AESB1320, TOETS-03, Solutions
15-04-15, 9:00
CT-IZ 1.96-1.98

The exam consists of 11 Conceptual Questions (CQs), each valid for 1 point, and 11 Exercises (EXs), each valid for 2 points. The maximum score is 33.

Answers to conceptual questions need to be accompanied by a short motivation of the choice.

Grading rules for multiple-choice questions:
- right answer, missing motivation: 50% penalty;
- wrong answer and/or wrong motivation: 100% penalty.

Grading rules for numerical exercises:
- wrong numeric value, but correct solution (computational mistake): 25% penalty;
- wrong solution, but correct setup (including sketch with all forces): 75% penalty;
- wrong solution, wrong/missing setup: 100% penalty.

This is a closed-book exam: only pens, blank paper and non-graphical calculators are allowed.

CQ1
Two objects are thrown from the top of a tall building and experience no appreciable air resistance. One is thrown up, and the other is thrown down, both with the same initial speed. What are their speeds when they hit the street?

A. The one thrown up is traveling faster.
B. They are traveling at the same speed.
C. The one thrown down is traveling faster.

B: The object thrown up will pass again by the starting point with the same velocity it was thrown with, just reversed in sign: so exactly the same as the other object. Also possible to use energy (as in CQ6).

EX1
A soccer ball is released from rest at the top of a grassy incline. After 2.9 seconds, the ball travels 84 meters and 1.0 s after this, the ball reaches the bottom of the incline.
What was the magnitude of the ball's acceleration? (assume it to be constant)

20 m/s^2
[$x=a/2\ t^2$]

CQ2
A pilot drops a package from a plane flying horizontally at a constant speed. Neglecting air resistance, when the package hits the ground the horizontal location of the plane will

A. be in front of the package.
B. be behind the package.
C. depend of the speed of the plane when the package was released.
D. be over the package.

D: there is no force acting in the horizontal direction (air resistance is neglected), so plane and package will keep moving forward with the same velocity.

EX2
A hockey puck slides off the edge of a table with an initial velocity of 27.7 m/s and experiences no air

resistance. The height of the tabletop above the ground is 2.00 m.
What is the angle below the horizontal of the velocity of the puck just before it hits the ground?

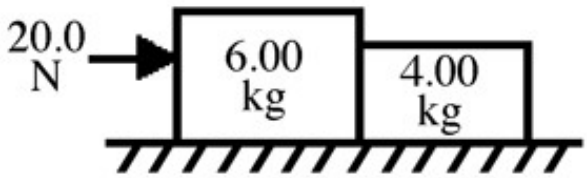
12.7°
[$v_y=v_{0y}+gt$; theta=arctan(v_y/v_0)]

CQ3
Consider what happens when you jump up in the air. Which of the following is the most accurate statement?

A. When you push down on the earth with a force greater than your weight, the earth will push back with the same magnitude force and thus propel you into the air.
B. Since the ground is stationary, it cannot exert the upward force necessary to propel you into the air. Instead, it is the internal forces of your muscles acting on your body itself that propels your body into the air.
C. You are able to spring up because the earth exerts a force upward on you that is greater than the downward force you exert on the earth.
D. It is the upward force exerted by the ground that pushes you up, but this force cannot exceed your weight.
E. When you jump up the earth exerts a force F1 on you and you exert a force F2 on the earth. You go up because F1 > F2.

A: it is about the force between you and the Earth (equal in magnitude, opposite in sign), which has to be larger than gravity.

EX3
A 6.00-kg block is in contact with a 4.00-kg block on a horizontal frictionless surface as shown in the figure. The 6.00-kg block is being pushed by a horizontal 20.0-N force as shown. What is the magnitude of the force that the 6.00-kg block exerts on the 4.00-kg block?



8.0 N
[a=F/m, with m=(6+4) kg; $F_{6,4}$=ma, with m=4 kg]

CQ4
A crate is sliding down an inclined ramp at a constant speed of 0.55 m/s. The vector sum of all the forces acting on this crate must point down the ramp.

A. True
B. False

B: If speed is constant, the net force in the direction of motion must be zero (no acceleration).

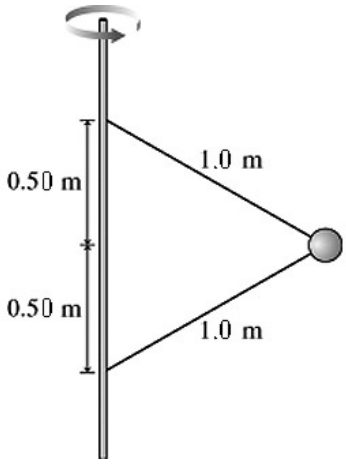
EX4 *(1 point if correct computation of centripetal force F_c)*
The figure shows two wires that are tied to a 180 g mass that revolves in a horizontal circle at a constant speed of 7.5 m/s. What is the tension in the upper wire?

With gravity: 8.5 N
Also accepted without gravity: 6.7 N

[$a=v^2/R$=64,7 m/s², with R=cos(30°); F_c=ma=11,6 N;

No gravity: $F_c=2T_x=2T\cos(30°)$; T=6.7 N

With gravity: T_U is tension upper wire, T_L is tension lower wire
Forces balance in y direction: $T_L=T_U-2mg$
Forces balance in x direction: $F_c=\cos(30^o)*T_U + \cos(30^o)*T_L$, then solving for T_U]



CQ5
If a force always acts perpendicular to an object's direction of motion, that force cannot change the object's kinetic energy.

A. True
B. False

A: The force will not change the magnitude of the velocity, so the kinetic energy remains constant.

EX5
A ball is thrown upward at an angle with a speed and direction such that it reaches a maximum height of 16.5 m above the point it was released, with no appreciable air resistance. At its maximum height it has a speed of 15.0 m/s. With what speed was the ball released?

23.4 m/s
[Energy in y direction: $1/2m(v_{0y})^2=mgd$, with d=16.5 m
In x direction v is constant and equal to the value at maximum height: $v_{0x}=15$ m/s
Since energy is conserved, the initial velocity is the squared sum of the two components.]

CQ6
A girl throws a stone from a bridge. Consider the following ways she might throw the stone. The speed of the stone as it leaves her hand is the same in each case, and air resistance is negligible.
In which case will the speed of the stone be greatest when it hits the water below?

A. When thrown straight up.
B. When thrown straight down.
C. When thrown out at an angle of 45° above horizontal.
D. When thrown straight out horizontally.
E. The speed will be the same in all cases.

E: Think about the kinetic energy of the stone: initial + gravitational (meaning opposite to the loss of gravitational potential energy). K_initial only depends on the magnitude of the initial velocity (and stone mass), K_gravitational only depends on the height of the bridge (and stone mass): both are the same in all cases.

EX6
A car on a roller coaster starts at zero speed at an elevation above the ground of 26 m. It coasts down a slope, and then climbs a hill. The top of the hill is at an elevation of 16 m. What is the speed of the car at the top of the hill? Neglect any frictional effects.

14 m/s
[Δy=h-d, with h=26 m and d=16m; $-\Delta U=mg\,\Delta y=\Delta K=1/2\ mv^2$, hence $v=\sqrt{2g\,\Delta y}$]

CQ7
Two planets having equal masses are in circular orbit around a star. Planet *A* has a smaller orbital radius than planet *B*. Which statement is true?

A. Planet *A* has more kinetic energy, less potential energy, and less mechanical energy than planet *B*.
B. Planet *A* and planet *B* have the same amount of mechanical energy.
C. Planet *A* has more kinetic energy, less potential energy, and more mechanical energy than planet *B*.
D. Planet *A* has more kinetic energy, more potential energy, and more mechanical energy than planet *B*.

A: Smaller radius: larger centripetal acceleration (velocity, kinetic energy), less potential energy (depending on the distance from the center of mass of the star), less K+U.
This because U and E are negative, while K is positive.

EX7
By how many newton does the weight of a 100-kg person change when he goes from sea level to an altitude of 5.0 km? Neglect the earth's rotational effects. (The mean radius of the Earth is 6.38×10^6 m, $G = 6.67\times10^{-11}$ N m^2/kg^2.)

-1.5 N
[At sea level $W_S=GmM/R^2$, on the mountain $W_M=GmM/(R+h)^2$, where R is Earth's radius and h=5 km; W_M-W_S=-1.5 N]

CQ8
A shell explodes into two fragments, one fragment 25 times heavier than the other. If any gas from the explosion has negligible mass, then

A. the momentum change of the heavier fragment is 25 times as great as the momentum change of the lighter fragment.
B. the momentum change of the lighter fragment is exactly the same as the momentum change of the heavier fragment.
C. the kinetic energy change of the heavier fragment is 25 times as great as the kinetic energy change of the lighter fragment.
D. the kinetic energy change of the lighter fragment is 25 times as great as the kinetic energy change of the heavier fragment.
E. the momentum change of the lighter fragment is 25 times as great as the momentum change of the heavier fragment.

B: Because total momentum is conserved.

EX8 *(1 point for using the right conservation laws)*
A 2.3-kg object traveling at 6.1 m/s collides head-on with a 3.5-kg object traveling in the opposite direction at 4.8 m/s. If the collision is perfectly elastic, what is the final speed of the 2.3-kg object?

7.1 m/s (elegant solution, as in the derivation of the correct equation in the book)
If solved by straight substitution after imposing conservation of momentum and kinetic energy, the value could be significantly different (depending on how many digits have been used): values in the range 6.4-7.8 m/s are also accepted, as long as the procedure is correct.

CQ9
If two forces of equal magnitude act on an object that is hinged at a pivot, the force acting farther from the pivot must produce the greater torque about the pivot.

A. false
B. true
C. unable to decide without knowing the shape of the object

A: It also depends on the angle between the force and the line between the pivot and the application point of

the force itself.

EX9
An extremely light rod 1.00 m long has a 2.00-kg mass attached to one end and a 3.00-kg mass attached to the other. The system rotates at a constant angular speed about a fixed axis perpendicular to the rod that passes through the rod 30.0 cm from the end with the 3.00-kg mass attached. The kinetic energy of the system is measured to be 100.0 J.
What is the moment of inertia of this system about the fixed axis?

1.25 kg m^2.
Since the shape of the masses in not given, the fact that the masses are small compared to the length of the rod should have been mentioned (point masses). If this motivation led to the answer "impossible to determine", it will be accepted.
[$I=m_1r_1^2+m_2r_2^2$]

CQ10
When you ride a bicycle, in what direction is the angular velocity of the wheels?

A. to your right
B. to your left
C. backwards
D. up
E. forwards

B: Right-hand rule.

EX10
A record is dropped vertically onto a freely rotating (undriven) turntable. Frictional forces act to bring the record and turntable to a common angular speed. If the rotational inertia of the record is 0.87 times that of the turntable, what percentage of the initial kinetic energy is lost?

47%
[Percentage energy lost is: $(1-k_f/k_i)*100$, with *f* for final and *i* for initial;
$k_f/k_i=(0.5*(I_T+I_R)\omega_f^2)/(0.5*I_T\omega_T^2)=(I_T+I_R)/I_T*(\omega_f/\omega_T)^2$, with T for turntable and R for record;
ω_f/ω_T can be obtained from the conservation of angular momentum: $L=L_i=I_T\omega_T=L_f=(I_T+I_R)\omega_f$].

CQ11
If the torque on an object adds up to zero

A. the object is at rest.
B. the object cannot be turning.
C. the object could be both turning and accelerating linearly.
D. the forces on it also add up to zero.
E. the object could be accelerating linearly but it could not be turning.

C: It only cannot change angular *speed*.

EX11
A uniform ladder 12 meters long rests against a vertical frictionless wall. The ladder weighs 400 N and makes an angle of 53° with the floor. A man weighing 861 N climbs slowly up the ladder. When he has climbed to a point that is 7.8 m from the base of the ladder, the ladder starts to slip. What is the coefficient of static friction between the floor and the ladder?

0.45
[Pivot point at the bottom of the ladder: $\mu=n_2/(w_M+w_L)$, with n_2 normal force from the wall, w_M weight of the man, w_L weight of the ladder]