KEYS AND SCORES
For Questions in Final Exam of Physics 1
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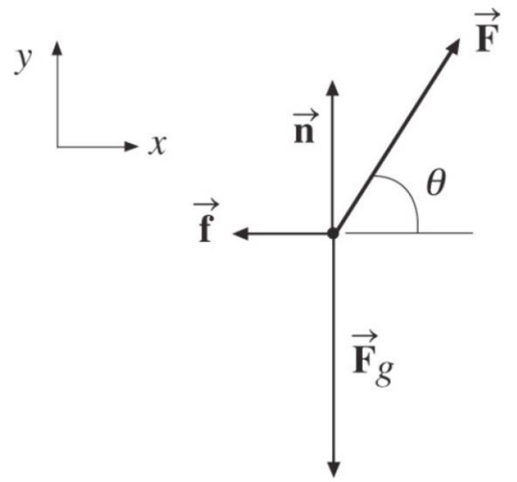
Question	Answer	Mark
1	(a) Increases. When the ice melts, it moves away from the axis of rotation and the distance increases. Moment of inertia of the Earth therefore increases (I ~ r^2).	0.5
	(b) Increase. The Earth is an isolated system, so its angular momentum is conserved when the distribution of its mass changes. When its moment of inertia increases, its angular speed decreases (L = Iω = const), so its period increases. However, most of the mass of Earth would not move, so the effect would be small: we would not have more hours in a day, but more nanoseconds.	0.5
2	Centripetal acceleration is given by: $a_c = R\omega^2$.	0.5
	Note that R = 29.0 ft = 8.845 m, and a_c = 20g = 196 m/s^2.	
	The angular speed is: $\omega = \sqrt{\frac{a_c}{R}}$.	0.5
	The rotation rate is given by: $f = \frac{1}{T} = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{a_c}{R}}$.	0.5
	Finally: f = 0.750 rev/s.	0.5
3	 (a) The freebody diagram of the suitcase	0.75
	(b) Newton 2nd law for the suitcase: $\sum \vec{F} = \vec{F_g} + \vec{n} + \vec{f} + \vec{F} = 0$ (the suitcase is moving at constant velocity, therefore its acceleration is zero)	0.25
	On the x-axis: $-f + F\cos\theta = 0$ $\Rightarrow \cos\theta = \frac{f}{F} = 0.571$ $\Rightarrow \theta = 55.2^o = 0.963\ rad$	0.5
	(c) On the y-axis: $-F_g + n + F\sin\theta = 0$ $\Rightarrow n = mg - F\sin\theta = 167\ N$	0.5
4	(a) Consider the system (car & Earth). This system is isolated (energy), and there is no non-conservative force acting in the system. Therefore, its mechanical energy is conserved.	0.25
	The initial configuration: at the top of the hill The final configuration: at the bottom of the hill Choose +y upward and y = 0 at the bottom of the hill One has: $U_{g,i} = mgy_i = mgh\ (= 1.68\ kJ); \qquad K_i = 0;$ $U_{g,f} = 0; \qquad K_f = \frac{1}{2}mv_f^2;$ Conservation of mechanical energy: $\Delta E_{mech} = \Delta U_g + \Delta K = (U_{g,f} - U_{g,i}) + (K_f - K_i) = 0$	0.5

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$$\Longrightarrow mgh = \frac{1}{2}mv_f^2$$
$$\Longrightarrow v_f = \sqrt{2gh} = 18.5 \text{ m/s}$$

(b) During the collision, consider the system including only the car. This system is non-isolated (momentum). The change in its momentum is due to the force exerted by the pile of sand, and is equal to the impulse of this force during the collision:

$$\Delta\vec{p} = \vec{I} = \int \vec{F}dt = \vec{F}_{avg}\Delta t.$$

On the x-axis (horizontal, +x pointing to the left):

$$\Delta p_x = F_{x,avg}\Delta t$$
$$\Longrightarrow F_{x,avg} = \frac{\Delta p_x}{\Delta t} = \frac{mv_f - mv_i}{\Delta t}$$

Here, the initial configuration is right before the collision, $v_i = 18.5$ m/s.
The final configuration is right after the collision, $v_f = 0$.
Time duration of the collision: $\Delta t = 4.00$ s.

Finally, $F_{x,avg} = -4.56 \times 10^3$N.

The magnitude of this average force is $|F_{x,avg}| = +4.56 \times 10^3$N.

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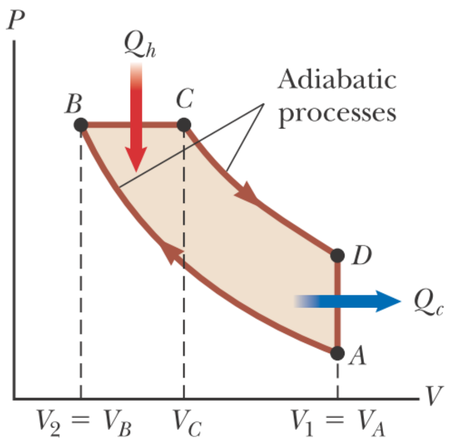

(a) Heat exchanged during each process:
$Q_{AB} = 0$ (adiabatic compression);
$Q_{CD} = 0$ (adiabatic expansion);
$Q_{BC} = nC_P(T_C - T_B) > 0$ (isobaric heating);
$Q_{DA} = nC_V(T_A - T_D) < 0$ (isovolumetric cooling);

Thermal efficiency of the engine:

$e = 1 - \frac{|Q_c|}{|Q_h|} = 1 - \frac{|Q_{DA}|}{|Q_{BC}|} = 1 - \frac{1}{\gamma}\frac{T_D - T_A}{T_C - T_B} = 0.604 = 60.4\%.$

(b) Thermal efficiency of a Carnot engine operating between the highest (T_C) and the lowest temperatures in this cycle (T_A):

$$e_C = 1 - \frac{T_c}{T_h} = 1 - \frac{T_A}{T_C} = 0.831 = 83.1\%.$$

(c) The compression ratio can be found by considering the adiabatic process A→B. One has:

$$T_A V_A^{\gamma-1} = T_B V_B^{\gamma-1} \Longrightarrow r_C = \frac{V_A}{V_B} = \left(\frac{T_B}{T_A}\right)^{\frac{1}{\gamma-1}} = 15.0.$$

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