 m
   [✓ c)] 0.6 m
   d) 8.0 m
   e) 1.3 m

$m = 63kg, \quad M = 780kg$

$m\vec{v} + M\vec{V} = 0$

$\frac{v}{V} = \frac{M}{m} = \frac{8m}{x\ m} \longrightarrow x = 0.6m$

2. A body of mass m is whiled at a constant angular velocity on the end of a string of length R. To double the kinetic energy of the body as it whirls while maintaining the angular velocity, the length of the string must be changed to

   a) 2R
   [✓ b)] $R\sqrt{2}$
   c) R/2
   d) 4R
   e) $R/\sqrt{2}$

$K = \frac{m\omega^2 R^2}{2}$

$K' = 2K \longrightarrow R' = R\sqrt{2}$

3. For this question, assume that all velocities are horizontal and that there is no friction. Two skaters A and B are on an ice surface. A and B have the same mass M = 90.5 kg. A throws a ball with mass m = 200 g toward B with a speed v = 21.5 m/s relative to the ice. B catches the ball and throws it back to A with the same speed. After A catches the ball, his speed with respect to the ice is.

   a) 4.3×10^3 m/s
   b) 4.3 m/s
   c) 4.8×10^{-2} m/s
   [✓ d)] 9.5×10^{-2} m/s
   e) 0.34 m/s

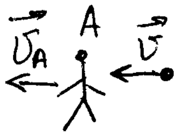
$m\vec{v} + M\vec{v}_A = 0$

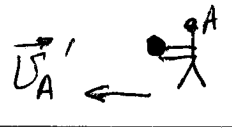
$v_A = \frac{m}{M} v$

As A catches the ball, momentum conservation:

$M\vec{v}_A + m\vec{V} = (M+m)\vec{v}_A'$

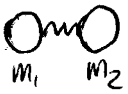
$v_A' = \frac{Mv_A + mv}{M+m} = \frac{2mv}{M+m} = 0.095 \frac{m}{s}$





4. A mass $m_1 = 2.5$ kg is connected to another mass $m_2 = 4.0$ kg by a compressed spring. Both masses are at rest on a frictionless surface. When the spring is released, the masses are pushed apart and a total energy of 16.8 J is given to the two masses. The speed of mass m_1 is

a) 3.2 m/s
[✓ b)] 2.9 m/s
c) 1.8 m/s
d) 8.3 m/s
e) 5.4 m/s



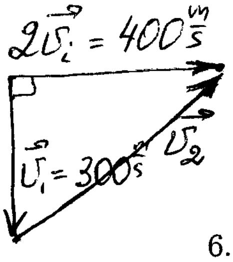
$m_1\vec{v}_1 + m_2\vec{v}_2 = 0$

$v_1 = v_2\frac{m_2}{m_1} = 1.6\,v_2 \qquad v_2 = \frac{v_1}{1.6}$

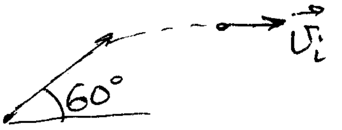
$16.8 = \frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2} = \frac{v_1^2}{2}\left[m_1 + \frac{m_2}{(1.6)^2}\right] \longrightarrow v_1 = 2.9\frac{m}{s}$

5. A projectile is fired at a speed of 400 m/s at an angle of 60° above the horizontal. At the highest point of its trajectory, the projectile is broken into two equal pieces by an internal explosion. Just after the explosion, one of the two pieces is known to be traveling vertically downward at a speed of 300 m/s. The magnitude of the velocity of the other half of the projectile is

v_i – initial velocity of the projectile (just before the explosion)



[✓ a)] 500 m/s
b) 1.50 km/s
c) 400 m/s
d) 710 m/s
e) 123 m/s



$v_i = (400\frac{m}{s})\cdot\cos 60^\circ = 200\frac{m}{s}$

m – mass of each piece

$(2m)\vec{v}_i = m\vec{v}_1 + m\vec{v}_2 \Rightarrow$

$\Rightarrow \vec{v}_2 = 2\vec{v}_i - \vec{v}_1$

$v_2 = \sqrt{400^2+300^2}$

$v_2 = 500\frac{m}{s}$

6. A 7000-kg coal car of a train coasts at 7.0 m/s on a frictionless track when a 3000-kg load of coal is dropped vertically onto the car. The coal car's speed after the coal is added is

a) 2.1 m/s
b) 3.0 m/s
[✓ c)] 4.9 m/s
d) 7.0 m/s
e) 16 m/s

$Mv_i = (M+m)v_f$

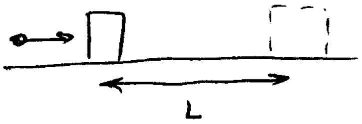
$v_f = \frac{M}{M+m}v_i = 4.9\frac{m}{s}$

7. A pitcher throws a baseball with a velocity of 27 m/s. After being struck by a bat the ball travels in the opposite direction with a velocity of 40 m/s. If the ball has a mass of 0.11 kg and is in contact with the bat for 3.0 ms, the average force exerted by the bat on the ball is

a) 0.99 kN
b) 4.8 kN
c) 1.5 kN
d) 7.4 kN
[✓ e)] 2.5 kN

$F\Delta t = \Delta p = m\Delta v = 0.11(40-(-27))\,(kg\cdot\frac{m}{s})$

$F = \frac{(0.11)(67)(kg\cdot\frac{m}{s})}{3\times10^{-3}\,s} = 2.5\,kN$



8. A 20-g bullet is fired into a 2.0-kg block of wood placed on a horizontal surface. The bullet stops in the block. The impact moves the block (+ bullet) a distance of 5 m before it comes to rest. If the coefficient of kinetic friction between the block and surface is 0.25, calculate the speed of the block (+ bullet) system immediately after impact.

a) 20 m/s
b) 3.5 m/s
c) 25 m/s
[✓ d)] 5.0 m/s
e) 2.2 m/s

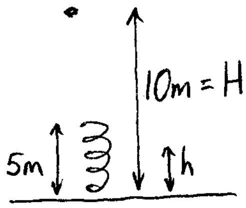
$F_k = (M+m)\mu g$

Acceleration of the (block + bullet) is: $-\mu g$

$L = \frac{v_f^2 - v_i^2}{2a} = \frac{0 - v_i^2}{-2\mu g} = \frac{v_i^2}{2\mu g} \longrightarrow v_i = \sqrt{2\mu g L} = 5\frac{m}{s}$

9. A 5-kg blob of putty is dropped from a height of 10.0 m above the ground onto a light vertical spring the top of which is 5 m above the ground. If the spring constant $k = 200$ N/m and the blob compresses the spring by 1.50 m, then find the amount of energy lost in sound and thermal energy.

a) 20.0 J
b) 169 J
c) 266 J
d) 438 J
[✓ e)] 94.0 J



$E_i = mgH$

$h = 5m - 1.5m = 3.5m$

$E_f = \frac{k(\Delta x)^2}{2} + mgh$

$E_i - E_f = 94 J$

10. A bicycle wheel, a hollow sphere, and a solid sphere each have the same mass and radius. They each rotate about an axis through their centers. Which has the greatest moment of inertia and which has the least?

[✓ a)] The wheel has the greatest; the solid sphere has the least.
b) The wheel has the greatest; the hollow sphere has the least.
c) The hollow sphere has the greatest; the solid sphere has the least.
d) The hollow sphere has the greatest; the wheel has the least.
e) The solid sphere has the greatest; the hollow sphere has the least.

11. The prefix "nano" means

10^{-9}

a) 10^{-12}
b) 10^{-6}
c) 10^{-3}
d) 10^{-2}
[✓ e)] None of these is correct

12. To convert a quantity from km/h to m/s, you must

a) multiply by 1000 and divide by 60.
[✓ b)] multiply by 1000 and divide by 3600.
c) multiply by 60 and divide by 1000.
d) multiply by 3600 and divide by 1000.
e) None of these is correct.

13. A wheel (radius = 0.20 m) starts from rest and rotates with a constant angular acceleration of 2.0 rad/s^2. At the instant when the angular velocity is equal to 1.2 rad/s, what is the magnitude of the total linear acceleration of a point on the rim of the wheel?

a) 0.40 m/s^2
b) 0.29 m/s^2
c) 0.69 m/s^2
[✓ d)] 0.49 m/s^2
e) 0.35 m/s^2

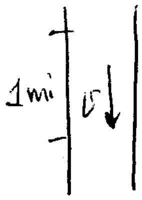
$$a = \sqrt{a_\tau^2 + a_n^2} = \sqrt{(\omega^2 r)^2 + (\varepsilon r)^2} = .49 \frac{m}{s^2}$$

$$a_n = \frac{v^2}{r} = \omega^2 r$$

$$a_\tau = \varepsilon r$$

14. A river 1.00 mile wide flows with a constant speed of 1.00 mi/h. A woman leaves from a point on the river bank. The woman rows a boat 1.00 mi directly upstream and returns to the starting point. Her speed in still water is 2.00 mi/h. The travel time for the woman is

a) 2.00 h
b) 1.15 h
c) 1.00 h
[✓ d)] 1.33 h
e) 0.67 h



v_u - velocity of the woman, as she moves upstream

v_d - velocity of the woman, as she moves downstream

$v_u = 2\frac{mi}{h} - 1\frac{mi}{h} = 1\frac{mi}{h}$, $v_d = 2\frac{mi}{h} + 1\frac{mi}{h} = 3\frac{mi}{h}$

$t_u = \frac{1mi}{v_u} = 1h$

$t_d = \frac{1mi}{v_d} = 0.33h$

$t = t_u + t_d = 1.33h$

15. A car accelerates uniformly from rest to a speed of 20 m/s at the end of 1 min; it then accelerates uniformly to a speed of 40 m/s at the end of the next minute. During this 2-min period, the average speed of the car is

a) 7.5 m/s
b) 30 m/s
c) 15 m/s
[✓ d)] 20 m/s
e) 40 m/s

$$a = const \Rightarrow v_{average} = \frac{v_i + v_f}{2}$$

$$v_{average} = \frac{0 + 40\frac{m}{s}}{2} = 20\frac{m}{s}$$

16. A 3-kg block sits on an incline where the top half of the incline has a coefficient of kinetic friction of 0.5 and the bottom half is frictionless (see Fig. A below). The angle of inclination is 35 degrees. If the block is released and travels 10 m along the rough part of the incline and then 10 m along the smooth part before it makes contact with the spring (k = 200 N/m), calculate the distance the spring is compressed.

- a) 1.47 m
- [✓ b)] 1.56 m
- c) 2.16 m
- d) 2.43 m
- e) 1.39 m

$ma = mg\sin\alpha - F_k \longrightarrow a = g(\sin\alpha - \mu\cos\alpha) = 1.57\frac{m}{s^2}$

$F_k = \mu N = \mu mg\cos\alpha \qquad v_1^2 = 2al = 31.44\frac{m^2}{s^2} \quad (l = 10m)$

$E_f = \frac{k(\Delta x)^2}{2} = \frac{mv_1^2}{2} + mg(l\sin 35° + \Delta x \sin 35°) \leftarrow$ quadratic equation with respect to Δx

Solving for Δx we obtain $\Delta x = 1.56m$

17. A balloon is ascending at a rate of 4.9 m/s at a height of 9.8 m above the ground when a package is dropped. The time taken, in the absence of air resistance, for the package to reach the ground is

- a) 1.0 s
- b) 1.5 s
- [✓ c)] 2.0 s
- d) 2.5 s
- e) 3.0 s

$9.8m = (4.9\frac{m}{s})t - \frac{gt^2}{2}$

$t^2 - t + 2 = 0$

$(t-2)(t+1) = 0$

$t = 2s$

18. The vector in Figure B below that could represent the vector $\vec{A} - \vec{B}$ is

- a) $\vec{1}$
- [✓ b)] $\vec{2}$
- c) $\vec{3}$
- d) $\vec{4}$
- e) $\vec{5}$

19. What angle does the vector $\vec{A} = 3\hat{\imath} - 4\hat{\jmath} + 5\hat{k}$ make with the positive z axis?

- a) 55.5°
- [✓ b)] 45.0°
- c) 64.9°
- d) 34.5°
- e) 25.1°

20. A train, starting from rest, accelerates along the platform at a uniform rate of 0.6 m/s^2. A passenger standing on the platform is 5 m away from the door when the train starts to pull away and heads toward the door at an acceleration of 1.2 m/s^2. How long does it take the passenger to reach the door?

a) 3.0 s
b) 17 s
c) 7.1 s
d) 5.6 s
[✓ e) 4.1 s]

X_p - position of the passenger

X_d - position of the door

$$X_p = X_{ip} + a_p\frac{t^2}{2} = 5m + (1.2\frac{m}{s^2})\frac{t^2}{2}$$

$$X_d = X_{iD} + a_D\frac{t^2}{2} = 0 + (0.6\frac{m}{s^2})\frac{t^2}{2}$$

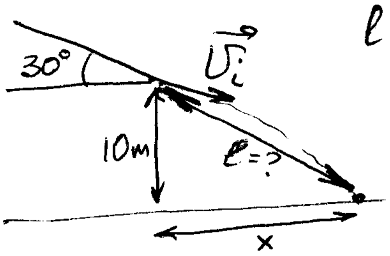
$X_p = X_d$ (reaches)

$$5 + \frac{1.2}{2}t^2 = \frac{0.6}{2}t^2$$

$$t = \sqrt{\frac{10}{0.6}} = 4.1s$$

21. A roofing tile slides down a roof and falls off the roof edge 10 m above the ground at a speed of 6 m/s. The roof makes an angle of 30 degrees to the horizontal. How far *from the exit point* on the roof does the tile land?

a) 6.0 m
b) 16.0 m
[✓ c) 11.7 m]
d) 13.6 m
e) 19.2 m



$$\ell = \sqrt{(10m)^2 + x^2} = \sqrt{(10m)^2 + (6m)^2} = 11.7m$$

$$v_x = v_i \cos 30° = 5.2\frac{m}{s}$$

$$x = v_x t \qquad v_{y_i} = v_i \sin 30° = 3\frac{m}{s}$$

$$10m = (3\frac{m}{s})t + \frac{gt^2}{2} \rightarrow t = 1.15s$$

$$x = 6m$$

22. A turntable rotating at 8.0 rad/s slows to a stop in 10 s. If the acceleration is constant, the angle through which the turntable rotates in the 10 s is

a) 0.80 rad
b) 0.40 rad
[✓ c) 40 rad]
d) 80 rad
e) 16 rad

$$\theta = \frac{1}{2}(\omega_i + \omega_f)t = \frac{1}{2}(8\frac{rad}{s})(10s) = 40rad$$

23. A 44.5-N weight is hung on a spring scale, and the scale is hung on a string (Fig. C below). The string is lowered at a rate such that the entire assembly has a downward acceleration of 4.90 m/s^2. The scale reads

a) 0 N
[✓ b) 22.2 N]
c) 44.5 N
d) 66.7 N
e) 71.2 N

$$ma = mg - T$$

$$T = m(g-a) = mg(1 - \frac{a}{g}) = (44.5N)(1 - \frac{1}{2})$$

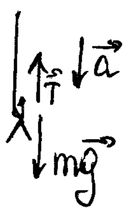
$$T = 22.2N$$

24. Which of the following free-body diagrams (Fig. D below) represents the block sliding down a frictionless inclined plane?

- a) 1
- b) 2
- c) 3
- d) 4
- [✓ e) 5]

25. You want to elope by sliding down a nylon rope made by tying stockings together. The rope will withstand a maximum tension of 300 N without breaking. Your mass is 61.2 kg. The magnitude of the smallest acceleration a with which you can slide down the rope is

- a) 9.8 m/s^2
- [✓ b) 4.9 m/s^2]
- c) zero
- d) 2.4 m/s^2
- e) 20 m/s^2



$m\bar{a} = m\bar{g} + \bar{T}$

$ma = mg - T$

$a = g - \frac{T}{m} = 9.8\frac{m}{s^2} - \frac{300N}{61.2kg} = 4.9\frac{m}{s}$

26. For this problem, (Fig. E below) assume no friction. A mass $m_2 = 3.5$ kg rests on a horizontal table and is attached by strings to masses $m_1 = 1.5$ kg and $m_3 = 2.5$ kg as shown. The masses m_1 and m_3 hang freely. The system is initially held at rest. After it is released, the acceleration of mass m_2 will be

- a) zero
- [✓ b) 1.3 m/s^2]
- c) 5.2 m/s^2
- d) 8.7 m/s^2
- e) 9.8 m/s^2

$m_1 a = T_1 - m_1 g$

$m_2 a = T_2 - T_1$

$m_3 a = m_3 g - T_2$

$(m_1 + m_2 + m_3)a = (m_3 - m_1)g \longrightarrow a = \frac{m_3 - m_1}{m_1 + m_2 + m_3} g = 1.3\frac{m}{s^2}$

27. A tired worker pushes a heavy (100-kg) crate that is resting on a thick pile carpet. The coefficients of static and kinetic friction are 0.6 and 0.4, respectively. The worker pushes with a force of 500 N. The frictional force exerted by the surface is

- a) 1000 N
- b) 600 N
- [✓ c) 500 N]
- d) 400 N
- e) 100 N

$F_{\substack{static\\max}} = \mu_s (mg) = 600N$

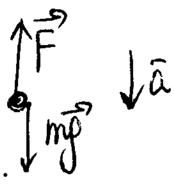
$F_{worker} < F_{\substack{static\\max}} \Rightarrow$ the crate doesn't move

$F_{static} = F_{worker} = 500N$

(3rd Newton's Law)

28. An object with a mass of $m = 12.0$ g is falling through a resistive fluid in which the gravitational acceleration is constant. The retarding frictional force due to the fluid is $F = bv$, where F is the force in newtons, b is a constant, and v the speed in meters per second. If $F = 3.2 \times 10^{-2}$ N when $v = 16.0$ m/s, the terminal speed of the object falling the fluid is

a) 0.12 m/s
[✓ b) 59 m/s]
c) 0.19 km/s
d) 16.0 m/s
e) None of these is correct.



$ma = mg - F$

$a_f = 0$

$mg = F_f = bv_f \rightarrow v_f = \frac{mg}{b} = 59\frac{m}{s}$

$b = \frac{F}{v} = \frac{3.2\times10^{-2}}{16}\frac{N}{m/s}$

29. Power P is required to lift a body a distance d at a constant speed v. What power is required to lift the body a distance $2d$ at constant speed $3v$?

a) P
b) 2P
[✓ c) 3P]
d) 6P
e) 3P/2

$P = \frac{W}{t} = \frac{mgd}{t}$

$v' = 3v \Rightarrow t' = \frac{t\cdot2}{3}$

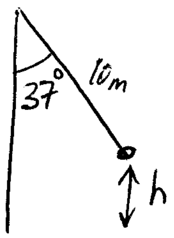
$d' = 2d$

$P' = \frac{mg(2d)}{t'} = \frac{mgd}{t}\cdot\frac{2}{2/3}$

$P' = 3P$

30. A child is sitting on the seat of a swing with ropes 10 m long. Her father pulls the swing back until the ropes make a 37° angle with the vertical and then releases the swing. If air resistance is neglected, what is the speed of the child at the bottom of the arc of the swing when the ropes are vertical?

a) 11 m/s
b) 8.8 m/s
c) 14 m/s
[✓ d) 6.3 m/s]
e) 12 m/s



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

$h = 10m(1-\cos 37°)$

$g\cdot(10m)(1-\cos 37°) = \frac{v^2}{2}$

$v = 6.3\frac{m}{s}$

Some possibly useful information:

$g = 9.80\ m/s^2$
1 mile = 1.609 km

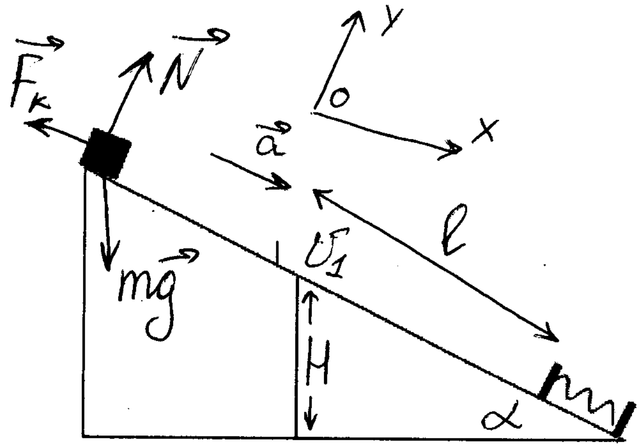


Fig. A

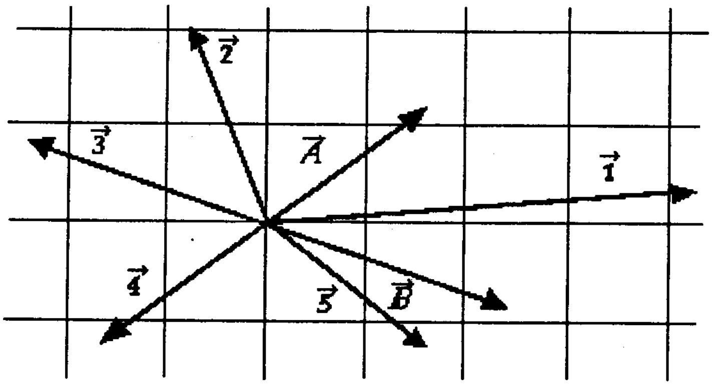


Fig. B

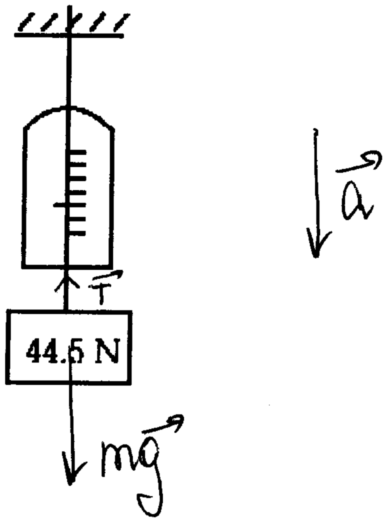


Fig. C

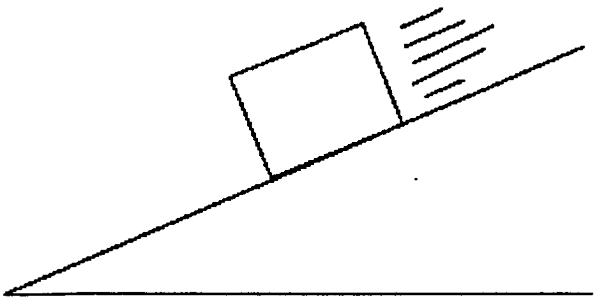
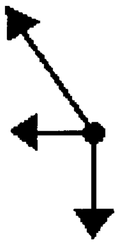
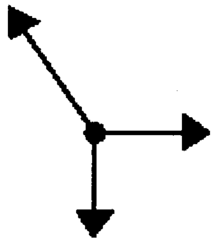


Fig. D



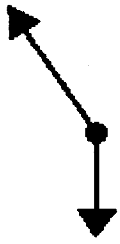
(1)



(2)

(3)

(4)



(5)

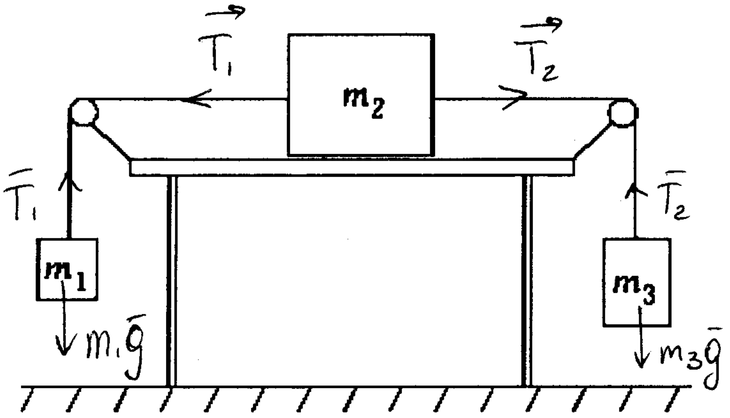


Fig. E