AESB1320-15
29-06-16, 9:00
CT 1.96

The exam consists of 10 Conceptual Questions (CQs), each valid for 1 point, and 10 Exercises (EXs), each valid for 2 points. The maximum score is 30.

Important: *Answers to conceptual questions need to be accompanied by a short (1-2 sentences) motivation of the choice. Credits for a conceptual question can only be obtained when both the answer and the motivation are correct.*

Grading rules for numerical exercises:
- correct numeric value and solution: 2 points;
- wrong numeric value, but correct solution (computational mistake): 1,5 points;
- wrong numeric value, correct intermediate numeric value (exercise half-done): 1 point;
- wrong solution: 0 points.

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

The exam is structured in three parts (conceptual questions, exercises 1-5, exercises 6-10):
Please answer every part on a separate sheet of paper.

PART I: Conceptual questions

CQ1

A ball is thrown directly upward and experiences no air resistance. Which one of the following statements about its motion is correct?

a. The acceleration of the ball is downward while it is traveling up and upward while it is traveling down.
b. The acceleration of the ball is upward while it is traveling up and downward while it is traveling down.
c. The acceleration of the ball is downward while it is traveling up and downward while it is traveling down but is zero at the highest point when the ball stops.
d. The acceleration is downward during the entire time the ball is in the air.

d: The only acceleration is gravitational.

CQ2

An object is moving to the right, and experiencing a net force that is directed to the right. The magnitude of the force is decreasing with time. The speed of the object is

a. constant in time.
b. decreasing.
c. increasing.

c: The net force is directed to the right, so there is a positive acceleration in the direction of motion.

CQ3

A box of mass m is pulled with a constant acceleration 'a' along a horizontal frictionless floor by a wire that makes an angle of 15° above the horizontal. If T is the tension in this wire, then

a. $T < ma$.
b. $T = ma$.

c. *T > ma.*

c: You need *ma* to accelerate the box horizontally, plus a vertical component due to the fact that the wire is not horizontal (note that the vertical component does not affect the acceleration).

CQ4
Is it possible for a system to have negative potential energy?

a. Yes, as long as the total energy is positive.
b. Yes, as long as the kinetic energy is positive.
c. Yes, since the choice of the zero of potential energy is arbitrary.
d. No, because this would have no physical meaning.
e. No, because the kinetic energy of a system must equal its potential energy.

c: Per definition.

CQ5
Which of the following statements is true?

a. A nonconservative force permits a two-way conversion between kinetic and potential energies.
b. A potential energy function can be specified for a nonconservative force.
c. The work done by a nonconservative force depends on the path taken.

c: The work done is independent from the path takes for a conservative force.

CQ6
A satellite is orbiting the earth. If a payload of material is added until it doubles the satellite's mass, the earth's pull of gravity on this satellite will double, but the radius of the satellite's orbit will not be affected.

a. True
b. False

a: The radius of the orbit depends on the gravitational acceleration, not on the force.

CQ7
There must be equal amounts of mass on both side of the center of mass of an object.

a. True
b. False

b: The position of the center of mass depends on both the amount of mass and its spatial distribution (i.e., you can have more mass at one side, if it's closer).

CQ8
If an irregularly shaped object is dropped from rest in a classroom and feels no air resistance, it will

a. accelerate and spin until its center of gravity reaches its highest point.
b. accelerate but will not spin.
c. accelerate and turn about its center of gravity with uniform angular speed.
d. accelerate and turn until its center of gravity reaches its lowest point.
e. accelerate and turn about its center of gravity with uniform angular acceleration.

b: All points will have the same acceleration (due to gravity), so the object will just translate.

CQ9
The angular momentum of a system remains constant

a. when the linear momentum and the energy are constant.
b. all the time since it is a conserved quantity.
c. when no net external force acts on the system.
d. when no external torque acts on the system.

e. when the total kinetic energy is constant.

d: You need an external torque to change the angular momentum of a system.

CQ10
A heavy boy and a lightweight girl are balanced on a massless seesaw. If they both move forward so that they are one-half their original distance from the pivot point, what will happen to the seesaw? Assume that both people are small enough compared to the length of the seesaw to be thought of as point masses.

a. The side the girl is sitting on will tilt downward.
b. The side the boy is sitting on will tilt downward.
c. Nothing will happen; the seesaw will still be balanced.
d. It is impossible to say without knowing the masses.
e. It is impossible to say without knowing the distances

c: Since the torques balanced before and they linearly depend on the distance from the pivot, they will still balance if both distances are halved.

PART II: Exercises 1-5

EX1
A child throws a ball with an initial speed of 8.00 m/s at an angle of 40.0° above the horizontal. The ball leaves her hand 1.00 m above the ground and experience negligible air resistance. What is the magnitude of the ball's velocity just before it hits the ground?

9.15 m/s

Only the vertical component changes while rising and falling. When is reaches again the initial height (call it point A, 1 m above the ground), the velocity is the same as the initial velocity (also same angle, this time below the horizontal), only pointing downwards:

$V_{ya}=-v_0 \sin 40^o = -5.14$ m/s

The horizontal component remains:

$V_{xa}=v_0 \cos 40^o = -6.13$ m/s

The velocity change in the vertical direction, while falling another meter, is:

$v_y^2=v_{ya}^2 + 2a(y-y_0)$ with $y_0=0$ m and $y=-1$ m (or $y_0=1$ m and $y=0$)

$v_y=\text{sqrt}(5.14^2 +2*9.81)=\text{sqrt}(46.04)=6.79$ m/s [*1.5 points if correct*]

Finally:

$v=\text{sqrt}(v_x^2+v_y^2)=\text{sqrt}(83.68)=9.15$ m/s

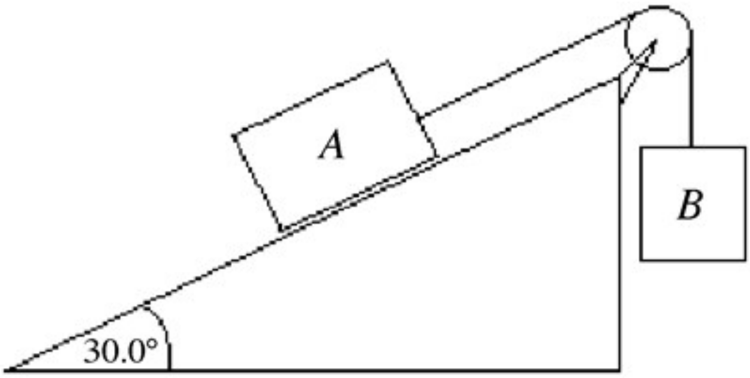
EX2
A 60.0-kg person rides in elevator while standing on a scale. The elevator is traveling downward but slowing down at a rate of 2.00 m/s^2. What is the reading (in Newton) on the scale?

709 N

The weight of the person is directed downwards, hence the force of the elevator on the person (which is what you read on the scale) is directed upwards. Since the elevator is travelling down and slowing down, its acceleration (a=2 m/s^2) is also directed upwards. The total force is then the sum of the two:

$F_{tot}=F_g+F_a=(g+a)\ m= 11.81*60=709$ N

EX3



Two blocks are connected by a string that goes over an ideal pulley as shown in the figure. Block *A* has a mass of 3.00 kg and can slide over a rough plane inclined 30.0° to the horizontal. The coefficient of kinetic friction between block *A* and the plane is 0.40. Block *B* has a mass of 2.77 kg. What is the acceleration of the blocks?

0.374

The two blocks have almost the same mass, but A is on a small slope, so the force of gravity on block B is larger and block B will fall (and block A move up).
On block A you have the component of gravity pointing down the slope, friction also pointing down the slope (because A moves up), and the tension T pointing up. On block B you only have gravity and tension. The acceleration of the two blocks is the same, since the pulley has no mass.

Block A: $m_A\, a=-m_A\, g \sin 30^o - m_A\, g \cos 30^o\, \mu +T$ [*0.5 points if correct*]

Block B: $m_B\, a = m_B\, g - T$ [*0.5 points if correct*]

Solving for acceleration (a) you obtain:

$a = g\, [-m_A\, (\sin 30^o - \cos 30^o\, \mu)+m_B]/(m_A+m_B)= 9.81 * (0.22/5.77)=0.374$ m/s^2

EX4

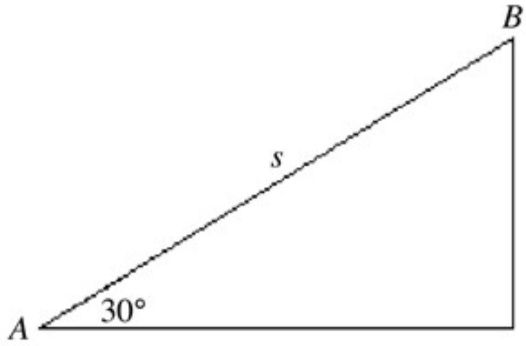
A traveler pulls on a suitcase strap at an angle 36° above the horizontal. If 242 J of work are done by the strap while moving the suitcase a horizontal distance of 15 m, what is the tension in the strap?

19.9 N

Only the horizontal component of the tension does some work (the other is perpendicular to the direction of motion).

$W=T \cos 36^o * 15 = 242$ J => $T= 242 / (15 * 0.81) = 19.9$ N

EX5



An object of mass 4.0 kg starts at rest from the top of a rough inclined plane of height 10 m as shown in the figure. If the speed of the object at the bottom of the inclined plane is 10 m/s, how much work does friction do on this object as it slides down the incline?

-192 J

Friction is a nonconservative force, hence it will change the total mechanical energy of the system:

$W_f = \Delta U + \Delta K = -mgh + ½ mv2 = -392+200 = -192$ J

PART III: Exercises 6-10

EX6
A man-made satellite is in orbit around the earth, making one revolution in 430 minutes. What is the radius of its orbit? (The mass of the earth is 6.0×10^{24} kg and $G = 6.67 \times 10^{-11}$ Nm^2/kg^2)

$1.9\ 10^7$ m (19000 km)

Centripetal acceleration is due to gravity. Linear and angular velocity are related through the radius.

$GM/R^2 = v^2/R = (\omega R)^2/R = \omega^2 R$ => $\omega^2 = GM/R^3$ => $R = (GM/\omega^2)^{1/3}$

$R = [(40\ 10^{13}) / (5.76\ 10^{-8})]^{1/3} = (6.96\ 10^{21})^{1/3} = 1.9\ 10^7$ m

EX7
A billiard ball traveling at 3.00 m/s collides perfectly elastically with an identical billiard ball initially at rest on the level table. The initially moving billiard ball deflects 30.0° from its original direction. What is the speed of the initially stationary billiard ball after the collision?

1.55 m/s

Total linear momentum (of both balls together) is conserved: it remains constant in the direction of initial motion and zero in the perpendicular direction.

$p_x = mv_0 = mv_{1x} + mv_{2x}$ => $v_{2x} = v_0 - v_{1x} = v_0(1-\cos 30^o) = 0.4$ m/s

$p_y = mv_{1y} + mv_{2y} = 0$ => $v_{2y} = -v_{1y} = -v_0 \sin 30^o = -1.5$ m/s

$v2 = sqrt(v_{2x}^2 + v_{2y}^2) = sqrt(2.41) = 1.55$ m/s

EX8
A 3.45-kg centrifuge takes 100 s to spin up from rest to its final angular speed with constant angular acceleration. A point located 8.00 cm from the axis of rotation of the centrifuge moves with a speed of 150 m/s when the centrifuge is at full speed. How many revolutions does the centrifuge make as it goes from rest to its final angular speed?

$1.5\ 10^4$ rad/s

Both angular acceleration and angular speed are the same for all points of the centrifuge. It's a kinematic problem, so mass is not necessary.

$\omega = v/R = 150/0.08 = 1875$ rad/s

$\omega = \omega_0 + \alpha t \Rightarrow \alpha = \omega/t = 18.75$ rad/s^2 [*1 point if correct*]

$\theta = \theta_0 + \omega_0 t + \alpha/2\ t^2 = \alpha/2\ t^2 = 9.4\ 10^4$ rad

$N_{revolutions} = \theta/(2\pi) = 1.5\ 10^4$ rad/s

EX9
A 5.0-m radius playground merry-go-round with a moment of inertia of 2000 kg m^2 is rotating freely with an angular speed of 1.0 rad/s. Two people, each having a mass of 60 kg, are standing right outside the edge of the merry-go-round and step on it with negligible speed. What is the angular speed of the merry-go-round right after the two people have stepped on?

0.4 rad/s

Total angular momentum (merry-go-round) is conserved.

$I_{people} = 2m\ R^2 = 3000$ km m^2

$L = \omega_0 I_{merry\text{-}go\text{-}round} = \omega_1 (I_{merry\text{-}go\text{-}round} + I_{people}) \Rightarrow \omega_1 = \omega_0\ I_{merry\text{-}go\text{-}round} / (\ I_{merry\text{-}go\text{-}round} + I_{people}) = 0.4$ rad/s

EX10
Two identical ladders are 3.0 m long and weigh 600 N each. They are connected by a hinge at the top and are held together by a horizontal rope, 1.0 m above the smooth floor forming a symmetric "A" arrangement. The angle between the ladders is 60° and both ladders have their center of gravity at their midpoint. What is the tension in the rope?

281 N

It is enough to balance torques for one ladder (tension is the same at both ends of the rope), about the pivot taken as the hinge where the two ladders connect. Three forces cause torques about the pivot: gravity on the middle of the ladder (down), the normal force from the floor due to the weight of the ladder (up) and the tension of the rope (horizontal, towards the inside).

If L=3.0 m and W= 600 N:

$\tau_{gravity} = -W\ L/2 \sin 30^o$
$\tau_{floor} = W\ L \sin 30^o$
$\tau_{rope} = -T\ (L \cos 30^o - 1)$

$\tau_{gravity} + \tau_{floor} + \tau_{rope} = 0 \Rightarrow T = 1/2\ WL \sin 30^o / (L \cos 30^o - 1) = 900/3.2 = 281$ N