

AP PHYSICS 1 & C: DYNAMICS

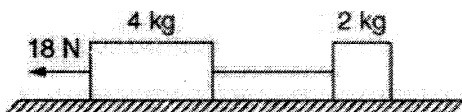
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10 \text{ m/s}^2$ in all problems.

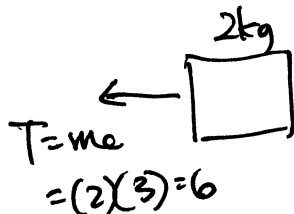
- 3rd law of motion
1. A small moving block collides with a large block at rest. Which of the following is true of the forces the blocks apply to each other
 - (A) The small block exerts twice the force on the large block compared to the force the large block exerts on the small block.
 - (B) The small block exerts half the force on the large block compared to the force the large block exerts on the small block.
 - ☒ (C) The small block exerts exactly the same amount of force on the large block that the large block exerts on the small block.
 - (D) The large block exerts a force on the small block, but the small block does not exert a force on the large block.
 - (E) The small block exerts a force on the large block, but the large block does not exert a force on the small block.

Questions 2-3

Two blocks, 4.0 kg and 2.0 kg, are connected by a string. An applied force F of magnitude 18 N pulls the blocks to the left.

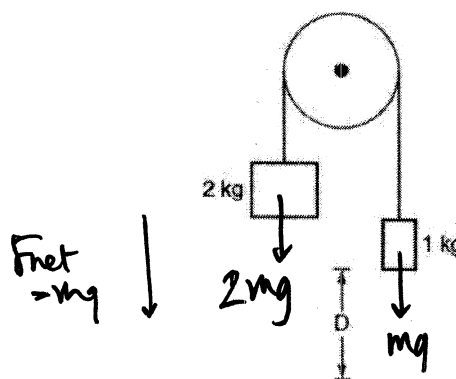


2. The acceleration of the 4.0 kg block is
 - (A) 2.0 m/s^2
 - ☒ (B) 3.0 m/s^2
 - (C) 4.0 m/s^2
 - (D) 4.5 m/s^2
 - (E) 6.0 m/s^2
3. The tension in the string between the blocks is
 - (A) 4.0 N
 - ☒ (B) 6.0 N
 - (C) 12 N
 - (D) 16 N
 - (E) 18 N



Questions 4-5

A system consists of two blocks having masses of 2 kg and 1 kg. The blocks are connected by a string of negligible mass and hung over a light pulley, and then released from rest.



4. The acceleration of the 2 kg block is most nearly

- (A) $\frac{2}{9}g$
- ☒ (B) $\frac{1}{3}g$
- (C) $\frac{1}{2}g$
- (D) $\frac{2}{3}g$
- (E) g

$$mg = 3ma$$

$$a = \frac{g}{3}$$

5. The speed of the 2 kg block after it has descended a distance D is most nearly

- (A) $\sqrt{\frac{4gD}{3}}$
- ☒ (B) $\sqrt{\frac{2gD}{3}}$
- (C) $\sqrt{\frac{gD}{3}}$
- (D) $\sqrt{\frac{gD}{2}}$
- (E) $\sqrt{\frac{4gD}{6}}$

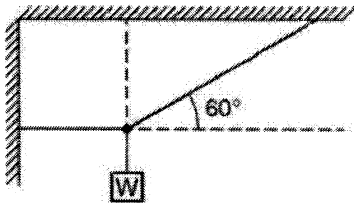
$$v^2 = v_0^2 + 2ad$$

$$v^2 = 2\left(\frac{1}{3}g\right)(D)$$

$$v = \sqrt{\frac{2}{3}gD}$$

Questions 6–7

A weight of magnitude W is suspended in equilibrium by two cords, one horizontal and one slanted at an angle of 60° from the horizontal, as shown.



6. Which of the following statements is true?

- (A) The tension in the horizontal cord must be greater than the tension in the slanted cord.
- ☒ (B) The tension in the slanted cord must be greater than the tension in the horizontal cord.
- (C) The tension is the same in both cords.
- (D) The tension in the horizontal cord equals the weight W .
- (E) The tension in the slanted cord equals the weight W .

7. The tension in the horizontal cord is

- (A) equal to the tension in the slanted cord
- (B) one-third as much as the tension in the slanted cord
- ☒ (C) one-half as much as the tension in the slanted cord
- (D) twice as much as the tension in the slanted cord
- (E) three times as much as the tension in the slanted cord

Questions 8–9

An object of mass m moves along a straight line with a speed described by the equation $v = c + bt^3$.

8. The initial velocity of the mass is

- ☒ (A) c
- (B) $ct + bt^3$
- (C) $ct + bt^4$
- (D) bt^2
- (E) bt

$\uparrow t=0$

9. The net force acting on the mass at time T is

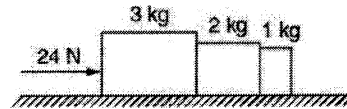
- (A) $3mbT$
- ☒ (B) $3mbT^2$
- (C) $3mbT^3$
- (D) $mc + 2mbT^2$
- (E) $mc^2 + 4mbT^4$

$$a = \frac{dv}{dt} = 3bt^2$$

$$F = ma =$$

Questions 10–11

Three blocks of mass 3 kg, 2 kg, and 1 kg are pushed along a horizontal frictionless plane by a force of 24 N to the right, as shown.



10. The acceleration of the 2 kg block is

- (A) 144 m/s^2
- (B) 72 m/s^2
- (C) 12 m/s^2
- (D) 6 m/s^2
- ☒ (E) 4 m/s^2

\leftarrow all blocks have the same acceleration

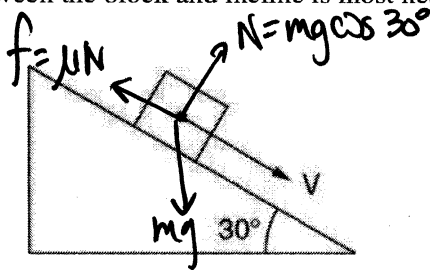
$$a = \frac{F}{m} = \frac{24}{6} = 4$$

11. The force that the 2 kg block exerts on the 1 kg block is

- (A) 2 N
- ☒ (B) 4 N
- (C) 6 N
- (D) 24 N
- (E) 144 N

$$\boxed{1} \rightarrow F_{2,1} = ma = (1)(4) = 4 \text{ N}$$

12. A block of mass 4 kg slides down a rough incline with a constant speed. The angle the incline makes with the horizontal is 30° . The coefficient of friction acting between the block and incline is most nearly



- (A) 0.1
(B) 0.2
(C) 0.3
(D) 0.4
(E) 0.6

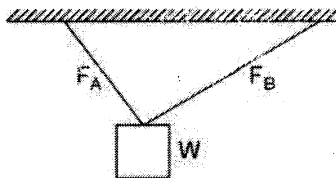
$$\mu mg \cos 30^\circ = mg \sin 30^\circ$$

$$\mu = \tan 30^\circ = 0.58$$

13. A ball is thrown straight up into the air, encountering air resistance as it rises. What forces, if any, act on the ball as it rises?

- (A) A decreasing gravitational force and an increasing force of air resistance
(B) An increasing gravitational force and an increasing force of air resistance
(C) A decreasing gravitational force and a decreasing force of air resistance
(D) A constant gravitational force and an increasing force of air resistance
(E) A constant gravitational force and a decreasing force of air resistance

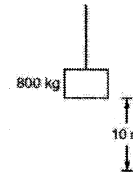
14. A weight w is hung from two threads, A and B, as shown below. The magnitudes of the tensions in each string are F_A and F_B , respectively. Which of the following describes the relationship between F_A , F_B , and W ?



- (A) $F_A = F_B = W$
(B) $F_A = F_B$
(C) $F_A < F_B$
(D) $F_A > F_B$
(E) $F_A + F_B = W$

Questions 15–16

An 800 kg elevator is supported by a vertical cable.



15. The cable has a tension of 10,000 N as it accelerates the elevator upward from rest to a height of 10 m. The acceleration of the elevator is most nearly

- (A) 1.0 m/s²
(B) 2.0 m/s²
(C) 2.5 m/s²
(D) 3.5 m/s²
(E) 4.0 m/s²

$$T = 10000 \text{ N}$$

$$mg = 8000 \text{ N}$$

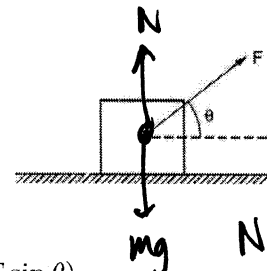
$$F_{\text{net}} = 2000 \text{ N} = ma$$

$$a = \frac{F}{m} = \frac{2000}{8000} = \frac{1}{4} = 0.25$$

16. The elevator passes the 10 m height on the way up, stops, then begins its descent downward, having an initial velocity as it passes the 10 m height again on the way down. If the tension in the cable is now 12,000 N, and it comes to rest just before reaching the ground, the initial velocity at the 10 m height must have been most nearly

- (A) 2.5 m/s
(B) 3.5 m/s
(C) 14.5 m/s
(D) 10 m/s
(E) 100 m/s

17. A force of magnitude F pulls up at an angle θ to the horizontal on a block of mass m . The mass remains in contact with the level floor and the coefficient of friction between the block and the floor is μ . The frictional force between the floor and the block is



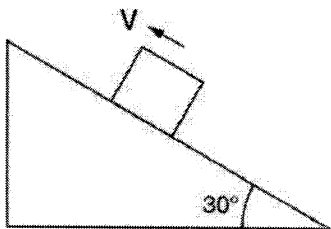
- (A) μmg
(B) $\mu(mg - F \sin \theta)$
(C) $\mu(mg + F \sin \theta)$
(D) $\mu(mg - F \cos \theta)$
(E) $\mu(mg + F \cos \theta)$

$$N + F \sin \theta = mg$$

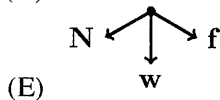
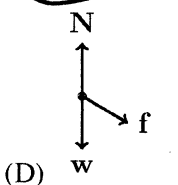
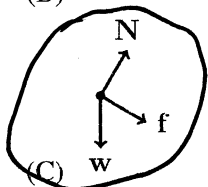
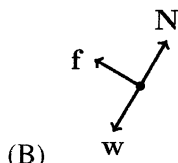
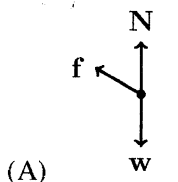
$$N = mg - F \sin \theta$$

Questions 18–19

A 1 kg block is sliding up a rough 30° incline and is slowing down with an acceleration of -6 m/s^2 . The mass has a weight w , and encounters a frictional force f and a normal force N . The direction up the ramp is positive.



18. Which of the following free body diagrams best represents the forces acting on the block as it slides up the plane?



19. The magnitude of the frictional force f between the block and the plane is most nearly

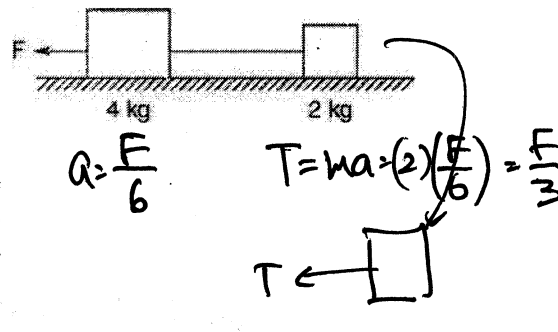
- (A) 1 N
(B) 2 N
(C) 3 N
(D) 4 N
(E) 5 N

$$f + w \sin 30^\circ = 6$$

$$f + \underbrace{mg \sin 30^\circ}_{10 \cdot \frac{1}{2}} = 6$$

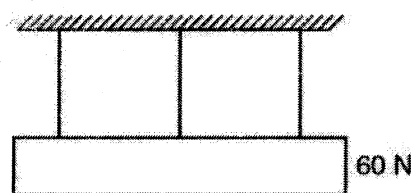
$$f + 5 = 6 \quad f = 1 \text{ N}$$

20. Two blocks are pulled by a force of magnitude F along a level surface with negligible friction as shown. The tension in the string between the blocks is



- (A) $F/4$
(B) $F/2$
(C) $F/3$
(D) F
(E) $2F$

21. A block weighing 60 N hangs from three ropes as shown. Which of the following statements is true?



- (A) Each rope has a tension of 60 N.
(B) The tension in each rope is higher in the lower part than in the upper part of the rope.
(C) The tension in each rope is higher in the upper part than in the lower part of the rope.
(D) The rope in the center has a higher tension than the other two ropes.
(E) Each rope has a tension of 20 N.

22. A stone falls through the air toward the Earth's surface. The resistive force the air applies to the stone as it falls is given by the equation $F = cv$, where c is a positive constant and v is the speed of the stone. The acceleration of the ball is given by the equation

- (A) $c - g$
(B) gcv/m
(C) $g + cv$
(D) $g - cv/m$
(E) cv/m

$$F = cv$$

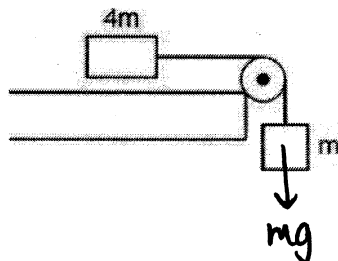
$$w = mg$$

$$ma = mg - cv$$

$$a = g - \frac{cv}{m}$$

GO ON TO THE NEXT PAGE.

23. A block of mass $4m$ can move without friction on a horizontal surface. Another block of mass m is attached to the larger block by a string that is passed over a light pulley. The acceleration of the system is

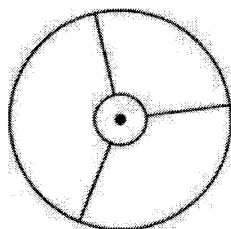


- (A) $g/5$
 (B) $g/2$
 (C) $2g/3$
 (D) g
 (E) $5g$

$$\Sigma F = mg = (5m)a$$

$$a = \frac{g}{5}$$

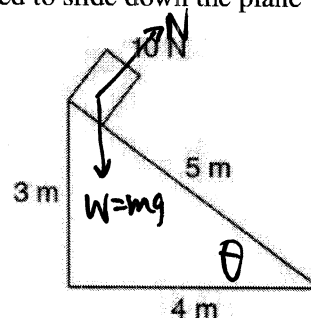
24. Three strings are attached to a ring in the center of a force table. The top view of the force table is shown. For the ring to remain in the center of the table, which of the following must be true?



- (A) The vector sum of the three forces must equal zero.
 (B) The lengths of the strings must be equal.
 (C) The strings must form an angle of 90° relative to each other.
 (D) The magnitudes of two of the tensions in the strings must equal the tension in the third string.
 (E) The tension in each string must be equal to each other.

Questions 25–26

A 10 N block sits atop an inclined plane in the shape of a right triangle of sides 3 m , 4 m , and 5 m , as shown. The block is allowed to slide down the plane with negligible friction.



$$\cos\theta = \frac{4}{5}$$

$$\sin\theta = \frac{3}{5}$$

25. The acceleration of the block is most nearly

- (A) 2 m/s^2
 (B) 4 m/s^2
 (C) 6 m/s^2
 (D) 10 m/s^2
 (E) 12 m/s^2

$$mg\sin\theta = ma$$

$$a = g\sin\theta = (10)\left(\frac{3}{5}\right) = 6$$

26. The normal force exerted on the block by the plane is most nearly

- (A) 2 N
 (B) 4 N
 (C) 6 N
 (D) 8 N
 (E) 10 N

$$N = mg\cos\theta$$

$$= (10)\left(\frac{4}{5}\right) = 8$$

Questions 27–28

The position of a 2 kg object is described by the equation $x = 2t^2 - 3t^3$, where x is in meters and t is in seconds.

27. The net force acting on the object at a time of 1 s is

- (A) -4 N
 (B) -8 N
 (C) -14 N
 (D) -20 N
 (E) -24 N

$$v = \frac{dx}{dt} = 4t - 9t^2 \quad a(1) = 4 - 18 = -14$$

$$a = \frac{dv}{dt} = 4 - 18t$$

$$F = ma = (2)(-14) = -28\text{ N}$$

28. The net force acting on the object is positive from $t = 0$ until a time of

- (A) 0.11 s
 (B) 0.22 s
 (C) 0.44 s
 (D) 0.67 s
 (E) 1.0 s

$$F > 0 \text{ if } a > 0$$

$$4 - 18t = 0$$

$$18t = 4$$

$$t = \frac{4}{18} = \frac{2}{9} = 0.22$$

GO ON TO THE NEXT PAGE.

29. A constant force acts on a particle in such a way that the direction of the force is always perpendicular to its velocity. Which of the following is true of the particle's motion?

(A) The acceleration of the particle is increasing.
 (B) The acceleration of the particle is decreasing.
 (C) The speed of the particle is increasing.
 (D) The speed of the particle is constant.
 (E) The speed of the particle is decreasing.

Uniform
circular
motion

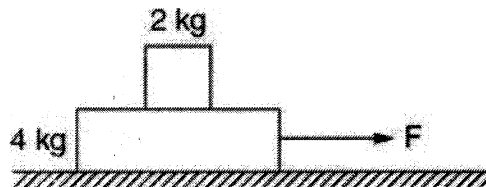
$$F = ma$$

$$= (6)(2)$$

$$= 12 \text{ N}$$

Questions 30–31

A block of mass 2 kg rests on top of a larger block of mass 4 kg. The larger block slides without friction on a table, but the surface between the two blocks is not frictionless. The coefficient of friction between the two blocks is 0.2. A horizontal force F is applied to the 4 kg mass.



30. What is the maximum force that can be applied such that there is no relative motion between the two blocks?

(A) zero
 (B) 1 N
 (C) 2 N
 (D) 4 N
 (E) 12 N

$$f_{\text{max}} = \mu_s N$$

$$= (0.2)(2)(10)$$

$$= 4 \text{ N}$$

31. What is the acceleration of the 2 kg block relative to the 4 kg block if a force is applied to the 4 kg block that causes the 4 kg block to accelerate at 3 m/s^2 to the right?

(A) 1 m/s^2 to the right
 (B) 1 m/s^2 to the left
 (C) 2 m/s^2 to the right
 (D) 2 m/s^2 to the left
 (E) zero

Max acceleration $a = \frac{F}{m} = 2 \text{ m/s}^2$

$$2 \text{ kg} \rightarrow a = 2 \text{ m/s}^2$$

$$4 \text{ kg} \rightarrow a = 3 \text{ m/s}^2$$

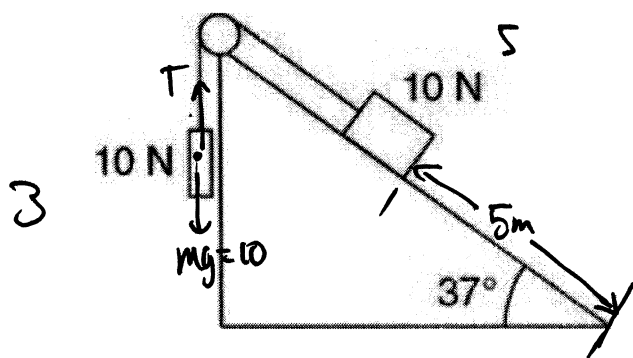
AP PHYSICS 1 & C: DYNAMICS
SECTION II
6 Questions

Directions: Answer all questions. The suggested time is about 10 minutes for answering each of the questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

1. Two balls are thrown with equal speeds v_0 from the top of a cliff of height H . One ball is thrown upward at an angle α above the horizontal; the other ball is thrown downward at an angle of β below the horizontal. Show that each ball strikes the ground with the same speed, and find that speed in terms of H and the initial speed v_0 .

2. Two blocks weighing 10 N each are connected by a light string that is passed over a light pulley. One of the blocks rests on an inclined plane at an angle of 37° to the horizontal. The friction between the inclined plane and the block is such that the system remains at rest. The length of the ramp is 5 m.

- (a) Determine the tension in the string while the system is at rest.
 (b) Determine the frictional force between the block and the inclined plane while the system is at rest.
 (c) If the string is suddenly cut, what is the speed of the block when it reaches the bottom of the plane?



(a) $T = 10 \text{ N}$
 $T = 10$
 $N = mg \cos \theta = 8 \text{ N}$

(b)

$mg = 10$
 $10 = f + 6$

$f = T = f + mg \sin \theta$

$10 = f + 6$

$f = 4 \text{ N}$

(c) assume that friction stays the same

$f = 4 \text{ N}$
 $N = 8 \text{ N}$
 $mg = 10 \text{ N}$

$F_x = 10 \sin \theta - 4 = 6 - 4 = 2 \text{ N}$

$a = \frac{F_x}{m} = 2 \text{ m/s}^2$

$v^2 = v_0^2 + 2ad$

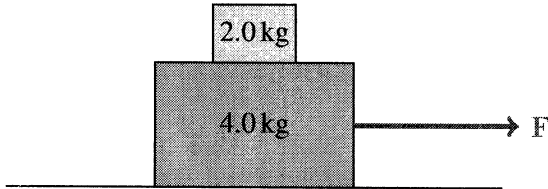
$v = \sqrt{2ad} = \sqrt{2 \times 2 \times 5} = \sqrt{20}$

GO ON TO THE NEXT PAGE.

$v = 4.5 \text{ m/s}$

3. A 2.0 kg block sits on a 4.0 kg that is resting on a frictionless table, as shown below. The coefficient of friction between the blocks are $\mu_s = 0.30$ and $\mu_k = 0.20$.

- (a) What is the maximum force F that can be applied if the 2.0 kg block is not to slide on the 4.0 kg block.
 (b) If F is half this value, find the acceleration of each block and the force of friction acting on each block.
 (c) If F is twice the value found in (a), find the acceleration of each block.



(a) max acceleration of 2.0 kg block

$$f_s = \mu N = \mu mg$$

$$= (0.3)(2.0)(10) = 6 \text{ N}$$

$$a = \frac{f_s}{m} = \mu g = 3 \text{ m/s}^2$$

$$F = ma = (6.0)(3.0) = \boxed{18.0 \text{ N}}$$

(b) $F = 9 \text{ N}$
 then $a = \frac{F}{m} = \frac{9}{6} = 1.5 \text{ m/s}^2$

$$f_s = ma \text{ on 2.0 kg block.}$$

$$= (2)(1.5) = \boxed{3 \text{ N}}$$

(b) if $F > 18 \text{ N}$, then they slide $\mu = \mu_k = 0.20$
 2.0 kg block

$$f_k = \mu_k mg = 4 \text{ N}$$

$$a = \frac{f_k}{m} = \frac{\mu mg}{m} = \mu g = \boxed{2.0 \text{ m/s}^2}$$

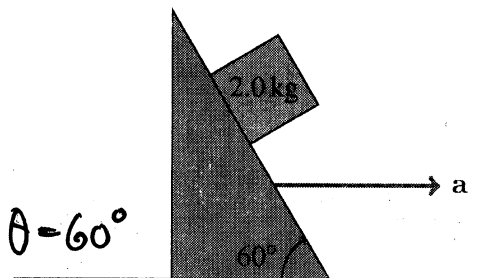
$$4 \text{ N} \leftarrow \bullet \rightarrow F = 36 \text{ N}$$

$$\frac{36 - 4}{4} = \boxed{8 \text{ m/s}^2}$$

4. A 2.0 kg body rests on a smooth wedge that has an inclination of 60° and an acceleration a to the right such that the mass remains stationary relative to the wedge.

(a) Find acceleration a .

(b) What would happen if the wedge were given a greater acceleration?



- no vertical acceleration

$$\sum F_y = 0$$

$$N \cos \theta = mg$$

$$N = \frac{mg}{\cos \theta}$$

- horizontal

$$a = \frac{N \sin \theta}{m} = \left(\frac{1}{\cos \theta} \right) \left(\frac{mg}{\cos \theta} \right) \sin \theta$$

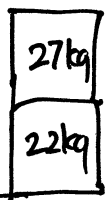
$$= g \tan \theta = (10) \tan 60^\circ = \boxed{17.3 \text{ m/s}^2}$$

independent of mass

(b) the ~~wedge~~ block would slide up the wedge

5. A pick-up truck with two stacked crates in the truck bed brakes quickly. The crate on the bottom just barely stays put on the bed of the truck. Does the top crate stay put or does it fall off? The top crate has a mass of 27 kg and the mass of the bottom crate is 22 kg. The coefficient of static friction between the bottom crate and the truck is 0.42, and the coefficient of kinetic friction for that surface is 0.35. The coefficient of static friction between the crate is 0.40, and the coefficient of kinetic friction is 0.32.

maximum static friction at that surface



$$F_s = \mu_s N$$

$$= (0.42)(44)(10) = ma$$

$$= 22 \times 4.2$$

$$a = \mu g = 4.2 \text{ m/s}^2$$

maximum acceleration that gives max. friction (if the blocks move together)

now look at 27kg block on top:

- to accelerate at 4.2 m/s^2 (same as bottom crate requires)

$$F = ma = (27)(4.2) = 113.4 \text{ N}$$

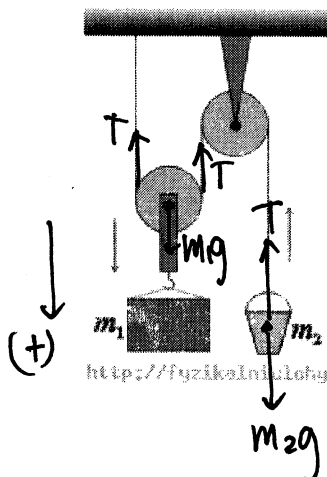
- max static friction

$$f_s = \mu N = \mu mg = (0.40)(27)(10)$$

$$= 108 \text{ N}$$

\therefore falls off

6. A bucket with mass m_2 and a block with mass m_1 are hung on a pulley system. Find the magnitude of the acceleration with which the bucket and the block are moving and the magnitude of the tension force T by which the rope is stressed. Ignore the masses of the pulley system and the rope. The bucket moves up and the block moves down.



$$a_2 = 2a_1$$

$$m_1: \sum F = m_1 g - 2T = m_1 a_1$$

$$m_2: \sum F = T - m_2 g = m_2 a_2 = 2m_2 a_1$$

$$\times 2 \quad 2T - 2m_2 g = 4m_2 a_1$$

$$m_1 g - 2T = m_1 a_1$$

$$- \quad 2T - 2m_2 g = 4m_2 a_1$$

$$m_1 g - 2m_2 g = (m_1 - 4m_2) a_1$$

$$a_1 = \frac{(m_1 - 2m_2)}{(m_1 - 4m_2)} g$$

$$a_2 = \frac{1}{2} 2a_1 = \frac{2(m_1 - 2m_2)}{(m_1 - 4m_2)} g$$

$$T = 2m_2 a_1 + m_2 g$$

\vdots

