Phys 111
Fall 2023

General Physics: Class Exam III

13 November 2023

Name: Solution **Total:** /70

Instructions

- There are 9 questions on 6 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$g = 9.80\,\text{m/s}^2$ $G = 6.67 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$ Disk/solid cylinder: $I = \frac{1}{2}MR^2$

Hoop/hollow cylinder: $I = MR^2$ Hollow sphere: $I = \frac{2}{3}MR^2$ Solid sphere: $I = \frac{2}{5}MR^2$

Question 1

A fisherman lifts a 7.0 kg fish vertically at a constant speed a distance of 1.5 m. The following questions refer to the period while the fish moves upward with constant speed.

a) Determine the work done gravity on the fish.

$W = Fd\cos\theta$ +1

$F = mg = 7.0\,\text{kg} \times 9.8\,\text{m/s}^2 = 69\,\text{N}$

$= 69\,\text{N} \times 1.5\,\text{m} \cos 180°$ +1

$W_{grav} = -103\,\text{J}$ +2

b) Determine the work done by the fisherman on the fish.

$W_{net} = \Delta K \Rightarrow W_{grav} + W_{fisherman} = \Delta K = 0$ ← constant speed

$\Rightarrow W_{fisherman} = -W_{grav}$

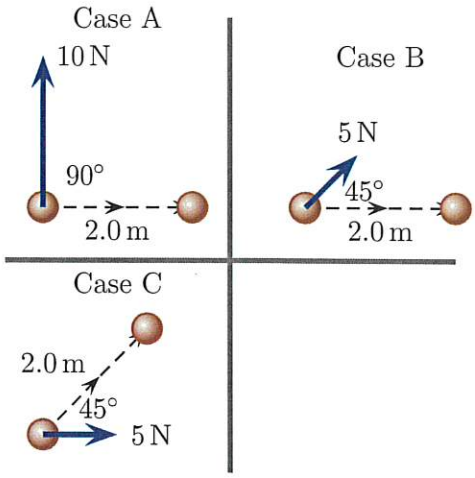
$= -(-103\,\text{J})$

$= 103\,\text{J}$

~~/5~~ +3 +4 /8

Question 2

Various rocks move on a frictionless horizontal surface. Rock A has mass 3.0 kg, rock B 6.0 kg and rock C 9.0 kg. The trajectories as viewed from above are illustrated. A person exerts the illustrated force on each rock. Rank the works done by the three forces, indicating any that may be equal. Explain your answer.



A: $W_A = Fd\cos\theta = 10N \times 2.0m \cos 90^\circ$

$W_A = 0J$

B: $W_B = 5.0N \times 2.0m \cos 45^\circ = 7.1J$

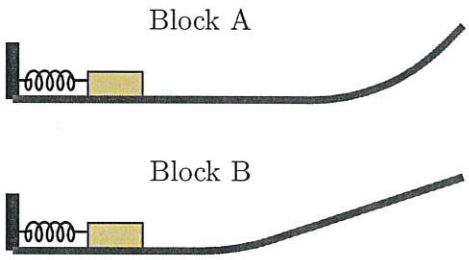
C: $W_C = 5.0N \times 2.0m \cos 45^\circ = 7.1J$

$W_A < W_B = W_C$

/~~XX~~ 6

Question 3

Identical blocks can slide along the illustrated frictionless tracks. The blocks are pushed against identical springs, compressing each spring by the same amount, held at rest and then released. The upward ramps have different slopes but the end of each ramp is the same height above the horizontal surface. Which of the following (choose one) is true?



(i) Block A and block B have the same speed at the top of the ramp.
ii) Block A has a larger speed than block B at the top of the ramp.
iii) Block A has a smaller speed than block B at the top of the ramp.

Briefly explain your answer. Energy is conserved.

$E_f = E_i$

$K_f + U_{grav\,f} + U_{spring\,f} = K_i + U_{grav\,i} + U_{spring\,i}$

$U_{grav\,f}$: same for both

$U_{spring\,i}$: same for both

$\Rightarrow K_f$ same for both $\Rightarrow$ speed same.

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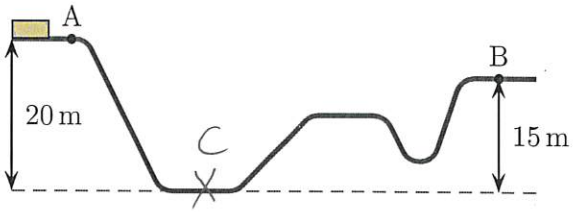
Question 4

A 500 kg sled moves from left to right along the illustrated track. At point A it moves right with speed 20 m/s. Ignore friction and air resistance.



a) Determine the speed of the sled at point B.

+1

$E_B = E_A$

$K_B + U_{grav\,B} = K_A + U_{grav\,A}$

$y_A = 20m$ $\quad y_B = 15m$

$V_A = 20m/s$ $\quad V_B = ?$

$\frac{1}{2} m V_B^2 + mgy_B = \frac{1}{2} mV_A^2 + mgy_A$

+1 +1

$\frac{1}{2} 500kg\, V_B^2 + 500kg \times 9.8 m/s^2 \times 15m = \frac{1}{2} 500kg \times (20m/s)^2 + 500kg \times 9.8 m/s^2 \times 20m$

$250kg\, V_B^2 + 73500J = 100000J + 98000J$

$\Rightarrow 250kg\, V_B^2 = 124500J$

$\Rightarrow V_B^2 = 498 m^2/s^2$

$\Rightarrow V_B = \sqrt{498 m^2/s^2} \Rightarrow V_B = 22.3 m/s$

+4

b) Determine the maximum speed of the sled during the trip from point A to B.

At point C → (+2)

$\frac{1}{2} mV_C^2 + mgy_C = \frac{1}{2} mV_A^2 + mgy_A$

$250kg\, V_C^2 = 198000J$

$V_C^2 = 792 m^2/s^2$

$\Rightarrow V_C = \sqrt{792 m^2/s^2} \Rightarrow V_C = 28.1 m/s$

+3

~~XX~~ 12

Question 5

Two ice skaters, Alice with mass 60 kg and Bob with mass 90 kg, slide toward each other on a sheet of ice. Alice moves right with speed 10 m/s and Bob moves left with speed 5.0 m/s. They collide and hold each other, subsequently moving together. Determine their speed after the collision.

$P_{tot\,f} = P_{tot\,i} \Rightarrow (M_A + M_B)V_f = M_A V_{Ai} + M_B V_{Bi}$

$\Rightarrow 150\,kg\ V_f = 60\,kg \times 10\,m/s + 90\,kg \times (-5.0\,m/s)$

$= 150\,kg\,m/s$

$\Rightarrow V_f = 1.0\,m/s$

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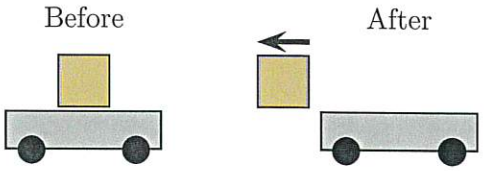
Question 6

A 10 kg cart carries a 1.0 kg block and both are at rest. The cart is on a frictionless surface. The block is thrown horizontally to the left from the cart. Which of the following is true after the block is thrown (choose one)?



i) The cart is at rest because the mass of the cart is greater than that of the block.
ii) The cart is at rest since the force exerted by the cart on the block equals that exerted by the block on the cart.
iii) The cart moves to the right at a slower speed than the block.
iv) The cart moves to the right at a faster speed than the block.
v) The cart moves to the left since the momentum of the cart is equal to that of the block.

$P_{tot} = 0 \Rightarrow M_B V_{Bf} + M_C V_{Cf} = 0$

$\Rightarrow V_{Cf} = -\frac{M_B}{M_C} V_{Bf}$

less than 1

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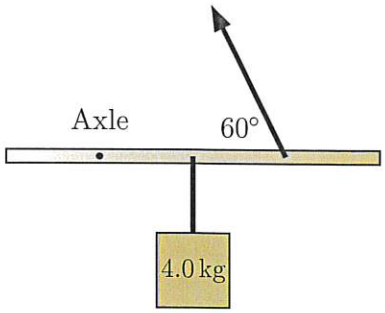
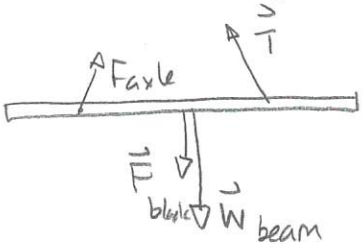
Question 7

A 1.0 m long rod with ~~negligible~~ 2.0kg mass can pivot about an axle through a point 0.25 m from its ~~right~~ left end. A 4.0 kg masspiece is suspended from the middle. A rope, connected 0.75 m from the left end pulls at the illustrated angle. Determine the tension in the rope so that the rod is at rest horizontally.





+1 $\tau_{net} = 0$

$\tau = rF\sin\phi$ (+1)

Axle: $r = 0 \Rightarrow \tau_{axle} = 0\ N\cdot m$

Weight: $\tau_{grav} = \underbrace{0.25m}_{+1} \times \underbrace{2.0kg \times 9.8m/s^2}_{+1} \underbrace{\sin 270^\circ}_{+1}$ (270°)

$= -4.9\ N\cdot m$

Beam: $\tau_{beam} = \underbrace{0.25m}_{+1} \times \underbrace{4.0kg \times 9.8m/s^2}_{+1} \underbrace{\sin 270^\circ}_{+1}$

$= -9.8\ N\cdot m$

Rope: $\tau_{rope} = \underbrace{0.50m}_{+1}\ T \underbrace{\sin 120^\circ}_{+1} = 0.43m\,T$

$\tau_{net} = 0 \Rightarrow 0N\cdot m - 4.9N\cdot m - 9.8N\cdot m + 0.43T = 0$ (+6)

$\Rightarrow 0.43T = 14.7Nm$

$\Rightarrow T = \frac{14.7N\cdot m}{0.43m} \Rightarrow T = 34N$

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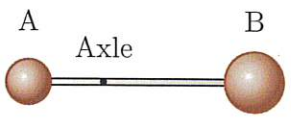
Question 8

A rigid barbell consists of two masses at the end of a rod and rotates around the illustrated axle. The distance from mass B to the axle is twice the distance from mass A to the axle. Mass B is twice as heavy as mass A. The barbell rotates counterclockwise. Which of the following (choose one) is true regarding the angular velocities?



i) $\omega_A = \omega_B = 0$
ii) $\omega_A = \omega_B$ and these are not zero.
iii) $\omega_A > \omega_B$
iv) $\omega_A < \omega_B$

ω same for rigid object

/~~XX~~ 9

Question 9

A merry-go-round (large horizontal disk that rotates about a vertical axle through its center) is initially at rest. A child pushes on the edge and it speed up at a steady rate. After 5.0 s it rotates at 150 rpm. Determine the angular acceleration in units of rad/s^2.

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega_f - \omega_i}{\Delta t}, \quad \omega_i = 0$$

$$\omega_f = \frac{150\ \text{rev}}{1\ \text{min}} \cdot \frac{2\pi\ \text{rad}}{1\ \text{rev}} \cdot \frac{1\ \text{min}}{60\ \text{s}} = 15.7\ \text{rad/s}$$

$$\alpha = \frac{15.7\ \text{rad/s}}{5.0\ \text{s}} \Rightarrow \quad \alpha = 3.1\ \text{rad/s}^2$$

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