ANGULAR MOMENTUM CONSERVATION & ENERGY Unit 16

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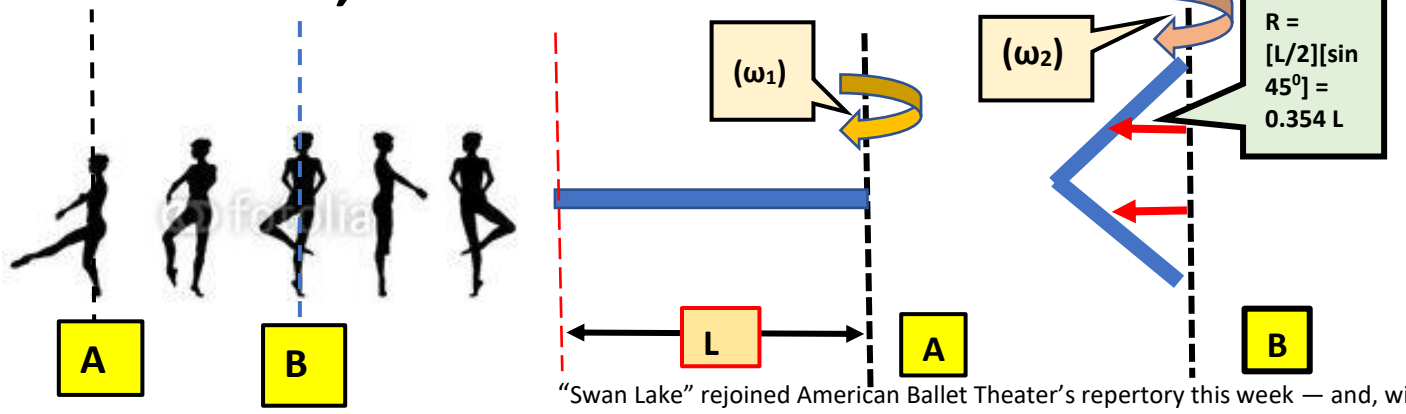
& New York Times , June 17, 2016 by Alastair Macaulay. Dedicated by this author to Kim Hollister, Ballerina from the 1990s.

Swan Lake,' and Its 32 Fouettés



"Swan Lake" rejoined American Ballet Theater's repertory this week — and, with it, the most notorious step in the ballet repertory: the 32 fouetté turns! Odile, the dangerous but seductive antiheroine, returns to the stage near the climax of her grand pas de deux with the hero, Prince Siegfried, **and revolves on one leg 32 times**. ***Her raised leg, never touching the ground, provides most of the propulsion***. After the first 16 bars, the music changes character; she carries on regardless. "Fouetté" is French for "whipped," and it's that whiplash motion of the raised leg that gives the turn its brilliance. That quick up-and-down of the ballerina's foot sometimes sends her traveling downstage; but the ideal sequence of 32 fouettés never travels from a single spot. Men can do fouetté turns, too. But part of the excitement with a ballerina is that she does most of the turn on point. **She comes off point as her raised "working" leg shoots out to the front and sweeps around to the side; but then, as she rises up onto point, that working leg whips inward.** Here's a YouTube clip of a ballet student taking us through the mechanics of a fouetté turn: How to do Fouette´ Turns. By: Just For Kix Video by Just For Kix And here's video of Pacific Northwest Ballet principal Carrie Imler, one of the America's strongest ballet technicians, rehearsing the "Swan Lake" sequence: Swan Lake - Act 3 Coda Fouettes with Carrie Imler Video by Pacific Northwest Ballet You may also want to consult 32fouettes.com, where you can see an anonymous dancer in practice costume doing 32 at the top, with an ensuing analysis and history of the step. Go to YouTube and hunt "Swan Lake fouettés" and, though individual performances come and go, you'll usually find several examples of Odile's grand pas de deux with the fouettés near the end.

INTRODUCTION: In this application you will use angular momentum conservation concept (since no torque is exerted on the ballerina)to find her angular velocity(ω_2) after she moves her leg from position A to B. In position A her moment of inertia (I_1) is 1/3 M L^2 . M = mass of her leg. L = total length of leg. In position B her moment of inertia (I_2) is reduced where $I_2 = M R^2$, where R = 0.354 L (see above sketch) B in upper right. In position B her leg is at a 45^0 angle. In the graphic in upper right can be seen the right triangle used to find R.

QUESTIONS: (a) Find ω_2 (in terms of ω_1) using angular momentum conservation concept: $I_1 \omega_1 = I_2 \omega_2$, (b) Find her Initial angular kinetic energy in terms of : M,L, ω_1 ?, (c) Find her final angular kinetic energy In terms of: M,L, ω_1 ? , (d) How MUCH WORK did she DO to increase her angular kinetic energy in terms of: M,L, ω_1?, (e) Where did this work come from to increase her angular KE?

HINTS: $KE = \frac{1}{2} I \omega^2$, $(KE)_1 + \text{Work done} = (KE)_2$

ANSWERS: (a) $\omega_2 = 2.66\ \omega_1$, (b) $KE_1 = \sim 0.1667(ML^2\ \omega_1^2)$, (c) $KE_2 = \sim 0.4422(ML^2\ \omega_1^2)$, (d) $W = \sim +0.276\ (ML^2\ \omega_1^2)$ (e) The ballerina does physical work(Fx) from position A to B causing an increase in her angular kinetic energy.