UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 115.3
MIDTERM TEST

October 23, 2009 Time: 90 minutes

NAME: MASTER STUDENT NO.: ________
(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 Dr. K. McWilliams
- ❑ 03 Dr. A. Robinson
- ❑ C15 F. Dean

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), a formula sheet, and an OMR sheet. The test paper consists of 8 pages. **It is the responsibility of the student to check that the test paper is complete.**
3. Only Hewlett-Packard HP 10s or HP 30s or Texas Instruments TI-30X series calculators may be used.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your student number in the top right-hand corner of each page of the test paper.
5. Enter your name and STUDENT NUMBER on the OMR sheet.
6. The test paper, the formula sheet and the OMR sheet must all be submitted.
7. The marked test paper will be returned. The formula sheet and the OMR sheet will NOT be returned.

ONLY THE THREE PART B QUESTIONS THAT YOU INDICATE WILL BE MARKED

PLEASE INDICATE WHICH THREE PART B QUESTIONS ARE TO BE MARKED

QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-15	-	15	
B1	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
TOTAL		45	

continued on page 2...

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. A typical influenza (H1N1) virus has a diameter of approximately 80 μm, when viewed in an electron microscope. Express this in scientific notation, in metres, to 2 significant figures.

D

(A) 8.00×10^{-4} m (B) 8.00×10^{-5} m (C) 8.0×10^{-4} m (D) 8.0×10^{-5} m (E) 8.0×10^{-3} m

$80\mu m = 80 \times 10^{-6} m = 8.0 \times 10^{-5} m$

A2. The mathematical relationship between three physical quantities is given by $a = b^2/c$. If the dimension of b is $[\mathbf{L}]/[\mathbf{T}]$ and the dimension of c is $[\mathbf{L}]$, which one of the following choices is the dimension of a?

E

(A) $[\mathbf{L}]$ (B) $\frac{[\mathbf{L}]}{[\mathbf{T}]}$ (C) $\frac{[\mathbf{L}]^2}{[\mathbf{T}]^2}$ (D) $[\mathbf{T}]$ (E) $\frac{[\mathbf{L}]}{[\mathbf{T}]^2}$

$a = b^2/c \quad [a] = [b]^2/[c] = \frac{[L]^2/[T]^2}{[L]} = [L]/[T]^2$

A3. A physics student in a hot air balloon ascends vertically. Consider the following four forces that arise in this situation:

B

F1 = the weight of the hot air balloon
F2 = the weight of the student = force of earth pulling on student
F3 = the force of the student pulling on the earth
F4 = the force of the hot air balloon pulling on the student

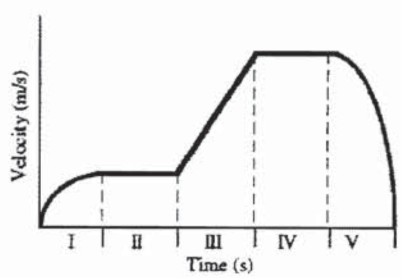
Which two forces form an "interaction pair" that obeys Newton's third law?

(A) F1 and F2 (B) F2 and F3 (C) F1 and F3
(D) F2 and F4 (E) F3 and F4

A4. A 2.0-kg object moves in a straight line on a horizontal frictionless surface. The graph shows the velocity of the object as a function of time. The various equal time intervals are labeled I, II, III, IV, and V. The net force on the object always acts along the line of motion of the object. Which section(s) of the graph correspond to a condition of zero net force?

C

(A) V only
(B) III only
(C) II and IV
(D) II, III, and IV
(E) I, III, and V



$\Sigma \vec{F} = 0 \Rightarrow \vec{a} = 0$

$\vec{a} = 0 \Rightarrow \vec{v}$ is constant

$\vec{v}$ constant $\Rightarrow$ v vs t is horizontal.

A5. Jupiter has 320 times the mass of the earth and a radius 11 times greater than that of the earth. Calculate the magnitude of the gravitational field strength at the surface of Jupiter, compared to that at the surface of the earth, g_E.

E

(A) $\frac{121}{320} g_E$ (B) $\frac{320}{11} g_E$ (C) $\frac{11}{32} g_E$ (D) $\frac{121}{160} g_E$ (E) $\frac{320}{121} g_E$

$g = \frac{GM}{R^2} \quad g_J/g_E = \frac{GM_J/R_J^2}{GM_E/R_E^2} = \left(\frac{R_E}{R_J}\right)^2 \cdot \frac{M_J}{M_E} = \left(\frac{1}{11}\right)^2 \cdot 320 = \frac{320}{121}$

A6. Which one of the following statements is correct concerning a situation where the net force on an object is **not** zero.

D

(A) The object **must** have an increasing speed.
(B) The object **must** have a decreasing speed.
(C) The object **must** be moving in a straight line.
(D) The object **must** have a velocity that is not constant.
(E) The object's acceleration **must** be zero.

$\Sigma \vec{F} \neq 0 \Rightarrow \vec{a} \neq 0$

$\Rightarrow \vec{v}$ is not constant

continued on page 3...

A7. John and Mary leave their apartment to go to school. John walks 3 km west and then turns and walks 4 km north. Mary walks a distance of 5 km in a direction of 53° north of west directly across an open field. Both John and Mary arrive at school at the same time. Which one of the following statements is correct concerning John's and Mary's average speeds and average velocities during their walks?

B

ave speed = $\frac{\text{distance}}{\text{time}}$

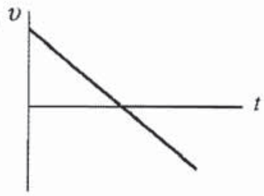
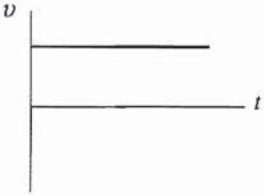
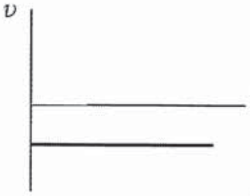
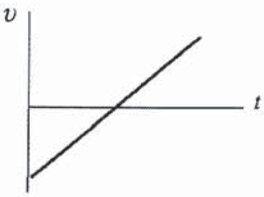
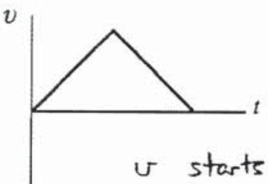
(A) Their average speeds are the same, their average velocities are not.
(B) Their average velocities are the same, their average speeds are not.
(C) Both their average speeds and their average velocities are the same.
(D) Neither their average speeds nor their average velocities are the same.
(E) The question cannot be answered without additional information.

ave velocity = $\frac{\text{displacement}}{\text{time}}$

times are equal, displacements are equal, John's distance is greater than Mary's distance.

A8. A ball is thrown vertically upward. Eventually it returns to the point from which it was thrown. Which one of the following velocity versus time graphs is correct for the motion of the ball while it is in free fall? (Up has been chosen as the positive direction and air resistance is negligible.)

A

(A)

(B)

(C)

(D)

(E)


v vs t is linear b/c $\vec{a}$ is constant for free fall.

v starts large positive, decreases to 0 (at top of trajectory) and then is increasingly negative as the ball moves faster and faster downward.

A9. If a car is travelling eastward and slowing down, which one of the following statements correctly describes the car's motion?

D

acceleration is oppositely directed compared to velocity, ∴ westward.

(A) The car has a constant speed.
(B) The car has a constant velocity.
(C) The car's acceleration is directed eastward.
(D) The car's acceleration is directed westward.
(E) The car's velocity is directed westward.

A10. Two identical balls are thrown horizontally from the roof of a building at the same time. Ignoring air resistance, if the initial velocity of ball 1 is twice the initial velocity of ball 2, which one of the following statements is **true**?

D

vertical quantities are the same, ∴ times of flight are equal.

(A) Ball 1 reaches the ground first.
(B) Ball 2 reaches the ground first.
(C) Both balls reach the ground at the same time and with the same final velocity.
(D) Both balls reach the ground at the same time but ball 1 has a greater final speed.
(E) Both balls reach the ground at the same time but ball 2 has a greater final speed.

A11. An object moving in a circle at a constant speed has an acceleration that is

B

(A) in the direction of motion.
(B) toward the centre of the circle.
(C) away from the centre of the circle.
(D) opposite to the direction of motion.
(E) zero.

continued on page 4...

Stu. No.: ____________________

A12. An object is initially moving in uniform circular motion with angular speed ω_1 and radius r_1. Both the angular speed and the radius are then doubled, and the object is once again in uniform circular motion. Which one of the following expressions for the new radial acceleration is **true**?

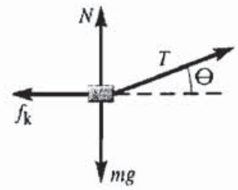
C

(A) $2r_1\omega_1$ (B) $4r_1\omega_1$ (C) $8r_1\omega_1^2$ (D) $4r_1\omega_1^2$ (E) $\left(\frac{\omega_1^2}{4}\right)r_1^2$

$a_r = \frac{v^2}{r} = r\omega^2$; $a_1 = r_1\omega_1^2$; $a_2 = (2r_1)(2\omega_1)^2 = 2r_1 \cdot 4\omega_1^2 = 8r_1\omega_1^2$

A13. The following is a free body diagram of an object which undergoes a displacement of magnitude Δr along the horizontal direction. Which one of the following equations represents the *total work* done on the object?

D



$\vec{N}$ and $\vec{W}$ do no work b/c ⊥ to displacement

$W_T = T\cos\theta\,\Delta r$

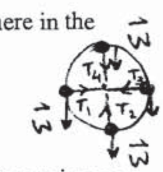
$W_{f_k} = f_k\,\Delta r\cos 180° = -f_k\,\Delta r$

(A) $(T\sin\theta)\Delta r$
(B) $(T\cos\theta)\Delta r$
(C) $(T\cos\theta - T\sin\theta)\Delta r$
(D) $(T\cos\theta - f_k)\Delta r$
(E) $(T\sin\theta - f_k)\Delta r$

$W_{tot} = (T\cos\theta - f_k)\Delta r$

A14. A ball on the end of string is being swung in a vertical circle at constant speed. Where in the ball's trajectory is the tension in the string greatest in magnitude?

C



(A) The tension in the string is constant throughout the ball's motion.
(B) The tension in the string is greatest at the highest point of the ball's motion.
(C) The tension in the string is greatest at the lowest point of the ball's motion.
(D) The tension in the string is greatest when the string is horizontal and the ball is moving up.
(E) The tension in the string is greatest when the string is horizontal and the ball is moving down.

$\Sigma F_r = ma_r$
$\Sigma F_r = m\frac{v^2}{r}$

at bottom $T_2 - W = \frac{mv^2}{r}$
$T_2 = mv^2/r + W$

A15. A projectile is launched at an angle θ above the horizontal. Ignoring air resistance, what fraction of its initial kinetic energy does the projectile have at the top of its trajectory?

D

(A) $\cos\theta$ (B) $\sin\theta$ (C) $\tan\theta$ (D) $\cos^2\theta$ (E) $\sin^2\theta$

$K_i = \frac{1}{2}mv_i^2$

$K_f = \frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2\cos^2\theta$

note that $v_f = v_{ix} = v_i\cos\theta$

so $\frac{K_f}{K_i} = \cos^2\theta$

PART B

ANSWER <u>THREE</u> OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND <u>INDICATE YOUR CHOICES ON THE COVER PAGE</u>.

FOR EACH OF YOUR CHOSEN PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

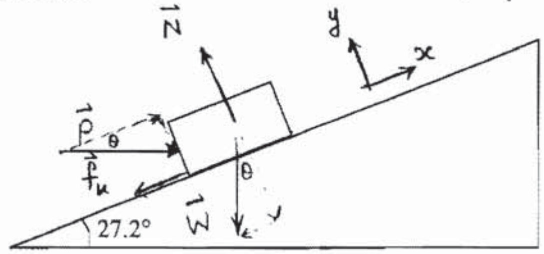
<u>SHOW AND EXPLAIN YOUR WORK</u> – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

continued on page 5...

B1. A ~~255~~ 262-N force is directed horizontally as shown to push a 29.1-kg box up a ramp at a constant speed. There is friction between the box and the ramp.



(a) On the diagram above, draw all the forces acting on the box and show your choice of coordinate system. (Air resistance can be ignored.) *(3 marks)*

(b) Calculate the magnitude of the normal force of the ramp on the box. *(4 marks)*

box is moving at constant speed in a straight line so $\vec{a} = 0$.

$\boxed{373\text{N}}$

$\therefore \sum \vec{F} = 0$ so $\sum F_x = 0$ and $\sum F_y = 0$

$$\sum F_y = 0 \Rightarrow N_y + W_y + P_y + f_{k_y} = 0$$

$$+N - W\cos\theta - P\sin\theta + 0 = 0$$

$$N = P\sin\theta + W\cos\theta$$

$$N = 262\,\text{N}\sin(27.2°) + (29.1\,\text{kg})(9.80\,\text{m/s}^2)\cos(27.2°)$$

$$N = 373\,\text{N}$$

(c) Calculate the coefficient of kinetic friction between the ramp and the box. *(3 marks)*

$f_k = \mu_k N$ so $\mu_k = \dfrac{f_k}{N}$

$\boxed{0.276}$

from $\sum F_x = 0$, $P_x + W_x + f_{kx} + N_x = 0$

$$+P\cos\theta - W\sin\theta - f_k + 0 = 0$$

$$f_k = P\cos\theta - W\sin\theta$$

$$f_k = 262\,\text{N}\cos(27.2°) - (29.1\,\text{kg})(9.80\,\text{m/s}^2)\sin(27.2°)$$

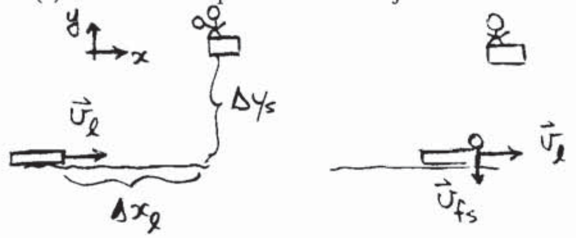
$$f_k = 103\,\text{N}$$

$$\mu_k = \frac{f_k}{N} = \frac{103\,\text{N}}{373\,\text{N}} = 0.276$$

continued on page 6...

B2. A small log is floating on a fast-moving river. A child standing on a bridge over the river drops a stone so that it hits the front of the log as the log passes under the bridge. The log is moving with a constant speed of 5.00 m/s and the stone is dropped from rest from a height of 75.0 m above the log.

(a) Calculate the speed of the stone just before it hits the log. *(3 marks)*



$\boxed{38.3\ m/s}$

For the stone

$v_{is} = 0$

$\Delta y_s = -75.0\,m$

$a_s = -9.80\,m/s^2$

Have $v_{fs}^2 - v_{is}^2 = 2a_s\Delta y_s$

$$v_{fs} = \sqrt{2a_s\Delta y_s} = \sqrt{2(-9.80\,m/s^2)(-75.0\,m)}$$

$$v_{fs} = -38.3\,m/s \quad \text{(speed is +ve)}$$

(b) Calculate the elapsed time from the stone's release until it hits the log. *(4 marks)*

$\boxed{3.91\,s}$

Can use either $v_{fs} - v_{is} = a_s\Delta t$

or $\Delta y_s = v_{is}\Delta t + \frac{1}{2}a_s(\Delta t)^2$

$$\Delta t = \frac{v_{fs} - v_{is}}{a_s}$$

$$\Delta t = \frac{-38.3\,m/s}{-9.80\,m/s^2}$$

$$\Delta t = 3.91\,s$$

$$\Delta y_s = 0 + \frac{1}{2}a_s(\Delta t)^2$$

$$\sqrt{\frac{2\Delta y_s}{a_s}} = \Delta t$$

$$\Delta t = \sqrt{\frac{2(-75.0\,m)}{-9.80\,m/s^2}} = 3.91\,s$$

(c) Calculate the horizontal distance of the log from the bridge when the child releases the stone. *(3 marks)*

$\boxed{19.6\,m}$

The log must cover the distance Δx_ℓ in the time Δt calculated in (b). Since the log has constant velocity,

$$\Delta x_\ell = v_\ell \Delta t$$

$$\Delta x_\ell = (5.00\,m/s)(3.91\,s)$$

$$\Delta x_\ell = 19.6\,m$$

continued on page 7...

Stu. No.: ____________________

B3. Europa travels around Jupiter in an orbit of radius 6.71×10^8 m with a period of 3.55 days.

(a) Calculate the angular speed of Europa in its orbit. Express your answer in rad/day and rad/s. (~~3~~ 2 *marks*)

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi \text{ rad}}{T} = \frac{2\pi \text{ rad}}{3.55 \text{ d}}$$

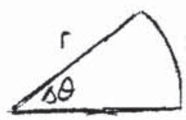
$\boxed{1.77 \text{ rad/day}}$

2.05×10^{-5} rad/s

$$\omega = 1.77 \frac{\text{rad}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{h}} \times \frac{1 \text{h}}{3600 \text{s}}$$

$$\omega = 2.05 \times 10^{-5} \text{ rad/s}$$

(b) Calculate the distance (arclength) that Europa travels in 1.00 day. (~~2~~ 3 *marks*)



$s = r\Delta\theta$

and $\Delta\theta = \omega \Delta t$

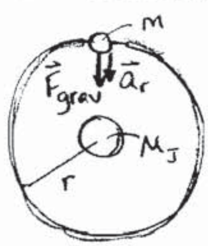
$\boxed{1.19 \times 10^9 \text{ m}}$

$$s = r\omega\Delta t$$

$$s = (6.71 \times 10^8 \text{m})(1.77 \text{ rad/day})(1.00 \text{ day})$$

$$s = 1.19 \times 10^9 \text{m}$$

(c) Given that the gravitational force of Jupiter on Europa keeps Europa in its circular orbit, calculate the mass of Jupiter. (*5 marks*)



Newton II for circular motion

$\boxed{1.90 \times 10^{27} \text{ kg}}$

$$a_r = \frac{v^2}{r} = r\omega^2$$

$$\Sigma F_r = ma_r$$

$$F_{grav} = mr\omega^2$$

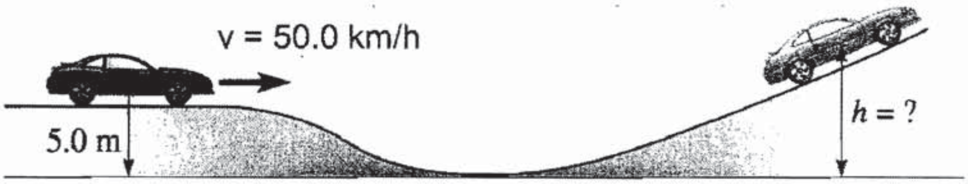
$$\frac{GM_J \cancel{m}}{r^2} = \cancel{m} r\omega^2$$

$$M_J = \frac{r^3\omega^2}{G} = \frac{(6.71 \times 10^8 \text{m})^3 (2.05 \times 10^{-5} \text{rad/s})^2}{6.674 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2}$$

$$M_J = 1.90 \times 10^{27} \text{ kg}$$

continued on page 8...

B4. A car of mass 1250 kg is moving at a speed of 50.0 km/h at a height of 5.00 m above the bottom of a hill, when it runs out of gas. The car coasts (without the engine on) down the hill and then coasts up the other side of the hill until it comes to rest. You may assume that air resistance and frictional forces are negligible.



(a) Calculate the initial kinetic energy of the car (express your answer in Joules). (~~8~~ 4 *marks*)

$\boxed{1.21 \times 10^5\ \text{J}}$

$$K_i = \frac{1}{2}mv^2$$

$$K_i = \frac{1}{2}(1250\ \text{kg})\left(50.0\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{3600\ \text{s}} \times \frac{1000\ \text{m}}{\text{km}}\right)^2$$

$$K_i = 1.21 \times 10^5\ \text{kg}\cdot\text{m}^2/\text{s}^2$$

$$K_i = 1.21 \times 10^5\ \text{J}$$

(b) Calculate *h*, the highest point that the car reaches above the bottom of the hill. (~~8~~ 6 *marks*)

$\boxed{14.9\ \text{m}}$

$$K_i + U_i + W_{nc} = K_f + U_f$$

$$K_i + mgh_i + 0 = 0 + mgh$$

($W_{nc} = 0$ b/c no friction, $K_f = 0$ b/c car comes to rest)

$$h = \frac{K_i}{mg} + h_i$$

$$h = \frac{1.21 \times 10^5\ \text{J}}{(1250\ \text{kg})(9.80\ \text{m/s}^2)} + 5.00\ \text{m} = 14.9\ \text{m}$$

END OF EXAMINATION

Phys 115 – 2009 Alternative Midterm

Part A Answer Key:

A1. E

A2. D

A3. C

A4. B

A5. D

A6. E

A7. D

A8. D

A9. B

A10. A

A11. B

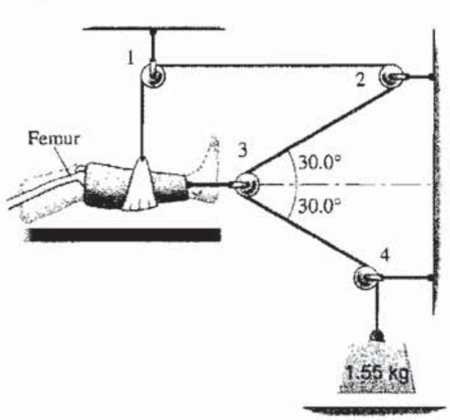
A12. D

A13. C

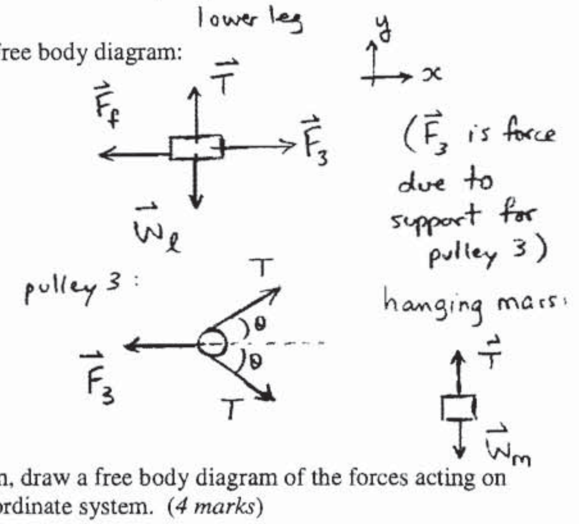
A14. D

A15. C

B1. The broken lower leg in the diagram is held immobile (stationary) by the mass and pulley system. The hanging mass is 1.55 kg. The femur bone in the upper leg exerts a force on the lower leg in the horizontal direction. You may assume that the pulleys are ideal and that the rope is massless.



Free body diagram:



(a) In the space to the right of the above diagram, draw a free body diagram of the forces acting on the lower leg. Also show your choice of coordinate system. (*4 marks*)

(b) Calculate the magnitude of the weight of the lower leg. (*3 marks*)

$\boxed{15.2\text{ N}}$

Since the entire system is at rest $\Sigma\vec{F}=0$ for the lower leg, pulley 3, and the hanging mass.

hanging mass:

$$\Sigma\vec{F}=0 \Rightarrow T-W_m=0 \Rightarrow T=W_m=(1.55\text{ kg})(9.80\text{ m/s}^2)$$

$$T=15.2\text{ N}$$

lower leg: $\Sigma\vec{F}=0 \Rightarrow \Sigma F_y=0$ and $\Sigma F_x=0$

$$\Sigma F_y=0 \Rightarrow T-W_\ell=0 \Rightarrow W_\ell=T\ (=W_m)$$

$$\therefore W_\ell=W_m$$

$$W_\ell=(1.55\text{ kg})(9.80\text{ m/s}^2)=15.2\text{ N}$$

(c) Calculate the magnitude of the force exerted by the femur on the lower leg. (*3 marks*)

$\boxed{26.3\text{ N}}$

$$\Sigma F_x=0 \Rightarrow -F_f+F_3=0 \text{ so } F_f=F_3$$

for pulley 3, $\Sigma F_x=0 \Rightarrow -F_3+T\cos\theta+T\cos\theta=0$

$$F_3=2T\cos\theta$$

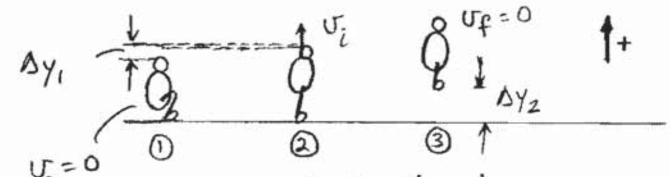
$$\therefore F_f=2T\cos\theta$$

$$F_f=2(15.2\text{ N})\cos(30.0°)=26.3\text{ N}$$

continued on page 6...

B2. A 400-N kangaroo, initially crouching at rest, exerts a constant force on the ground during the first 0.600 m of a vertical jump as it straightens its body with its feet in contact with the ground. After the kangaroo's feet leave the ground it rises an additional 1.80 m. You may ignore any effects due to air resistance.

(a) Calculate the speed of the kangaroo just after it loses contact with the ground. Hint: After losing contact with the ground the only force on the kangaroo is its weight. *(3 marks)*



$\boxed{5.94\ \text{m/s}}$

From ② to ③ the kangaroo is in free fall

$$v_f^2 - v_i^2 = 2a\Delta y_2$$

$$v_f^2 - 2a\Delta y_2 = v_i^2$$

$$v_i = \sqrt{0 - 2a\Delta y_2} = \sqrt{-2(-9.80\ \text{m/s}^2)(1.80\ \text{m})}$$

$$v_i = 5.94\ \text{m/s}$$

(b) Calculate the constant acceleration of the kangaroo while it is still in contact with the ground. *(3 marks)*

$\boxed{29.4\ \text{m/s}^2}$

While in contact with the ground the kangaroo rises 0.600 m. ($= \Delta y_1$)

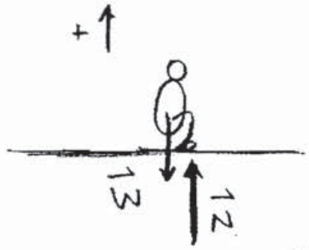
$v_0 = 0$, $v_i = 5.94$ m/s from (a)

Since $\vec{a}_1$ is constant, can use same eq'n as in (a).

$$v_i^2 - v_0^2 = 2a_1\Delta y_1$$

$$a_1 = \frac{v_i^2}{2\Delta y_1} = \frac{(5.94\ \text{m/s})^2}{2(0.600\ \text{m})} = 29.4\ \text{m/s}^2$$

(c) Calculate the magnitude of the force that the kangaroo exerts on the ground during the first 0.600 m of the vertical jump. *(4 marks)*



$\boxed{1.60 \times 10^3\ \text{N}}$

$$\Sigma\vec{F} = m\vec{a}$$

$$N - W = ma_1$$

$$N = ma_1 + W$$

$$N = ma_1 + mg$$

$$N = \left(\frac{400\ \text{N}}{9.80\ \text{m/s}^2}\right)(29.4\ \text{m/s}^2) + 400\ \text{N}$$

$$N = 1.60 \times 10^3\ \text{N}$$

The force that the kangaroo exerts on the ground has the same magnitude as the force that the ground exerts on the kangaroo (the normal force)

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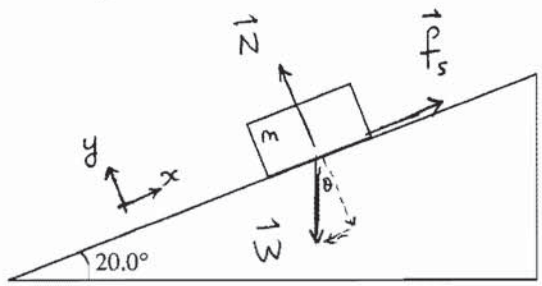
B3. A 225-kg crate is at rest on a ramp that is inclined above the horizontal at an angle of 20.0°.



(a) On the diagram above, draw all the forces acting on the crate and show your choice of coordinate system. (Air resistance can be ignored.) (*3 marks*)

(b) Calculate the magnitude of the static frictional force of the ramp on the crate. (*3 marks*)

Crate is at rest so $\Sigma\vec{F} = 0$ $\boxed{754\text{ N}}$

$$\Sigma F_x = 0$$

$$f_{sx} + N_x + W_x = 0$$

$$f_s + 0 - W\sin\theta = 0$$

$$f_s = W\sin\theta$$

$$f_s = mg\sin\theta = (225\text{ kg})(9.80\text{ m/s}^2)(\sin 20.0°)$$

$$f_s = 754\text{ N}$$

(c) The crate is now bumped and it slides down the ramp. The coefficient of kinetic friction between the crate and the ramp is 0.325. Calculate the magnitude of the acceleration of the crate as it slides down the ramp. (*4 marks*)

Same diagram as for (a), but now have $\vec{f}_k$ rather than $\vec{f}_s$. $\boxed{0.359\text{ m/s}^2}$ (magnitude)

$$\Sigma F_x = ma \qquad \Sigma F_y = 0$$

$$f_k - W\sin\theta = ma \qquad N_y + f_y + W_y = 0$$

$$f_k - mg\sin\theta = ma \qquad N + 0 - W\cos\theta = 0$$

$$N = mg\cos\theta$$

$$a = \frac{f_k}{m} - g\sin\theta \quad \text{and} \quad f_k = \mu_k N = \mu_k mg\cos\theta$$

$$a = \frac{\mu_k mg\cos\theta}{m} - g\sin\theta = \mu_k g\cos\theta - g\sin\theta$$

$$a = g(\mu_k\cos\theta - \sin\theta)$$

$$a = 9.80\text{ m/s}^2(0.325\cos 20.0° - \sin 20.0°)$$

$$a = -0.359\text{ m/s}^2$$

down the ramp

continued on page 8...

B4. An asteroid of mass 1.65×10^9 kg has a speed of 2.50 km/s toward Mars when it is at a distance of 2.78×10^9 m from Mars's surface. The mass of Mars is 6.42×10^{23} kg and its radius is 3.39×10^6 m.

(a) Calculate the gravitational potential energy of the asteroid due to Mars when it is at a distance of 2.78×10^9 m from Mars's surface. (Let the gravitational potential energy of the asteroid be zero when the asteroid is infinitely far away from Mars.) *(4 marks)*

$\boxed{-2.54 \times 10^{13}\ \text{J}}$

$$U_i = -\frac{G M_m m_a}{r_1}$$

$$U_i = -\frac{(6.674 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(6.42 \times 10^{23}\ \text{kg})(1.65 \times 10^9\ \text{kg})}{(2.78 \times 10^9\ \text{m} + 3.39 \times 10^6\ \text{m})}$$

$$U_i = -2.54 \times 10^{13}\ \text{J}$$

(b) Calculate the speed of the asteroid just before it hits Mars's surface. *(6 marks)*

$\boxed{5.61\ \text{km/s}}$

$$K_i + U_i + W_{nc} = K_f + U_f$$

$W_{nc} = 0$ b/c only force is the conservative gravitational force.

$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2} m_a v_i^2 + U_i = \frac{1}{2} m_a v_f^2 + U_f$$

$$v_i^2 + \frac{2}{m_a}(U_i - U_f) = v_f^2$$

$$v_f = \sqrt{v_i^2 + \frac{2}{m_a}\left(-\frac{G M_M \cancel{m_a}}{r_i} - \left(-\frac{G M_m \cancel{m_a}}{r_M}\right)\right)}$$

$$v_f = \sqrt{v_i^2 + 2 G M_m \left(\frac{1}{r_M} - \frac{1}{r_i}\right)} = 5.61 \times 10^3\ \text{m/s}$$

$$= 5.61\ \text{km/s}$$

END OF EXAMINATION