PHYS 101 Midterm examination #1 (vers. 1A)

Feb 14, 2003 Name______________________________

Time: 50 minutes Student No._________________________

For questions 2 and 3, please show complete solutions and explain your reasoning, stating any principles that you have used.

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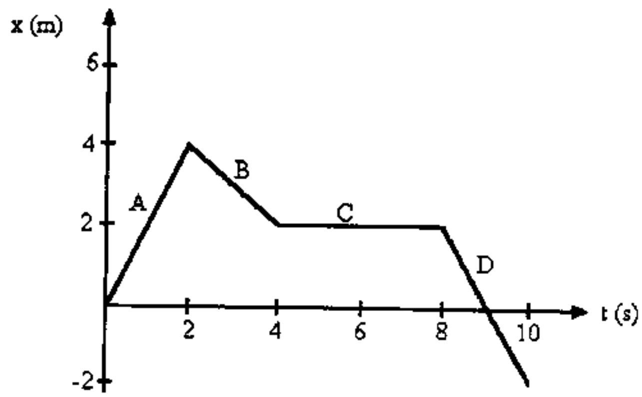
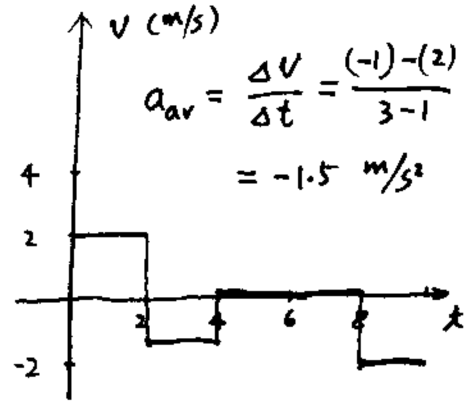
1 (10/20 marks). For each of the following five questions, please circle one answer only.

(b) (i) The figure below represents the position of a particle as it travels along the x axis. What is the average acceleration of the particle in the time interval between t=1 s and t=3 s ?
(a) 6 m/s^2 (b) -1.5 m/s^2 (c) 1.5 m/s^2 (d) 0.5 m/s^2 (e) -0.5 m/s^2

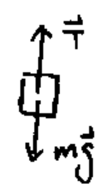




$$a_{av} = \frac{\Delta v}{\Delta t} = \frac{(-1)-(2)}{3-1} = -1.5 \text{ m/s}^2$$

(c) (ii) A lamp of mass m hangs from a spring scale that is attached to the ceiling of an elevator. When the elevator is stopped at the sixteenth floor, the scale reads mg. What does it read while the elevator descends toward the ground floor at a constant speed?

(a) Greater than mg
(b) Less than mg
(c) mg
(d) Zero
(e) Depends on how fast the elevator is descending.



$T - mg = ma$.

$a = 0$: $T = mg$.

(b) (iii) What is the exponent n in the expression [power] ∝ [speed]^n for a drag force that varies with speed as $F_{drag} \propto v^2$?
(a) 4 (b) 3 (c) 2 (d) 1 (e) 0

$P = F \cdot v \propto v^2 \cdot v = v^3$

(d) (iv) A 2000-kg car traveling east at 10 m/s collides with a 1000-kg car traveling north at 15 m/s. The cars stick together. What is the speed of the wreckage just after the collision?
(a) 18.0 m/s (b) 25.0 m/s (c) 11.7 m/s (d) 8.33 m/s (e) 5.0 m/s

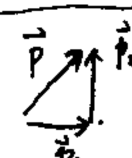
(e) (v) An object at the end of a string is swung in a circular path at constant speed with a period T. If the period is doubled without changing the radius of the circle, what is the new centripetal acceleration in terms of the original acceleration *a* ?
(a) 4a (b) 2a (c) a (d) a/2 (e) a/4

$$a = \frac{v^2}{r} \quad \left(\frac{2\pi r}{v} = T, \quad v = \frac{2\pi r}{T} \right)$$

$$= \frac{4\pi^2 r}{T^2}.$$

$$a_{new} = \frac{4\pi^2 r}{(2T)^2} = \frac{1}{4} \cdot \frac{4\pi^2 r}{T^2} = \frac{a}{4}$$

(iv): $\vec{P} = \vec{p}_1 + \vec{p}_2$,



$P = \sqrt{p_1^2 + p_2^2} = 25000$ (kg·m/s)

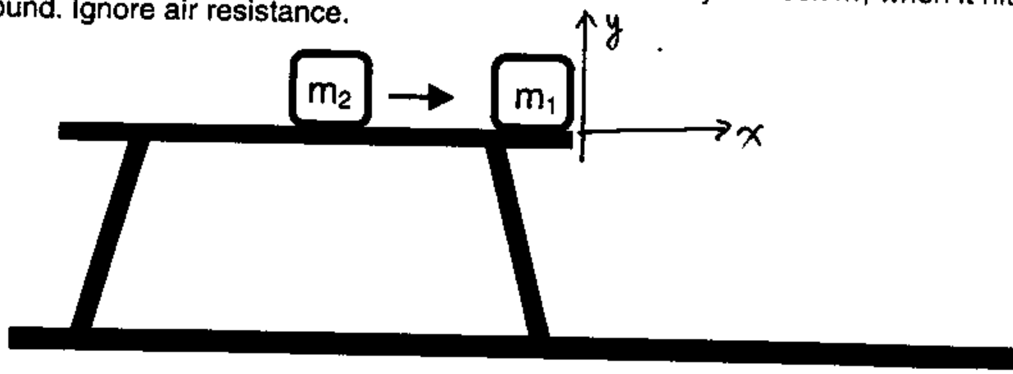
$v = \frac{P}{M} = \frac{P}{m_1 + m_2} = 8.33$ m/s.

2 (5/20 marks). A block of mass m_1=0.2 kg resting at the edge of a table is hit by a block of mass m_2=0.8 kg moving at a speed of 1.0 m/s, as shown in the figure below. Block m_2 stops immediately after the collision.

[2] A) Find the velocity of block m_1 immediately after the collision.

[1] B) During the collision, the two blocks interact with each other for a small time interval of 0.05 s, find the magnitude of the average force that m_2 exerts on m_1.

[2] C) If the tabletop is 1.0 m above the ground, find the velocity of block m_1 when it hits the ground. Ignore air resistance.



A). $\vec{F}_{ext} = 0$: Total momentum is conserved:

$$m_2 v_2 = m_1 v_1'$$

$$v_1' = \frac{m_2 v_2}{m_1} = \frac{(0.8)(1.0)}{(0.2)} = 4.0 \text{ m/s}.$$

B). $F_2 \cdot \Delta t = \Delta P_2$,

$$F_2 = \frac{\Delta P_2}{\Delta t} = \frac{m_1 v_1' - 0}{0.05} = \frac{(0.2)(4.0)}{0.05} = 16 \text{ N}$$

C). The motion of m_1 after the collision:

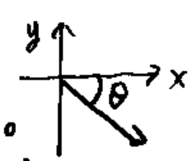
$$\left.\begin{array}{l} a_x = 0 \\ a_y = -g \end{array}\right\} \Rightarrow \left\{\begin{array}{l} v_x = v_{x0} = v_1' = 4.0 \text{ m/s}. \\ v_y = v_{y0} - gt = -gt. \end{array}\right.$$

$$\left.\begin{array}{l} x = v_1' t. \\ y = -\frac{1}{2} g t^2. \end{array}\right\} \Rightarrow \text{ when } m_1 \text{ hits the ground, } y = -1.0 \text{ m}, \quad t = \sqrt{\frac{2}{g}}.$$

$$v_y = -g \cdot \sqrt{\frac{2}{g}} = -\sqrt{2g} = -4.43 \text{ m/s}$$

$$\therefore \; v = \sqrt{v_x^2 + v_y^2} = 5.97 \text{ m/s}.$$

$$\theta = \tan^{-1}\frac{v_y}{v_x} = -47.9°, \text{ OR } 312.1°.$$

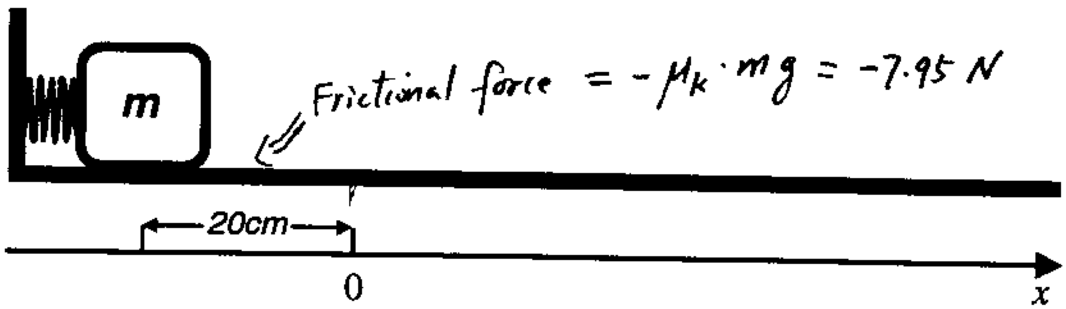


3 (5/20 marks). A block of mass m=1.8 kg is pushed against a spring that has a force constant of 250 N/m, compressing it 20 cm (the block is not attached to the spring). The block is then released, and the spring pushes the block to move to the right. The coefficient of kinetic friction between the block and the ground is 0.45.

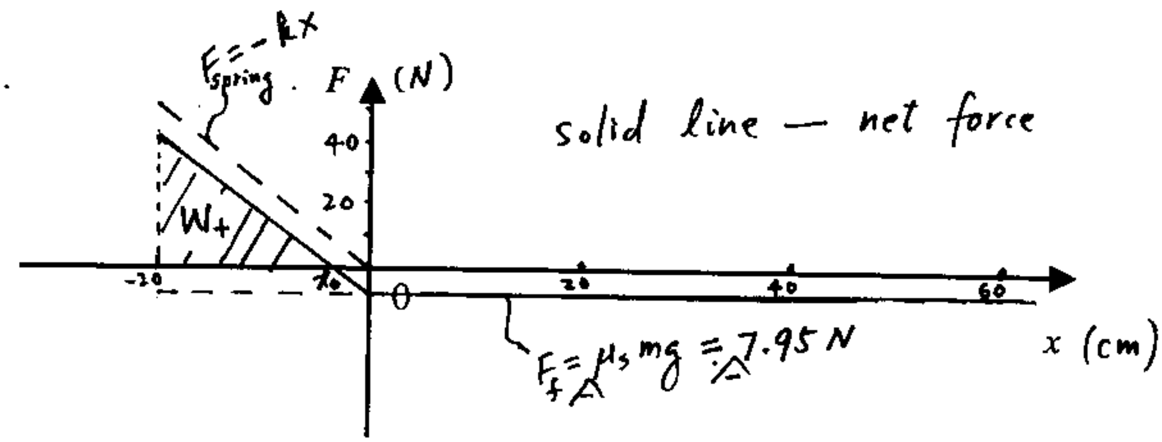
[2] A) Determine the distance the block will travel before it stops.

[1] B) Sketch the F ~ x curve, i.e., the net force acting on the block as a function of the block's position.

[2] C) Find the maximum speed of the block.



B).



A). Generalized work-energy theorm: $W_{nc} = \Delta E$.

$$(\Delta x)\,\mu_s \cdot mg = \frac{1}{2} k x^2 \qquad (x = -20 \text{ cm} = -0.20 \text{ m})$$

$$\Delta x = \frac{k x^2}{2 \mu_s mg} = \frac{(250)(0.2)^2}{2(0.45)(1.8)(9.8)} = 0.63 \text{ m}$$

C). At x_0, the force of the spring equals the frictional force:

$$k x_0 = -\mu_s mg \quad \text{i.e.} \quad x_0 = \frac{-\mu_s mg}{k} = -0.0318 \text{ m}.$$

Max K·E: $\frac{1}{2} m v_{max}^2 = W_+ = \frac{1}{2}(x_0 - x)(-kx - \mu_s mg)$

$$v_{max} = \sqrt{\frac{1}{m}(x_0 - x)(-kx - \mu_s mg)} = 1.98 \text{ m/s}$$